ARMY MAP SERVICE

TECHNICAL REPORT

Number 25

MAPPING OF THE COUNTRIES IN DANUBIAN AND ADRIATIC BASINS

Project No. MO-011
June 1959

Submitted to

THE CHIEF OF ENGINEERS, U. S. ARMY

By

The Commanding Officer

Army Map Service
Washington 25, D. C.

FOREWORD

This report contains an exhaustive study of the past and present mapping stages in the countries of the Danubian and Adriatic Basins -- still largely covered by the maps of former K. und k. Military Geographic Institute of Vienna -- and should serve as a source of valuable information to all agencies concerned with the mapping projects of these countries.

The Austro-Hungarian Empire was surveyed at a time when topographic surveys were based partially on geometry and partially upon art. The topographer, more an artist than a surveyor, proudly made the map by himself. Therefore the proverb: "There are plenty of surveyors, but few topographers." Since that time, considerable changes have occurred in mapping. Photogrammetry, with its mechanical compilation of maps -- to which the Military Geographic Institute of Vienna made such a revolutionary contribution (first mechanical plotting instrument: von Orel's stereoautograph in 1909) -- eliminated art from topographic surveying. The maps are no longer produced by ingenious topographer-artists, but by a team of specialists composed of triangulators, aerial photographers, photogrammetrists, topographer-revisors, cartographers, draftsmen, and photolithographers. Consequently, contemporary maps, as the products of the work of various specialists, include less art, but are a more exact expression of topography. Since a picturesque map with artistically expressed contents is not merely more legible, but is also attractive to map readers, and creates among soldiers, students, and the educated public a passionate admiration for map use and map reading, art is not eliminated from the production of good maps, but is merely transplanted from the topographic survey to the fields of cartography and photolithography.

The author, Andrew M. Glusic, who since 1950 has been translator, cartographer, mathematician, and geodesist with the Army Map Service, is especially qualified to report on the mapping in the countries of the Danubian and Adriatic Basins. He was born in 1905 in Slovenia, Yugoslavia, attended the scientific high school in Ljubljana, and in 1927 graduated from the Yugoslav Military Academy in Belgrade. While serving as 2d Lieutenant in Infantry in 1930, he entered the Military Geodetic School at the Military Geographic Institute of Yugoslavia. After graduation and completion of practice in 1935, he became an officer of the Geodetic Service. In 1937 he completed a one-year course of specialization in photogrammetry. During and after this training, he served in the Military Geographic Institute as chief of topographic party, chief of triangulation party, cartographer, photogrammetrist, instructor in photogrammetry, and acting chief of the Photogrammetric Division. During World War II, as Lieutenant Colonel, he was chief of staff and acting commander of the Slovene Army of the Yugoslav Armed Forces (Guerrilla of General Milhailović). In 1944, he was captured by the Germans and sent to Dachau concentration camp. He was liberated on 29 April 1945 by the U. S. Army, and served until 1950 in the Headquarters of USAF in Austria as cartographer on special assignments.

All "file numbers" to which references are made throughout this Technical Report are Army Map Service Geodetic Library file numbers.

CONTENTS

Page

SECTION C

Page

SECTION D

Page

Page

Page

Page

Page

SECTION E

TABLES

SECTION A

INTRODUCTION

MAPPING OF THE COUNTRIES IN DANUBIAN AND ADRIATIC BASINS

A. INTRODUCTION

The history of the European Wars undoubtedly demonstrates the strategic importance of the Danubian basin and those surrounding regions through which the main operational routes to the heart of Europe and vice versa are leading. Using these operational routes the Roman legions conquered the Balkans, the fierce Langobard and Hun hordes stabbed deep into Italy, the flood of the Ottoman armies under Suleymans and Bayazits rushed as far as Vienna, victorious Napoleonic armies brought freedom to Illyria, and the fiery tongue of the German dragon on his march - "Drang nach Osten" twice swept along the routes leading theough the Danubian basin and Balkans.

Should World War III occur Europe would be the main battlefield because both the Russian center of gravity (consistering satellites areas) and U. S. A. strongest (NATO) allies are there located.

The mountain ranges of the Alps, Tatras, Beskides and Carpathians would divide the Soviet offensive forces into two parts; the main force operating on direction Poland-Germany-France and the southern force which, after rapid seizure of the Central Danubian (Panonic) basin and domination of the Balkans, with the main spearhead would proceed through the Ljubljana Gate into Italy.

On the other side the Western forces advancing from Italy and strengthened by landings along the Yugoslav Adriatic coast would stream into the Panonic basin from which, proceeding through the Moravian Gate as well as via routes along the Danube and Vltava-Elbe rivers, would seriously hamper the drive of the main Soviet forces toward their objectives.

Consequently, the vulnerable Adriatic-Danubian sector represents the soft underbelly of Europe, seizure of which would cause disaster for the main forces operating on the route Warszawa-Berlin-Paris.

Military operations in such an important area evidently require tactical and operational maps which would be geodetically homogeneous; topographically would meet contemporary requirements for accuracy, manner of expression and completeness; and would be cartographically uniform and highly legible.

The area considered prior to 1918 largely belonged to the Austro-Hungarian Empire and was after World War I divided among the successor states. The III and IV topographical surveys of the Austro-Hungarian

Empire covering the area were neither geodetically homogeneous nor topographically uniform and do not meet the standards required for the period after World War I. The successor states after the disintegration of the Austro-Hungarian Empire only partially covered the inherited territories by new topographical surveys of which each is based on a different geodetic foundation, hence larger parts of these territories remain covered only by the manuscripts of the Austro-Hungarian topographical survey and by Austro-Hungarian maps. Some countries recasted the Austro-Hungarian manuscripts, revised them in the field, and utilized them in the compilation of the new national maps. In other countries the revision covered relatively small areas and the sheets remain in original position without change of sheet lines; therefore large parts of the considered territory are still covered merely by the unrevised 1:25,000 manuscripts of the III topographical survey (1869-1896) of the Austro-Hungarian Empire and by partially revised 1:75,000 special maps, which revision in some areas includes only the main communications and nationalization of toponymy.

Since the manuscripts of the topographical surveys and the tactical maps covering the Danubian and Adriatic basins are constructed in six various projections belonging to eight different systems, some of which even within themselves are not geodetically homogeneous, the present mapping situation of this area, in respect to diversity of cartographic material (which has to be utilized if a new uniform tactical map would be compiled), is a very complex one. (Having once a uniform large scale topographical map it would be easy by the process of reduction and generalization to obtain the uniform operational map.)

In the mobile warfare of today and tomorrow there will be little time for observations. The artillery will have urgent need for a good tactical map. The present maps referring to various systems with sheets many times inaccurately positioned and having large internal inconsistency, with native grids in many cases superimposed in disagreement with the coordinates of trig points would be conducive to great confusion. The sheets obtained by direct reproduction of the native sheets of these maps, provided with uniform UTM grid referring to International ellipsoid and European datum, should be considered merely a preliminary solution. These sheets can serve for general orientation as a marching map, but they certainly do not completely satisfy artillery requirements.

In the area with which we are concerned, we have at present time a homogeneous geodetic foundation - uniformly adjusted first order net of the European triangulations. This first order net and to it adjusted lower order nets utilized in the existing mapping should be used as a basis in the construction and compilation of the new tactical map, and into this homogeneous foundation the diverse cartographic material covering the Danubian and Adriatic basins should be fitted.

In order to accomplish this difficult task properly, the cartographic material which has to be used in the compilation needs to be carefully evaluated. Since an exact analytical evaluation of the maps, because of lack of the check survey and numerical records, would be seldom possible, it is essential to have a complete knowledge of the history of how each of these maps was made. This history should include a critical review of geodetic foundation, topographical survey with the instruments and methods applied, methods and techniques used in the compilation and reproduction, and in maintaining the maps up to date.

The endeavor of this study is to produce such a critical review of all phases of the mappings of the Austro-Hungarian Empire and of successor states in the Danubian and Adriatic basins and particularly to shed new light upon those phases which have not previously been included into numerous publications discussing these mappings nor sufficiently clarified; consequently, finally make it clear how Austro-Hungarian maps and maps produced by successor states can be utilized in the compilation of a new topographical map more nearly approaching the requirements of modern military mapping.

SECTION B

FORMER

AUSTRO-HUNGARIAN EMPIRE

B. TOPOGRAPHICAL SURVEYS OF AUSTRO-HUNGARIAN EMPIRE

Private topographic and cartographic activities in the Austro-Hungarian Empire started in the middle of the XVI century. Meanwhile, the order to survey all of Hapsburg's provinces issued in 1763 by the Queen-Empress Maria Theresia should be considered as the beginning of the official topographical survey and cartography.

The official topographical activities in the former Austro-Hungarian Empire may be divided into four periods having distinct differences in geodetic foundation used, in projection, in method of survey, and in the accuracy of topo plans produced. Special attention will be given to the topo surveys producing original plane table sheets rather than to maps compiled from condensed plane table sheets. It should be mentioned also that topographical surveys III and IV provided the latest coverage of the Empire's territory.

I. The First Topographical Survey 1763 - 87 (Josephinishe Aufnahme).

1. Geodetic foundation: Liesganig triangulation with attached triangulations of which some were executed graphically. There was no methodical geodetic survey on which the topographical survey could be based.

2. Topographical Survey: Not uniform. The instructions differ in various provinces. The major part was surveyed by plane table. Scale 1:28,800 based on Vienna Klafter System. (1 Zoll = 400 Klafters = 758.6 m).

   Sheet lines were uniform rectangulars with dimensions 63 x 42 cm. The topographic manuscripts were drawn in colours with relief expressed by a combination of hachures and shading at oblique light. The elevations were not measured and included into manuscripts. The topographical survey was carried out by the officers of the Corps of Military Engineers.

   Altogether about 4500 sheets were surveyed. These manuscripts were kept secret. No part of the first topographical survey was incorporated into the second topographical survey.

3. Map: From the first topographical survey there were compiled 12 sheets of the 1:86,400 map covering the province Upper Austria. This confidential map was drawn in perspective manner.

II. The Second Topographical Survey 1806 - 69 (Franziszeische Aufnahme).

1. Geodetic foundation: II Military Triangulation which started

in 1806 with the datum Vienna, St. Stephen's Tower, latitude, longitude and azimuth to Leopoldsberg determined astronomically.

$$\phi = 48^{\circ}\ 12'\ 34''.0$$

$$\lambda = 34^{\circ}\ 02'\ 15''.0 \text{ East of Ferro.}$$

$$\alpha = 345^{\circ}\ 55'\ 22''.0.$$

Coordinates for mapping were computed in uniform plain rectangular system (Cassini projection). In fact only the survey of provinces Upper and Lower Austria, Salzburg, Tyrol and part of Northwest Hungary was completed in this system.

Cadastral Triangulation: With the establishment of Austrian Cadaster in 1817, Cadastral triangulation with its 10 plain rectangular system (Cassini projection) was started. The Military topographical survey, in order to utilize reduced cadastral planimetry, adopted all 10 cadastral systems as follows:

1 Vienna, St. Stephen's Tower, for provinces Lower Austria, Moravia, Silesia and Dalmatia;

2 Gusterberg, for provinces Bohemia, Upper Austria and Salzburg;

3 Löwenburg (Sandberg near Lvov) for Galicia;

4 Radovec (Radautz) West Base Point for Bucovina;

5 Schöckl (near Graz) for Styria;

6 Krim (Krimberg near Ljubljana) for Carinthia, Carniola and Littoral;

7 Innsbruck, Tower of City-parish church for Tyrol and Vorarlberg;

8 Budapest, Gellérthegy Observatory for Hungary;

9 Kloštar Ivanić, Monastery Tower for Croatia and Slavonia,

10 Vizakna, Sibiu (Hermannstadt) Observatory for Transylvania. (See Inclosure 1).

The triangulation of each cadastral system was carried out independently. The scale and the orientation was based either on a directly measured base line and directly determined azimuth or on a side and an azimuth of II Military triangulation. Each of the systems was computed independently with the adjustment carried out empirically. The coordinates were computed in Cassini projection, and represent an average value obtained from individual values computed in different ways after the removal of the angular and side differences empirically. Thus the unstable relationships among the positions of origins and among the orientations of systems caused the discrepancies along the boundaries of provinces (systems) which made the construction of a uniform map impossible. The stations were marked by wooden posts. Stone markers were placed 30 - 50 years later where the remnants of wooden posts and signals were found. At the time of placing the stone markers, 12% of the stations were not found.

2. Topographical Survey: Topographical survey was carried out by plane table method. The instructions for the survey changed gradually (1807, 1817, 1833 and 1860) and the manner of drafting also was subject to many changes; thus the plane table sheets were not completed uniformly. Prior to 1860 elevations, except for trig points, were not measured. The instructions of 1860, provided the measurement of elevations for detail points as well as the introduction of contour lines. The scale remained 1:28,800 as in the first topographic survey. The plane table sheets were of two types:

a. At the outset there were retained the old sheet lines of uniform rectangulars with dimensions:
24 x 16 Zolls = 9600 x 6400 Klafters
or 63.226 x 42.144 cm = 18,206.2 x 12,137.5 meters.
These sheet lines were used in the survey of 1807-1825 and in Transylvania (1853-1873) as well as in the dukedom of Serbia and Banat (1864-1866).

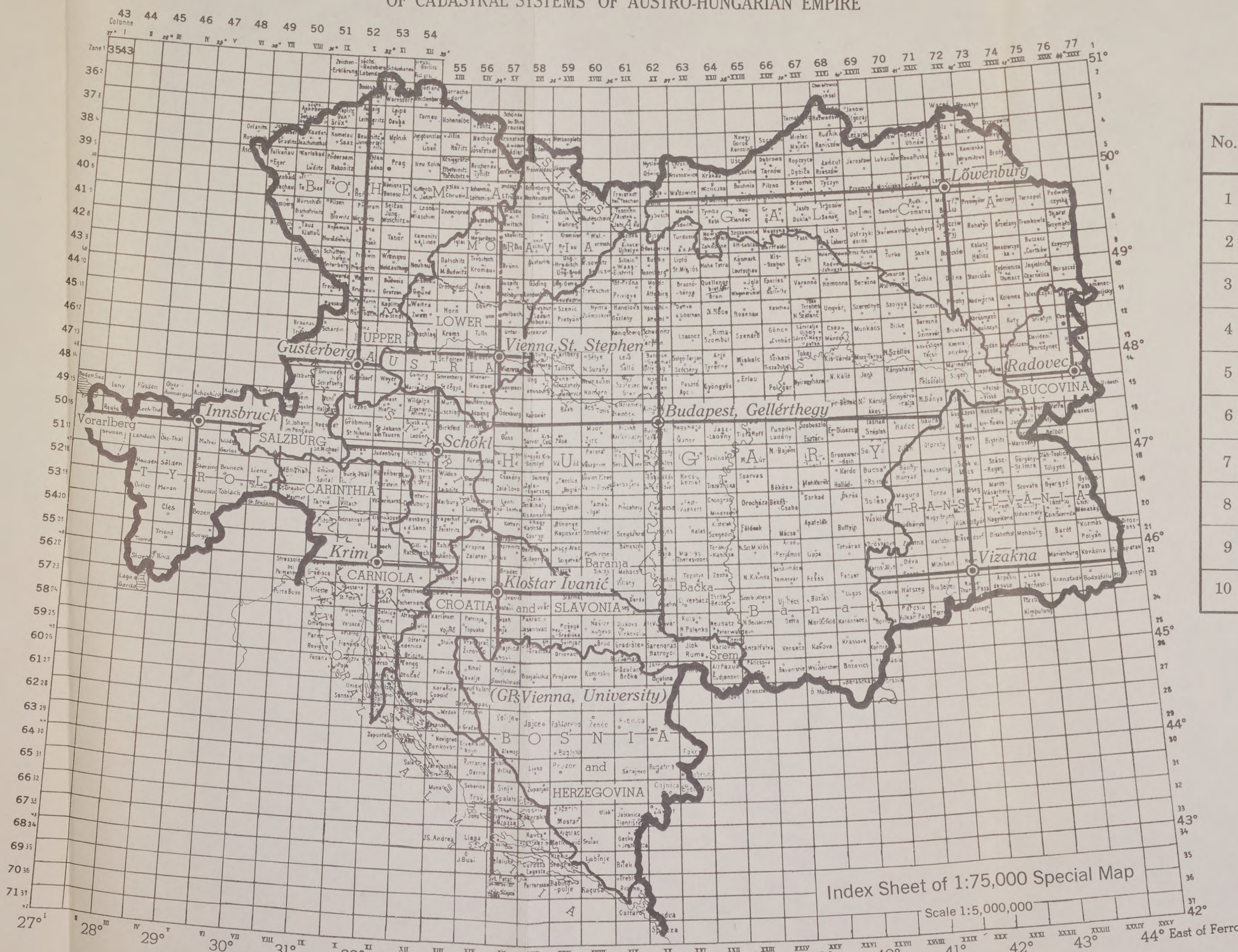
b. The new "square mile" sheet lines of
20 x 20 Zolls = 8000 x 8000 Klafters
or 52.68 x 52.68 cm = 15,171.9 x 15,171.9 meters
were used in all survey completed in the years 1825-1869, except in Transilvania and in the dukedom of Serbia and Banat.

Because some of the Second topographical survey sheets were used as a base for the Third topographical survey it is important to know the areas where the topographical survey was based on reduced cadastral planimetry. The cadastral survey was not yet completed at the time this topographical survey was under way and the cadastral maps were not used in the following provinces:

Inclosure 1

INDEX SHEET

OF CADASTRAL SYSTEMS OF AUSTRO-HUNGARIAN EMPIRE



ORIGINS

OF AUSTRIAN CADASTRAL SYSTEMS

No.	ORIGIN		Original coordinates used 1817–1904	Coordinates used since 1904	In Hermannskogel system of K.u.K. III. MT
1	Vienna, St. Stephen's Tower	φ λ	48°12′32″75 34 02 21.60	31″54 27.32	31″5277 27.3275
2	Gusterberg	φ λ	48 02 20.50 31 48 09.17	18.47 15.05	18.4753 15.0242
3	Löwenburg (Lvov)	φ λ	49 50 56.00 41 42 33.00	49°50′55″2429 41 42 29.5684	
4	Radovec	φ λ	47 54 22.97 43 28 58.46	47 54 22.4742 43 28 56.9218	
5	Schöckl	φ λ	47 11 56.36 33 07 54.49	47 11 54.8745 33 07 59.9472	
6	Krim	φ λ	45 55 44.51 32 08 13.25	43″75 18.71	43.7228 18.8027
7	Innsbruck	φ λ	47 16 14.10 29 03 25.90	11.27 39.57	11.3060 39.3157
8	Budapest, Gellérthegy	φ λ	until 1874 47 29 15.97 36 42 51.57	since 1879 14.93 51.69	14.0714 56.2316
9	Vizakna, Observatory Sibiu (Hermannstadt)	φ λ	45 50 25.430 41 46 32.713		24.8802 37.0834
10	Kloštar-Ivanić	φ λ	45 44 21.25 34 05 09.16	20.01 13.55	22.0052 13.3520

Salzburg	surveyed	topographically	in	1807 - 1819
Tyrol and Vorarlberg	"	"	"	1816 - 1820
Hungary (Partially)	"	"	"	1810 - 1866
Transylvania	"	"	"	1853 - 1873
Serbia and Banat (Vojvodina)	"	"	"	1864 - 1866
Croatia and Slavonia	"	"	"	1867 - 1869

In these areas with very sparse density of triangulation (on the average 3 trig points to 221 square kilometers) a graphical triangulation was developed from first, second and third order trig stations.

From graphical points the detail (planimetry, hydrography and orography) was surveyed.

3. **Maps:**
The second topographical survey was utilized in the compilation of the following maps:

a. The special map of the Monarchy at 1:144,000 scale:

This map was constructed in the Cassini projection with the origin Vienna, St. Stephen's Tower for which geographic position the following values were adopted:

$$\phi = 48^{\circ}\ 12'\ 34''.0$$

$$\lambda = 34^{\circ}\ 02'\ 15''.0 \text{ East of Ferro.}$$ [60]

The sheets were composed each of nine 1:28,800 manuscripts reduced at ratio 1:5, and have uniform sheet lines, i.e. rectangulars with dimensions

9.6 x 14.4 Zolls, or

25.29 x 37.93 cm.

The sheet lines are consistent for the entire map.

Since the topographical survey was carried out separately for each province the compilation of the map was prepared in the same manner. The relief is expressed with hachures according to Lehmann's scale. The map was reproduced in black colour by the copper-engraving process. The sheets covering each province were considered as a whole and were published under title of the province, for instance "Special-Karte des Koenigreiches Dalmatien". The entire territory of the Monarchy never was covered by this map. In 1869, the compilation was discontinued and there still were not compiled the maps of Galicia, Bucovina, Transylvania and the sheets of the southern parts of Hungary and Croatia. Altogether 323 sheets had been published.

b. The general map at 1:288,000 scale: By process of reduction and generalization of the special map the sheets of the general map were compiled. The sheets were constructed in Cassini projection with Vienna, St. Stephen's Tower as origin, except 11 sheets covering Galicia and Bucovina having origin Löwenburg near Lvov. The map was reproduced in the same manner as "Specialkarte". The sheets were published separately for each province. The compilation was discontinued and the entire territory of the Monarchy never was covered. Together there were published 53 sheets.

c. Scheda's synoptical map of Central Europe at 1:576,000 scale: Col. Joseph von Scheda compiled his 1:576,000 "Generalkarte von Zentral-Europa" largely from sources of the second topographical survey. Since the entire map consists of 47 sheets constructed in Bonne projection of which 20 cover the entire territory of the Monarchy in the compilation of this map evidently there were used also various other sources. The reproduction in black colour was made by process of copper-engraving. The relief is expressed by hachures. This map has two editions (1870 and 1877) which in respect to reproductional technique at that time represented a World famous masterpiece of Cartography.

d. The general map of Central Europe at 1:300,000 scale: Since this map for the area covered by Scheda's 1:576,000 map represents merely an enlarged reproduction of Scheda's map the sheets are constructed in Bonne projection. The map consists of 207 sheets of which 72 sheets cover the entire territory of the Monarchy. The sheets were reproduced by process of helio-engraving with transfer from copper plates to lithographic stones and printed in three colours, i.e. cultural features, hydrography and nomenclature in black; relief expressed by hachures (sheets covering Balkans by shading) in brown; and woodland in green. The map was considered provisional and was after 1885 gradually replaced by sheets of the 1:200,000 general map of Central Europe compiled from the cartographic material of the III Topographical survey.

III. The Third Topographical Survey 1869 - 1896 (Neue Aufnahme).

The lack of a uniform map and the need for a more accurate map, with sufficient detail to meet the existing requirements of the army, forced the War Ministry to order a new topographical survey. For the survey which started in 1869 in Transylvania and in Tyrol new "provisional instructions" were issued. The new instructions prescribed the following improvements:

- a better system for representing communication lines with added details important from the military viewpoint,

- greater precision in the measurement of the elevations and in the drawing of contours,

- in representation of orography to replace the pallid manner of hatching by the black manner,

- the introduction of topo and military tactical descriptions for each plane table sheet.

From the very beginning uniformity was impossible because the topographical survey in Transylvania was completed in 1873, without reduced cadastral planimetry by use of the old sheet lines of 63 x 42 cm and the old 1:28,800 scale; meanwhile in Tyrol the new "square mile" sheet lines, the new 1:25,000 scale, and cadastral planimetry were used.

In 1872, the metric system was legally established in the Austro-Hungarian Empire, the 1:25,000 scale was finally adopted for topographical survey, and graticule sheet lines of the polyhedric projection were introduced in order to eliminate inconsistency in sheet lines and differences in size and shade of sheet lines.

In 1875, final instructions for the execution of the third topographical survey were published. These instructions. based on the experience obtained during five years of survey, represent a modification of the provisional instructions. The instructions were issued together with topographical symbols.

The survey of the entire Monarchy including occupied territory Bosnia and Herzegovina was completed in 1887. (675.000 km^2). The third topographical survey should be considered as the final topo survey for the area consisting of 95% of Empire's territory. It consists of 2780 plane table sections (each of 4 plane table sheets); of them only 860 plane table sections later were reambulated (instrumentally revised in the field) by the Military Geographic Institute of Vienna. The fourth topographical survey 1896 - 1913 (Präzisionsaufnahme), covered only 120 plane table sections. Thus at the time of disintegration of the Austro-Hungarian Empire in 1918, more than 61.4% of the topographical material represented the plane table sheets surveyed prior to 1887 and never revised. (See Inclosure 2).

1. Geodetic foundation: The geodetic elements upon which the third topographical survey of Austro-Hungarian Empire was based as well as the maps at scale 1:75,000, 1:200,00, and others compiled from plane table sheets of the third survey, could be explained as follows:

a. Ellipsoid: Ellipsoid of Bessel with:

$$a = 6\ 377\ 397.15 \text{ meters}$$
$$b = 6\ 356\ 078.96 \text{ "}$$
$$f = \frac{1}{299.1528}$$

b. Projection: Polyhedric. The trapezoidal-shaped sheets bounded by meridians and parallels of 15' in latitude and 30' in longitude are individual projecting planes where this small spheroidal trapezoid is considered as plane trapezoid.
The starting meridian of Ferro with

17° 39' 46".02 West of Greenwich.

c. Triangulation: II Military Triangulation 1806 - 1869, with several datums where in the position computations for the new special map were used:

Vienna, University Observatory,
latitude 48° 12' 35".50,
longitude 34° 02' 36.00 East of Ferro,
azimuth to Leopoldsberg $163^{\circ}42'13".35$ (12".27 after 1859).
All determined astronomically.[101]

Arad, St. Anna S.B.P.
latitude 46° 18' 47".63 determined astronomically,
longitude 39° 06' 54.19 geodetically derived from Vienna,
azimuth to Kurtics determined astronomically.[101]

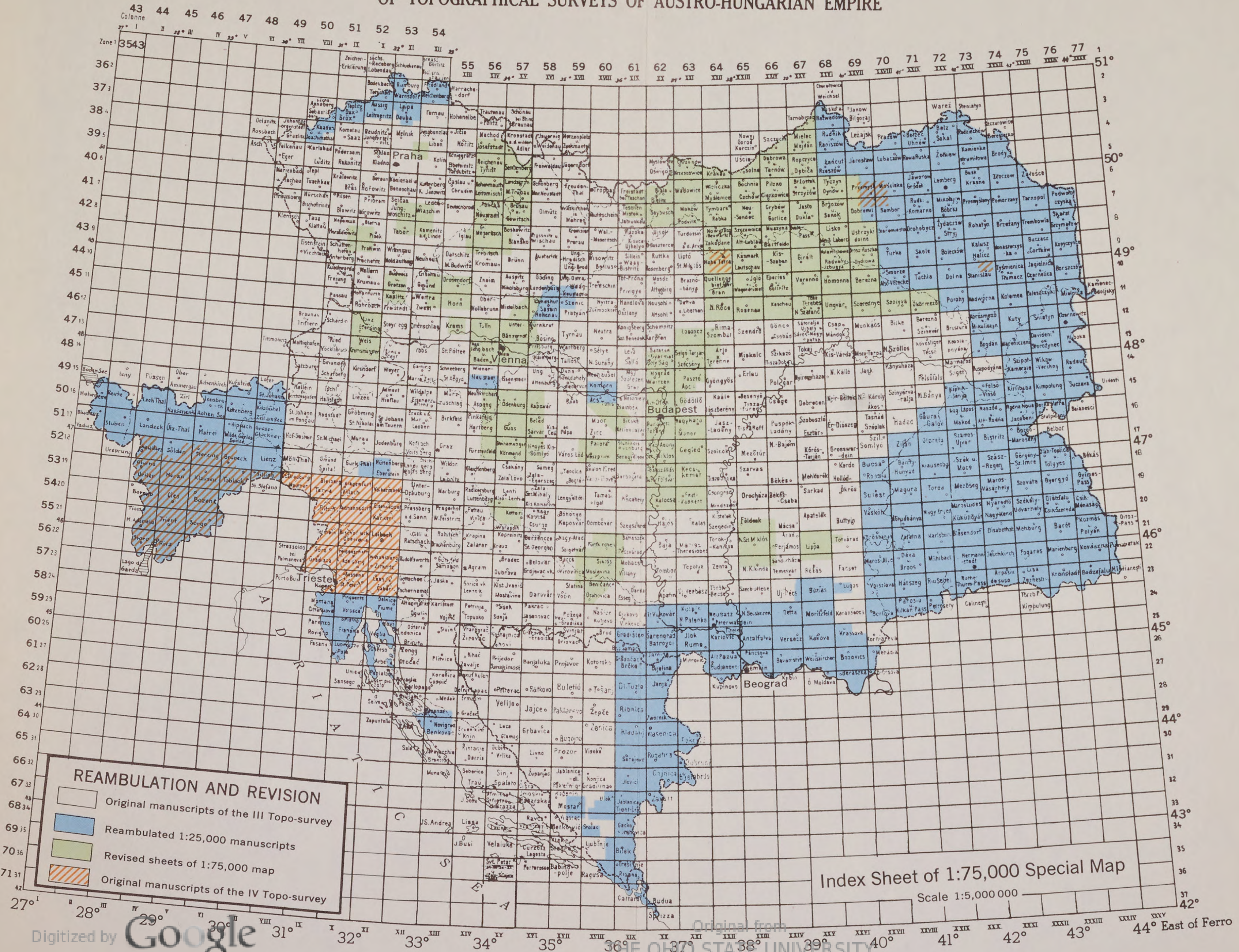
The second military triangulation surveyed in 1806 - 1829 consists of the main chains covering the western part of the Monarchy (West of the meridian of Budapest) and the chain which extends along the Carpathian Mountains to Transylvania. The triangulation including the base lines at:

Wiener-Neustadt (1762)	6410.90	Klafters	(12,158.170 m)
Wels (1806)	7904.045 ± 0.360	Klafters	(14,989.896 m)
Raab (1810)	9429.429 ± 0.010	Klafters	(17,882.762 m)
Radovec (Radautz 1818)	5199.597	Klafters	(9,860.953 m)

Inclosure 2

INDEX SHEET

OF TOPOGRAPHICAL SURVEYS OF AUSTRO-HUNGARIAN EMPIRE



was of lower accuracy and after the establishment of Military Geographic Institute (1839) it was resurveyed.

In order to cover the entire Monarchy with a first order net the base lines at:

Arad, St. Anna, Hungary (1840)	8767.578 m
Partin (Tarnow), Galicia (1849)	5972.501 m ± 1/2,000,000
Hall, Tyrol (1851)	5671.317 m ± 1/ 740,000
Wiener-Neustadt (1857 resurveyed)	9484.065 m ± 1/ 700,000
Maribor, Styria (1860)	5697.405 m ± 1/4,200,000
Josefov(Josefstadt) Bohemia(1862)	5257.266 m ± 1/ 850,000
Sinj, Dalmatia (1870)	2475.474 m ± 1/1,600,000

were measured and the triangulation extended over the eastern and southern parts of the Monarchy. For the purpose of orientation of the base lines and chains 11 astro stations were determined.[91]

Considering the accuracy, the chains were not observed uniformly and were never rigorously adjusted. No adjustment of the loops (polygonal adjustment) and no uniform astronomic orientation of the net was ever made. Thus geographic coordinates were computed from different datum points. The computations were carried out on various ellipsoids, i.e:

1810-1845	Bohnenberger,	a = 6 376 602 m, f = 1/324	[61]
1845-1863	Zach	a = 6 376 480 m, f = 1/310	
1847-1851	Walbeck	a = 6 376 896 m, f = 1/302.78	[66]

Walbeck ellipsoid was used as reference surface in the computing of the chains in Galicia and Bucovina by means of which the II Military Triangulation was tied with the Russian triangulation.[66] Finally in 1863, Bessel ellipsoid by the instructions for triangulation was prescribed.

Such was the triangulation used as the foundation of a "uniform graticule system"; whereas in order to utilize the cadastral planimetry in topographical survey the cadastral sections of the 10 different systems should be uniformly positioned. Fourthermore the military triangulation at that time did not yet embrace the entire area of the Empire and in some regions the cadastral chains had to be used in position computations for the new map. For instance, in Lower Austria in the computations of a link the cadastral records were used. In northern Hungary and in Galicia two chains of cadastral triangulation executed prior to 1830 were used; meanwhile in Transylvania a chain of "new" triangulation surveyed from 1869-1871 was included in the position computations. The scale of these three chains was largely affected by the erroneously measured base line of Radovec (Radautz) in Bucovina. The base line of Radovec was measured by the Austrian Cadastral Survey in 1818 with an error of 1 klafter (1.896 meters). It was remeasured in 1874. It should be mentioned that, despite the fact that the degree survey (Gradmessungen, begun 1862, was not nearly completed at the time, some chains of that survey were used in the position computations even through no adjustment had been made in some of these chains and only preliminary adjustment had been made in others. One example is the chain along the entire Austrian Adriatic Coast.

This was the stage of the development of triangulation in the Austro-Hungarian Empire at the beginning of the Third topographical survey. At that time, about 1870, the positions for the new "special map" were computed. These positions were compiled much later (1887 and 1889) in two sections of "Positions Rechnungen", M.G.I. Protocols 290 A, 290 B (File No. 661.0895). Prior to the time of compilation some documents of computations had been lost. Photostatic copies in possession of A.M.S. are not complete. There is available only the list of geographic coordinates, angles, and logarithms of sides; but the list of geographic positions of sheet corners of cadastral sections, all enclosed computations and a key-index map are missing. The information given in the preface of the "Positions Rechnungen" is already summarized in Geodetic Memorandum 1000 and need not be repeated.[140]

The lack of rigorous adjustment of the individual chains, and particulary the lack of polygonal adjustment of closed chains, caused tensions in the chains, disparities among the coordinates of identical stations belonging to different chains, and large variances in orientation among the chains. Thus the triangulation with the coordinates derived from one datum, either Vienna, University or Arad, St. Anna, can not be considered homogeneous.

(1) System Vienna, University: The triangulation of the western and southern parts of the Monarchy with coordinates referring to Vienna, University Observatory, which covers the provinces: Bohemia, western parts of Moravia and Silesia, Upper Austria, Lower Austria, Salzburg, Tyrol and Vorarlberg, Styria, Carinthia, Carniola, Coastland, Dalmatia, Croatia and Slavonia, as well as the western and southern parts of Hungary, should be regarded as more uniform than the triangulation of the St. Anna System. In general the interior disparities would rarely exceed 15 meters of linear value. Meanwhile in lower Styria, Carniola, Coastland and Dalmatia the geographic coordinates of some identical stations computed in different chains would differ as follows:

No.	Station name	dφ	dN	dλ	dE
243 282	Hochstradenkogel	+ 0".56	+ 17.26 m	+ 0".57	+ 12.07 m
165 262	Krim (Krimberg)	- 0.08	- 2.47	- 0.73	- 15.72
166 267	Nanos	+ 0.12	+ 3.70	- 0.68	- 14.68
216 286	Sneżnik (Schneeberg)	- 0.24	- 7.41	- 0.84	- 18.21
217 285	Slavnik	- 0.05	- 1.54	- 0.87	- 18.87
219 272	Pirano	+ 0.06	+ 1.85	- 0.86	- 18.66
222 287	Učka (Mt. Maggiore)	- 0.11	- 3.40	- 1.02	- 22.22
223 288	Tuhobić	- 0.23	- 7.10	- 1.00	- 21.77
224 292	Sis (Mt. Sys)	- 0.27	- 8.33	- 1.28	- 27.99
230 294	Oser (Mt. Ossero)	- 0.43	- 13.27	- 1.28	- 28.19

(See Inclosure 3).

The disparity at Hochstradenkogel results from computation of the Carinthian chain and the chain which extends through Upper Styria. The disparities in coordinates at southern stations, which appear to be systematical, obviously arose where the coordinates of old triangulation and of unadjusted chains of the new degree-survey are compared. The preface of Protocal 290 B includes a remark that these disparities came from "recomputation" of the chain and that the values used in the mapping are underlined in the index-map. (The map is missing). Beyond all doubt these disparities, if applied to the positions of sheets in the area considered, represent the interior twist of the graticule in the Vienna University System.

(2) System Arad, St. Anna: The geographic positions referring to datum Arad, St. Anna S.B.P. were used in the topographical survey of Transylvania, Bucovina, Galicia, the Northern part of Hungary and Eastern part of Moravia and Silesia. These geographic positions should be considered to be less homogeneous than those referring to Vienna, University used in the mapping of the Western and Southern parts of the Monarchy.

Arad, St. Anna S.B.P., as datum was determined as follows: The latitude

$$46^{\circ}\ 18'\ 47''.63$$

and the azimuth to Kurtics (angular value not shown in any of the available records) were determined astronomically. The longitude

$$39^{\circ}\ 06'\ 54''.19 \text{ East of Ferro}$$

was geodetically derived from Vienna, St. Stephen's Tower. In the computations Zach ellipsoid with flattening 1/310 was used. These values, compared with the geographic coordinates derived in 1870 from Vienna, University using the Bessel ellipsoid would differ as follows:

ϕ A = 46° 18' 47".63;	λ = 39° 06' 54".19	derived from St. Stephen
ϕ G = 46° 18' 44.71;	λ = 39° 06' 49.94	derived from University
d ϕ = +2.92	d λ = +4.25	

These differences would express the relationship between the two systems at point Arad, St. Anna S.B.P.

A chain from St. Anna base line to Sibiu (Hermannstadt), Observatory was computed in 1846. The computations again were based on the Zach f = 1/310 ellipsoid and St. Anna S.B.P. was used as starting point. From these computations for Sibiu (Hermannstadt), Observatory the following values were obtained:

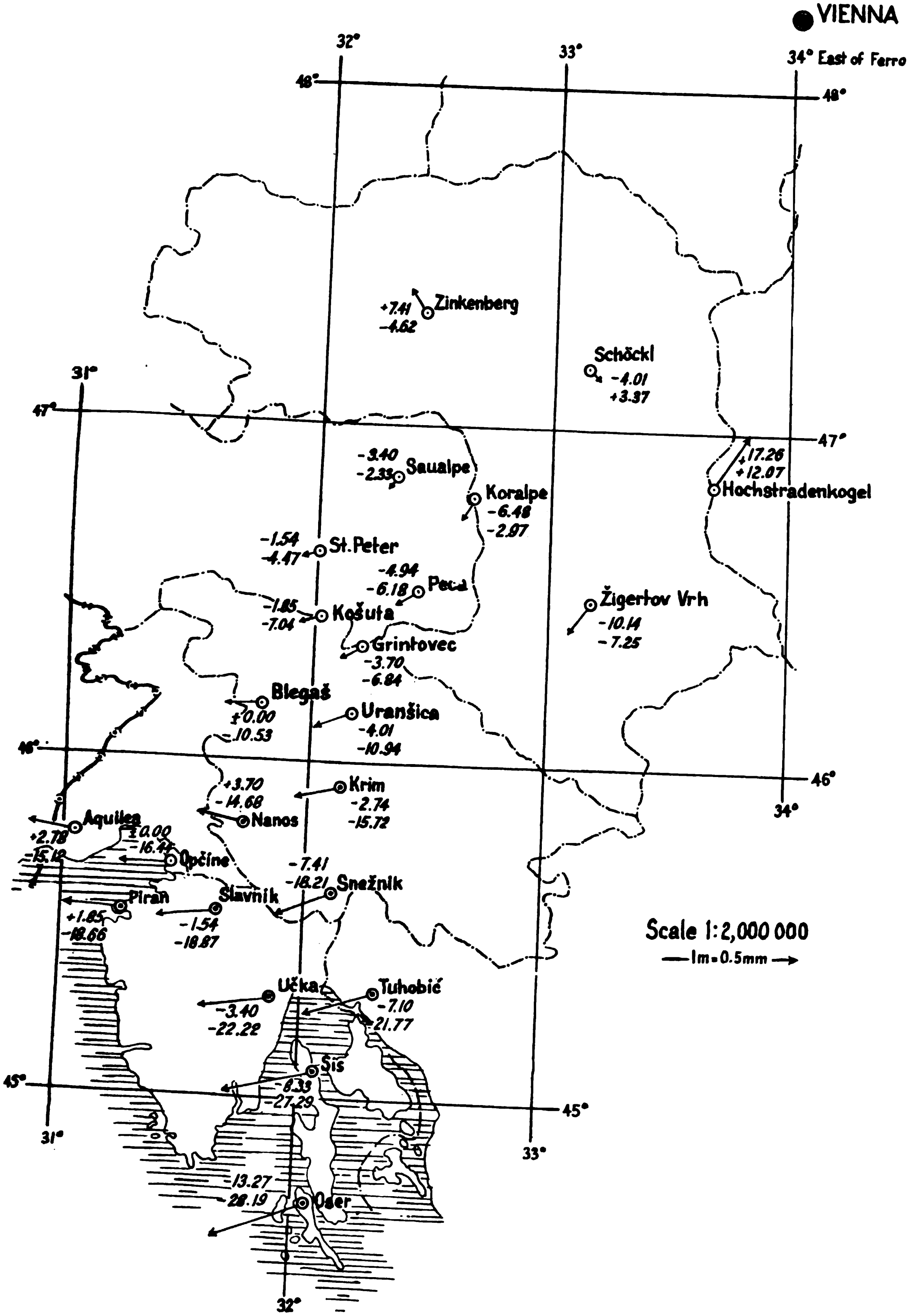
$$\phi = 45^{\circ}\ 50'\ 28''.95$$
$$\lambda = 41^{\circ}\ 46'\ 39''.00 \text{ East of Ferro}$$
$$\alpha \text{ to Presbe} = 359^{\circ}\ 16'\ 33''.78.$$

If these values are compared with the values derived in 1870 from Vienna, University using the Bessel ellipsoid:

$$\phi = 45^{\circ}\ 50'\ 25''.97$$
$$\lambda = 41^{\circ}\ 46'\ 31''.66 \text{ East of Ferro}$$
$$\alpha \text{ to Presbe} = 359^{\circ}\ 16'\ 43''.24$$

[101]

Inclosure 3



VIENNA
32°
33°
34° East of Ferro
48°
48°
+7.41
-4.62
Zinkenberg
Schöckl
-4.01
+3.37
31°
47°
47°
-3.40
-2.33
Saualpe
Koralpe
-6.48
-2.97
+17.26
+12.07
Hochstradenkogel
-1.54
-4.47
St. Peter
-4.94
-6.18
Peca
Žigertov Vrh
-10.14
-7.25
-1.85
-7.04
Košuta
Grintovec
-3.70
-6.84
Blegaš
±0.00
-10.53
Uranšica
-4.01
-10.94
46°
46°
34°
+3.70
-14.68
Krim
-2.74
-15.72
Nanos
Aquilea
+2.78
-15.12
±0.00
-16.44
Opčine
-7.41
-18.21
Snežnik
Piran
+1.85
-18.66
Slavnik
-1.54
-18.87
Scale 1:2,000 000
1m = 0.5mm
Učka
-3.40
-22.22
Tuhobić
-7.10
-21.77
Sis
-8.33
-27.29
45°
45°
31°
33°
-13.27
-28.19
Oser
32°

the following disparities are obtained:

$$d\phi = +2''.98$$
$$d\lambda = +7.34$$
$$d\alpha = -9.46$$

These values represent the relationship between Vienna, University and Arad, St. Anna Systems at Sibiu (Hermannstadt), Observatory. The latitude is greater by about 3". The longitude increases toward the East because the Zach f = 1/310 ellipsoid was used in the computations and differs between 7 - 9". Moreover, due to the rotation which was thus caused, the disparities at numerous identical points are not constant.

In 1870 a new first order chain between Sibiu (Hermannstadt) and Radovec (Radautz) base line was surveyed. It was utilized in the computation of the geographic positions for the new special map. The side Bükve - Kitserer was used as the starting side in the computations with the coordinates and azimuth derived from St. Anna S.B.P. Meanwhile the logarithm of side

4 330 3298 (21 395.86 m)

is the same as is used in the computations of 1870 from Vienna and differs from the logarithm obtained in 1846 in the computation of the chain St. Anna - Sibiu (Hermannstadt)

4 330 2098 (21 394.88 m)

for

$$d \log = 200 \cdot 10^{-7} = (0.98 \text{ m})$$

As already mentioned, the base line of Radovec, used in the computations of this chain, was in error by 1.896 m.

Starting from Radovec base line, two chains composed mostly of cadastral triangles surveyed prior to 1830 in the computations of geographic positions for the special map were used. The northern chain extends through Galicia to Silesia and Moravia, the southern chain through Marmaros and Upper Hungary to Moravia. The following stations are common to both chains and the coordinates of St. Anna datum computed through the southern chain would differ from those derived through the northern chain as follows:

No.	Station name	$d\phi$	dN	$d\lambda$	dE
95 303	Krivan	- 0".55	- 16.99 m	+ 1".69	+ 34.20 m
97 302	Baraniec	- 0.50	- 15.44	+ 1.56	+ 31.56

No.	Station name	dφ	dN	dλ	dE
98 225	Niedzwiezd (Klucky)	- 0".52	- 16.06	+ 1".77	+ 35.56
113 224	Babiagora	- 0.57	- 17.61	+ 1.77	+ 35.51
125 280	Lopenik	- 0.18	- 5.56	+ 1.69	+ 34.37
149 263	Lysa Gora	- 0.36	-11.12	+ 1.73	+ 34.73

(See Inclosure 4).

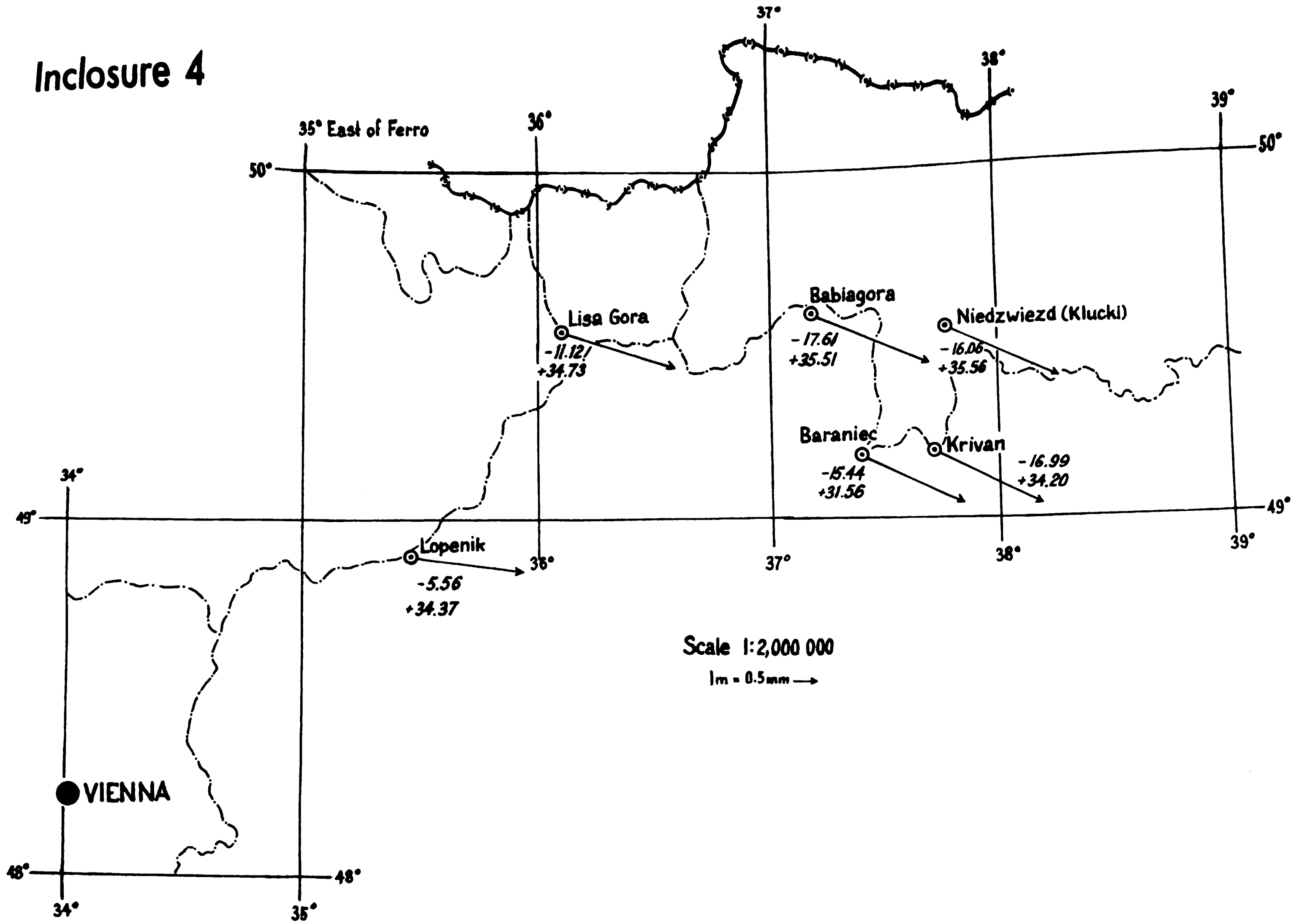
The systematical disparities which arose between the coordinates obtained in the computations of northern and southern chain required for certain areas of Upper Hungary and Galicia, both of St. Anna System, the adjustment of geographic positions of trig points and of the cadastral section sheet corners. The adjustment was made empirically and in many cases there were taken just the mean values of coordinates obtained in the computations of northern and southern chain. The index map (now missing) would indicate for which sections adjusted positions were used. In general the adjusted area lies between the 37° and 41° meridians and between the 49° and 50° 15' parallels.

The listed differences indicate the average interior disparity of St. Anna System in the area of Galicia and Upper Hungary would be a follows:

$$d\,N_a = -\,13.80 \text{ m}$$
$$d\,E_a = +\,34.32 \text{ m}$$
$$S_a = \sqrt{d\,N_a^2 + d\,E_a^2} = 37.00 \text{ m}$$

In respect to the adjustment of geographic positions of trig points and sheet corners of cadastral sections, it is to be noted, that a remark in the introduction of Protocol 290 A indicates that the positions in this area were adjusted along with the conversion of geographic positions into rectangular coordinates in order to plot the stations into plane table sections. The method of adjustment is not mentioned. Some later publications, such as "Planheft", mention empirical adjustment or just say "mean values were used" as it is said in the study "The relationship between the German Army Grid (D.H.G.) and Yugoslav and Hungarian

Inclosure 4

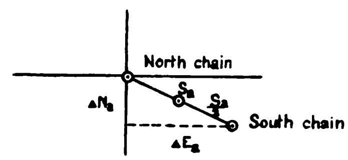

35° East of Ferro
36°
37°
38°
39°
50°
49°
48°
34°
35°
Lisa Gora
-11.121
+34.73
Babiagora
-17.61
+35.51
Niedzwiezd (Klucki)
-16.06
+35.56
Baraniec
-15.44
+31.56
Krivan
-16.99
+34.20
Lopenik
-5.56
+34.37
VIENNA
Scale 1:2,000 000
1m = 0.5mm

maps" by Dr. Ledersteger.[107] Thus, in the area of Galicia and Upper Hungary if the mean values are applied to the sheet corners we can expect an average shift as follows:

$$\frac{d\,N_a}{2} = -\,6.90 \text{ m} = 0.28 \text{ mm at scale } 1{:}25{,}000$$

$$\frac{d\,E_a}{2} = +17.16 \text{ m} = 0.69 \text{ mm at scale } 1{:}25{,}000$$

$$\frac{Sa}{2} = \sqrt{\left(\frac{dNa}{2}\right)^2 + \left(\frac{dEa}{2}\right)^2} = 18.50 \text{ m} = 0.74 \text{ mm at scale } 1{:}25{,}000.$$



Scale 1:2500

The comparisons of coordinates at identical stations common to the uniformly adjusted First Order Net published in the "Ergebnisse der Triangulierungen" and to "Positions Rechnungen" (File No. 661.1184, Anlage 2 and 3) would confirm the same interior twist of the St. Anna System in the regions of Galicia and Upper Hungary.

(3) <u>The Areas of Adjustment</u> between the systems of Vienna University and Arad, St. Anna S.B.P.

The most inaccurately positioned maps from the viewpoint of geographic position are the sheets of the III topographical survey at 1:25,000 and 1:75,000 scale covering the areas of adjustment. In those regions where the sheets are based on original geographic positions, referring either to Vienna University datum or to Arad, St. Anna datum, the positions of sheets within the region are determined by one of the two systems with an accuracy discussed in the previous two paragraphs. Meanwhile, in order to match the sheet lines of the two systems within the areas of adjustment, the geographic positions obtained corrections of unknown numerical value; thus the sheet-corner values must be considered as <u>mathematically unknown</u>.

In the regions of the two systems, where the maps are based on unchanged geographic positions, the numerical values of geographic positions can be compared with the geographic coordinates of the adjusted and oriented uniform first order net. By use of the disparities obtained from these comparisons in the Helmert's conformal transformation the transformation elements can be determined and the corrections to the sheet-corners computed. Thus the sheets of each system can be recasted and regrided by means of exact mathematical operation. It is impossible by using such mathematical procedure to reconcile the sheets within the "adjustment areas" with the uniform first order net because there exist no numerical values for the positions which were the basis for construction of the sheets. In these areas the extent of displacement of the sheets can be determined within proper limits of graphical accuracy only by comparison of scaled positions with the coordinates of the uniform first order net. Hence by elimination of displacement at identical stations the sheets, or parts of the sheets, can be restored only cartographically to proper position.

The chains of the Vienna and St. Anna Systems were joined in the northern part of the Monarchy (Silesia and Moravia) and in southern part (Banat). (See Inclosure 5). Thus northern and southern area of adjustment.

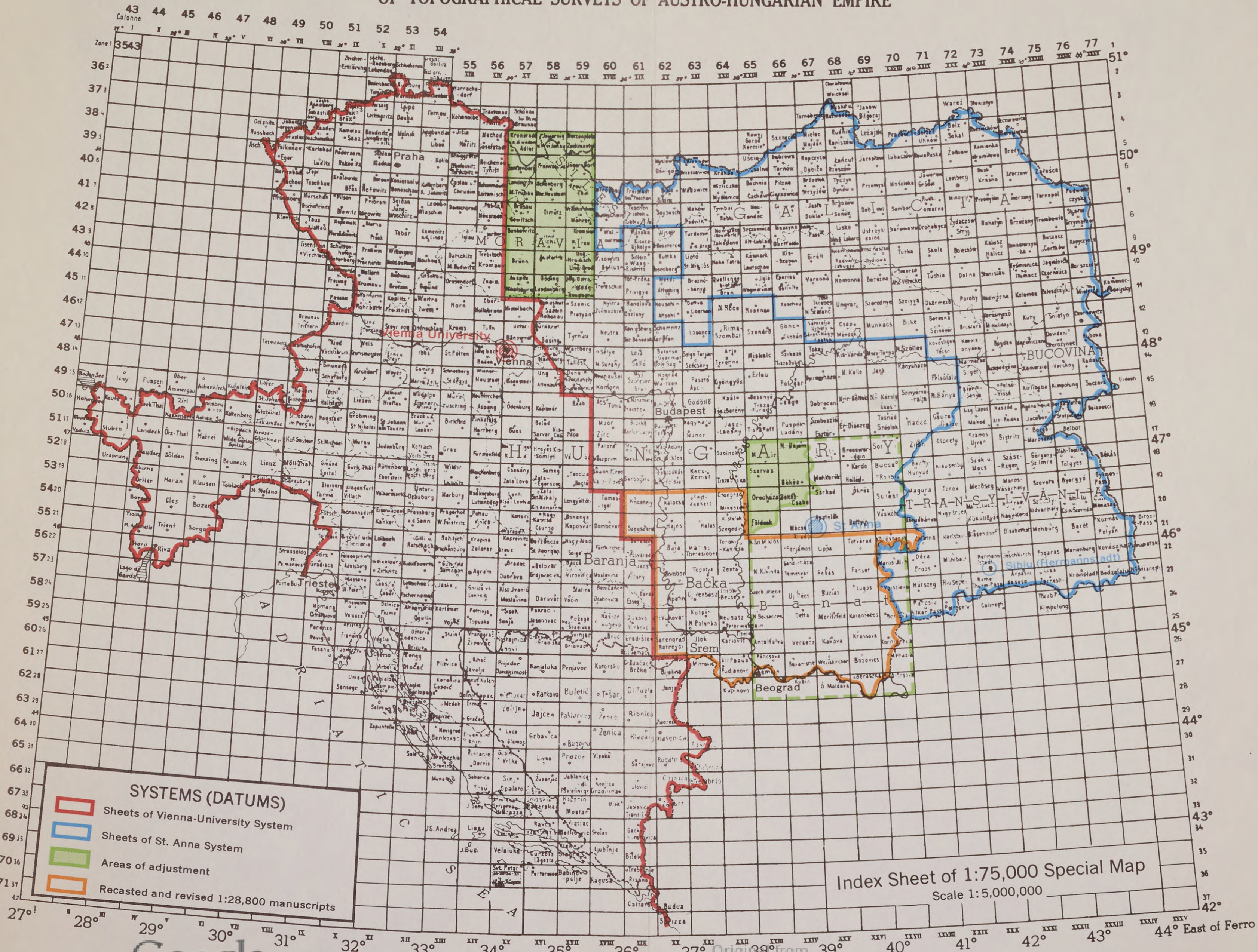
(a) The Northern Area of Adjustment; In the Provinces Moravia and Silesia a comparison of the geographic positions of Vienna University System and St. Anna System give the following disparities: (St. Anna - Vienna)

No.	Prot.No.	Station name	$d\phi$	dN	$d\lambda$	dE
1	54/299	Horny les	+ 1".58	+ 48.80 m	+ 7".27	+ 145.84 m
2	37/298	Leskona	+ 1.70	+ 52.50	+ 7.64	+ 155.16
3	53/301	Sekorce	+ 1.56	+ 48.18	+ 7.37	+ 148.33
4	64/293	Maidenberg	+ 1.71	+ 52.72	+ 7.64	+ 155.55
5	67/284	Buchberg	+ 1.68	+ 51.89	+ 6.98	+ 138.71
6	63/296	Nadanov	+ 1.73	+ 53.43	+ 7.59	+ 154.18
7	69/283	Schneeberg	+ 1.70	+ 52.51	+ 6.85	+ 135.55
8	66/285	Bradstein	+ 1.77	+ 54.67	+ 7.07	+ 141.05
9	75/288	Kosirc	+ 1.78	+ 54.98	+ 7.28	+ 146.08

Inclosure 5

INDEX SHEET

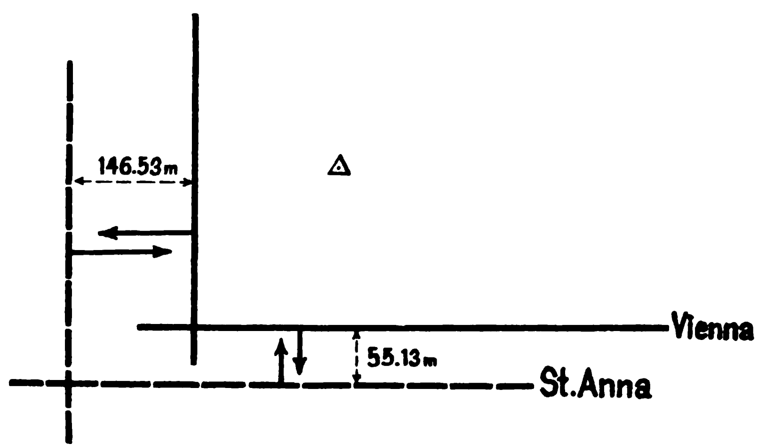
OF TOPOGRAPHICAL SURVEYS OF AUSTRO-HUNGARIAN EMPIRE



No.	Prot.No.	Station name	dΦ	dN	dλ	dE
10	69/281	Hohe Haide	+ 1".81	+ 55.91	+ 6".94	+ 137.77
11	74/282	Bischofskuppe	+ 1.86	+ 57.46	+ 6.82	+ 134.81
12	85/272	Javornik Kelsky	+ 1.94	+ 59.92	+ 7.35	+ 148.02
13	84/273	Kominek	+ 1.97	+ 60.84	+ 7.58	+ 153.43
14	110/280	Lopenik	+ 1.94	+ 59.91	+ 7.67	+ 156.01
15	90/269	Javornik	+ 2.05	+ 63.32	+ 7.34	+ 147.42

$$dN_{av} = \frac{[dN]}{n} = + \ 55.13 \text{ m}$$

$$dE_{av} = \frac{[dE]}{n} = + \ 146.55 \text{ m}$$



According to the preface of "Positions Rechnungen" (Protocol 290 A) the plotted positions in this area were adjusted along with the conversion of geographic positions into rectangular coordinates. In order to avoid the creation of the overlapping strips along the junction of the sheets of the two systems, the empirically adjusted positions were plotted on plane table sections and the sheets of both systems were matched by a gradual shift of the sheet lines.

(b) <u>The Southern Area of Adjustment:</u> The region of Central and South Hungary was topographically surveyed in 1881 - 1884. This, the last part of the III topographical survey, is confined as follows:

- from the East by the topographical survey of Transylavania executed in 1869 - 1874, on the base of very sparse triangulation and without use of any cadastral records; scale 1:28,800.

- from the North by the topographical survey of Northern Hungary and Moravia carried out in 1875 - 1878, by use of cadastral planimetry.

- from the West by the topographical survey of Lower Austria and West Hungary executed in 1878 - 1880, by use of cadastral planimetry. (See Inclosure 6)

The cadastral survey to be utilized in the topographical survey was completed only in the districts Zemplen, Bereg, Ugosca and Marmaros at the northwestern edge of the region and in the districts Hajdu, Jasz-Nagy-Kun-Szolnok and Csongrad of the central part of the region. The largest part was surveyed without any cadastral planimetry.

In the region covered by the 1881 - 1884 topographical survey the geographic positions were derived either from Vienna, University or from Arad, St. Anna S.B.P. In order to match the sheet lines of the two systems in the southern area (Banat) an adjustment was made similar to that in Moravia and Silesia. Because the cadastral survey was completed only in the northwestern corner of the area of adjustment (See Inclosure 5) the plane table sheets with cadastral grid (1 mile) constructed on the basis of empirically adjusted geographic positions were used only in the northwestern corner. By reason of the lack of the cadastral planimetry and in order to maintain the progress in the survey it was decided to use as a base the recasted and enlarged sheets of the Second topographical survey; for this reason the results of the adjustment were ignored and the Third topographical survey in this area was degraded to an instrumental field revision of the old map.

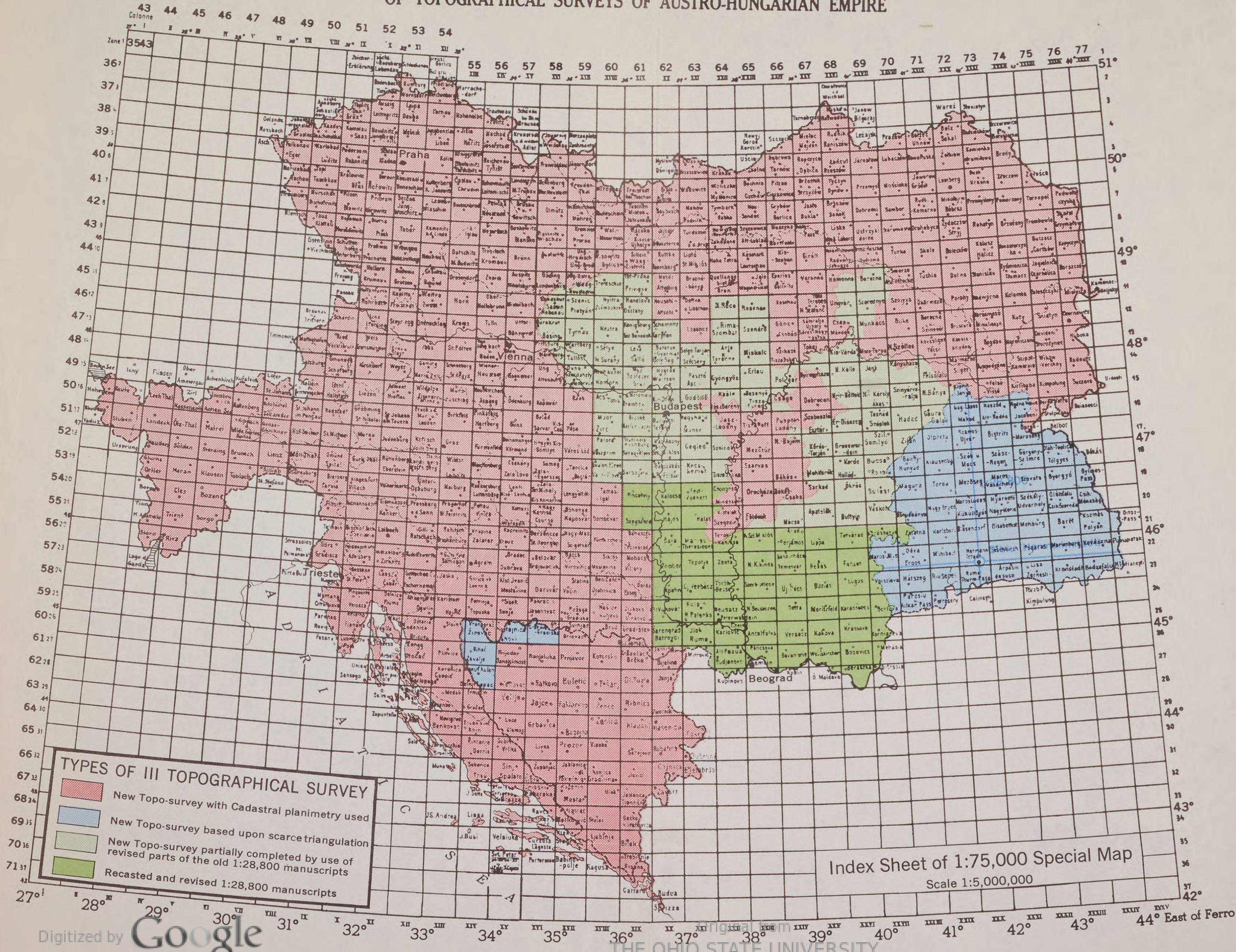
For this purpose on the old rectangular sections at 1:28,800 scale the sheet-corners of the polyhedric sheets were plotted and the sheet-lines drawn. The sections were photographically enlarged to 1:25,000 scale and recasted into the "uniform graticule system".

The recasting and composing was done on the litographic stones, where the sheet-lines were constructed and the fragments of blue-lines of the old sections matched together

Inclosure 6

INDEX SHEET

OF TOPOGRAPHICAL SURVEYS OF AUSTRO-HUNGARIAN EMPIRE



and fitted into sheet-lines. In order to obtain the proper size the fragments had to be wet or dryed. From the blue-greased negatives composed by the described method the blue-lines were printed. On the blue lines the trig points were plotted and the blue lines were revised in the field. (On the photostated plane table sections at 1:25,000 scale the primary position of the planimetry can still be traced).

In the recasting and composition of polyhedric sheets with consequent numerous distortions, the adjustment computations mentioned in the preface of "Positions Rechnungen" were not considered. By the recasting procedure, in order to match the sheets of Vienna and St. Anna systems cartographically, the sheet corner values were corrected and the sheet lines shifted. The corrections were applied erratically from sheet to sheet and thus no satisfactory connection between the two systems was reached.

In order to establish the actual situation regarding the positions of 1:25,000 and 1:75,000 maps, a careful analysis of the sheets which cover the area of adjustment was made. (See Inclosures 7 and 8).

From the analysis these conclusion could be drawn:

- The differences between the geographic positions of two systems at identical stations are:

No.	Prot. No.	Station name	$d\phi$	dN	$d\lambda$	dE
1	220/2	Elek	+ 3".02	+ 93.23 m	+ 3".96	+ 84.38 m
2	225/4	Segenthau	+ 0.09	+ 2.78	+ 5.65	+ 121.36
3	222/1	Kurtics	+ 2.91	+ 89.83	+ 4.09	+ 87.46
4	227/1	St.Anna S.B.P.	+ 2.92	+ 90.14	+ 4.25	+ 90.91
5	231/4	Dimpu Weszestyi	+ 2.82	+ 87.05	+ 4.73	+ 101.72
6	224/3	Hegyes	+ 2.92	+ 90.14	+ 4.68	+ 100.30
7	223/3	Mokra	+ 3.04	+ 93.85	+ 4.66	+ 99.55
8	232/7	Mogura	+ 2.73	+ 84.27	+ 5.12	+ 110.64
9	310/6	Pless	+ 3.16	+ 97.55	+ 4.90	+ 104.39

10	230/6	Drocsa	+ 2"98	+ 91.99	+ 5"08	+	109.07 m
11	311/8	Mogura Korbest	+ 3.37	+ 104.04	+ 4.87	+	103.02
12	233/7	Dimpu Cornulur	+ 2.85	+ 87.97	+ 5.32	+	114.46
13	235/8	Ruszka	+ 2.72	+ 83.96	+ 5.46	+	118.16
14	309/11	Maguraja	+ 3.02	+ 93.22	+ 5.87	+	125.97
15	265/9	Bihar	+ 3.15	+ 97.24	+ 5.48	+	117.13
16	266/9	Vladeasca	+ 3.36	+ 103.73	+ 5.57	+	118.17
17	239/14	Vurvu Caratului	+ 2.72	+ 83.96	+ 5.84	+	126.47
18	246/12	Vulkan	+ 3.05	+ 94.15	+ 5.82	+	124.64
19	243/14	Hajto	+ 2.94	+ 90.75	+ 6.03	+	129.77
20	268/30	Ejszakhegy	+ 2.91	+ 89.85	+ 6.95	+	139.48
21	248/10	Muntile Mare	+ 3.26	+ 100.64	+ 6.08	+	129.63

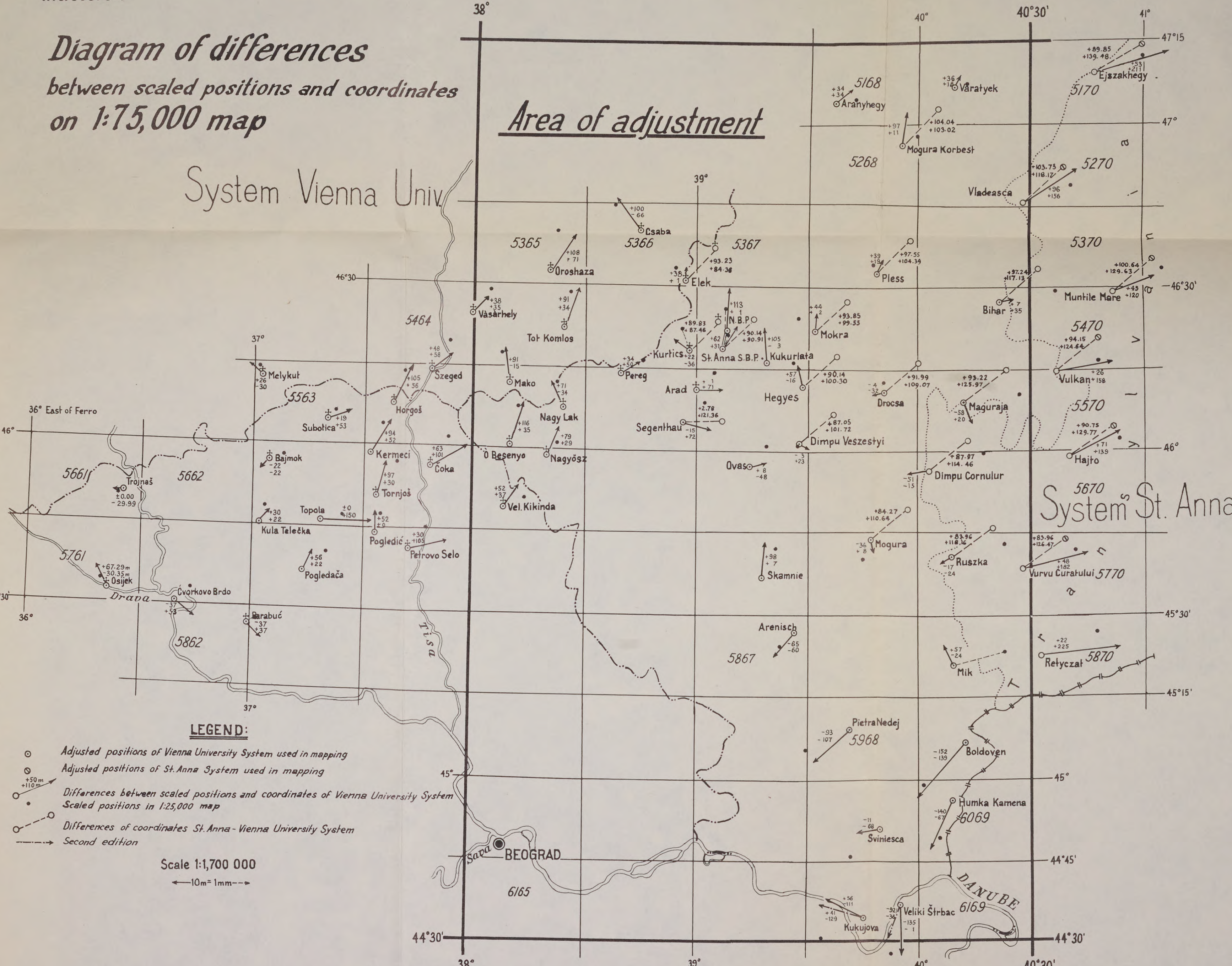
These differences, except that of station Segenthau, are in such a degree systematical that a gradual shift of the sheet-lines would satisfy the connection of the two systems with an accuracy of ± 10 meters. Regarding the method of construction of the plane table sections, previously explained, this accuracy would be satisfactory.

The sheets positioned on the two different systems create an overlapping area. If the sheets of two systems have to be matched along the meridian $40^\circ\ 30'$ the average disparity derived from the differences of stations:

Vladeasca
Vurvu Caratului
Vulkan
Hajto
Ejszakhegy
Muntile Mare

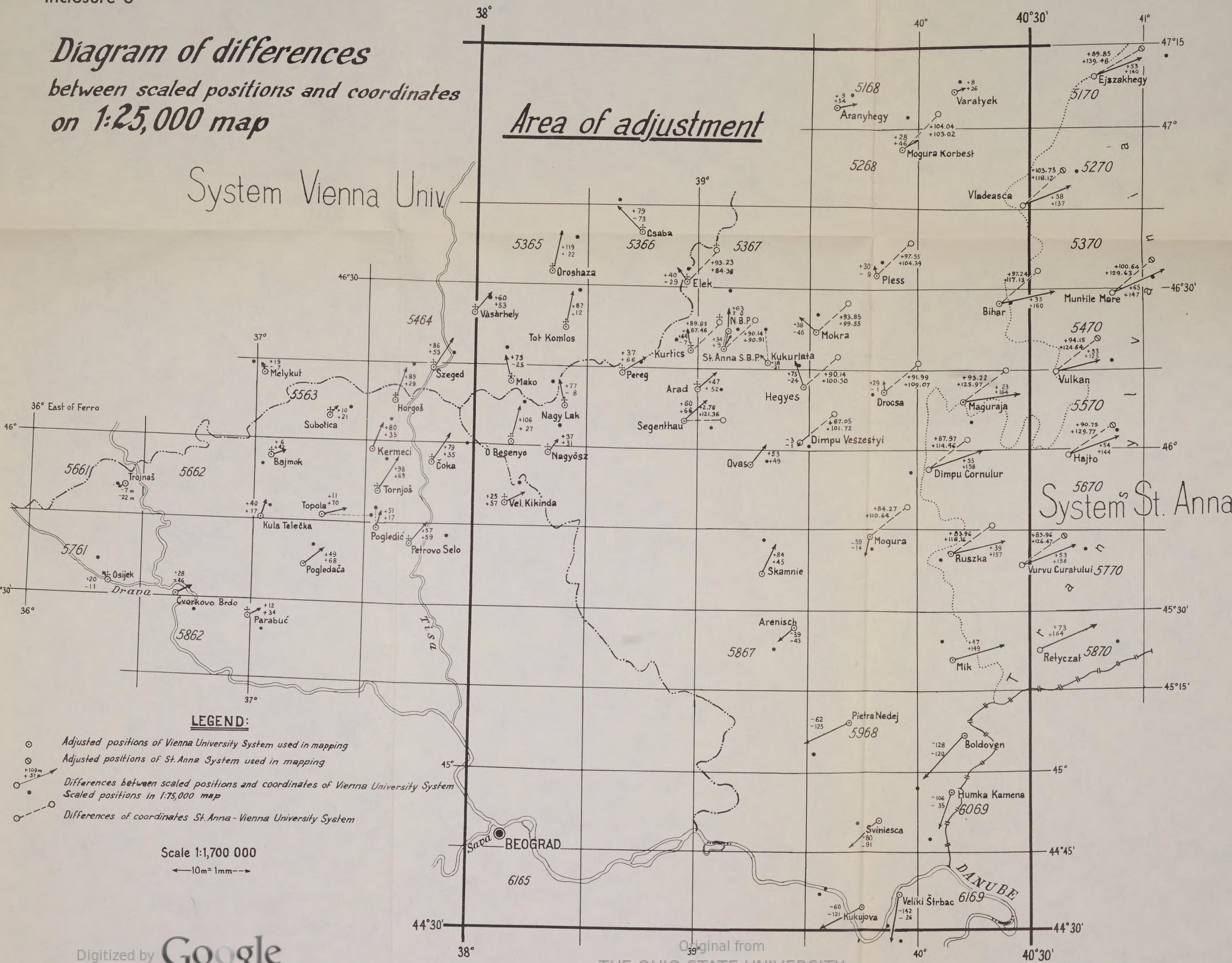
would be:

Diagram of differences
between scaled positions and coordinates on 1:75,000 map



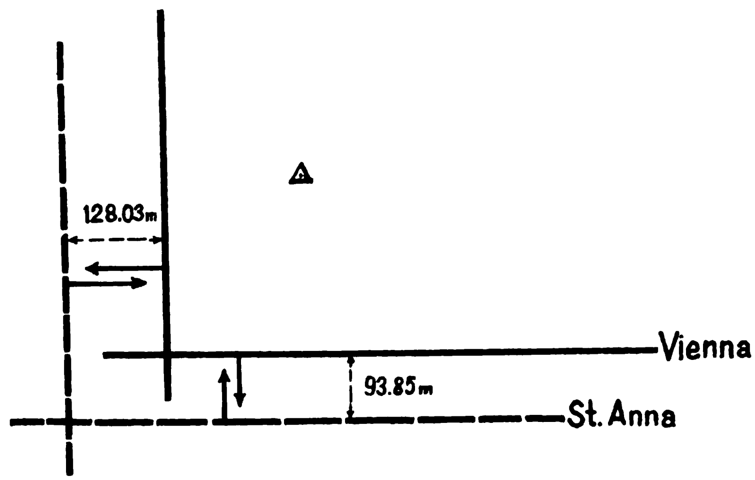
Inclosure 8

Diagram of differences
between scaled positions and coordinates on 1:25,000 map



$$dN_{av} = \frac{[dN]}{n} = 93.85 + 10 \text{ meters}$$

$$dE_{av} = \frac{[dE]}{n} = 128.03 + 10 \text{ meters}$$



By a shift of the sheet-lines of the Vienna system toward the South and West increasing the N and E of trig stations located in the column 5169 - 6169 (See Inclosure 7) for the average dN and dE the sheet-lines would match with an accuracy of ± 10 meters. If the positions of the sheets located west of the 38° meridian and of the sheets situated east of 40° 30' meridian are held fixed and if the coordinates of Vienna system at the stations in the area of adjustment would be gradually increased in each zone and column of 15' for

$$dN = 8.5 \text{ meters}$$
$$dE = 12.8 \text{ meters}$$

the connection would be achieved with an accuracy that in no case would be lower than the accuracy by which the sheets in the transition area were composed and recasted. Any adjustment of greater accuracy would be useless. It could be supposed that a similar gradual shift was made by the empirical adjustment applied after the conversion of geographic positions into rectangular coordinates in order to plot the cadastral planimetry in sympathy with the "uniform graticule system"; but the comparisons of the geographic positions with the positions scaled from 1:25,000 and 1:75,000 maps show that such a gradual shift was not used in actual mapping.

The geographic positions of the Vienna system for the 64 stations available in the area of adjustment were compared to the scaled positions of the 1:25,000 and 1:75,000 maps.

The comparisons show:

- The area of adjustment is not confined (as it is contended in the introduction of the "Positions Rechnungen") to the area between the meridians of 38° and 40° 30' and 47° 15' parallels. It extends west to the Danube River and covers exactly the area in which the recasted old maps were used in the Third topographical survey. (See Inclosures 5 and 6).

- The positions of 1:25,000 sheets are not completely identical with the positions of 1:75,000 sheets, as they should be because each sheet of 1:75,000 scale is composed of four plane table sections at 1:25,000 scale.

- The displacement of 1:75,000 sheets resulted from:

  the poor construction wherever the reduced 1:25,000 sheets without exact size were forced to match the 1:75.000 sheet-lines. (This is a general deficiency of 1:75,000 maps traced over all territory of the Monarchy and will be discussed in a special paragraph);

  and because the 1:75,000 sheets in the column west of 40° 30' meridian obtained positions close to that of the Vienna system, contrary to the positions of 1:25,000 scale sheets, reambulated in 1888 - 1895*, which along the provincial boundary of Transylvania were based on the positions of St. Anna system with an average shift of the sheet-lines toward the north of approximately 1".50. (Stations were plotted with a $d\phi = -1''.50$).

- The erratic application of the corrections made the positions of sheets in the western part of the transition area closer to the St. Anna system than the sheets of the central and eastern area which are positioned close to the Vienna system and the sheets of the southern area which were shifted in a direction opposite to the direction of adjustment.

* The positions used in the comparison were scaled from the sheets reambulated in 1888-1895, at scale 1:25,000 which were composed of recasted and enlarged 1:28,800 sheets surveyed in 1872-1873. The original 1:28,800 sheets were rectangulars of 9600 x 6400 Klafters (18,206.2 x 12,137.5 meters) with the sheet lines parallel to prime vertical and meridian of Sibiu (Hermannstadt) Observatory.

The inconsistent cartographic shifts of the sheets in the transition area made it impossible to apply any mathematical operation to remedy the positions of sheets. The coordinates of plotted positions are unknown and can be ascertained only by scaling; the scaled positions on the same sheet many times have conflicting corrections and thus the sheet-corner values are unknown.

It should be mentioned that in the study "The relationship between the German Army Grid (D.H.G.) and Yugoslav and Hungarian maps" by Dr. Ledersteger (File No. 658.0394) all formulae are based solely on the disparities between the geographic coordinates of the "Ergebnisse der Triangulierungen" and the geographic positions of the "Positions Rechnungen".[107] Thus in the recasting and re-griding of the sheets covering the transition area these formulae have no application. The sheets of the transition area can be only cartographically placed in proper position by the shifts which would within the limits of graphical accuracy eliminate the differences between the coordinates of adjusted triangulation and scaled positions.

(c) <u>The Area of Central Hungary</u>; (See Inclosures 5). This area which lies between the northern and southern adjustment areas is covered by the sheets of the 1881-1884 survey based on the geographic positions either of Vienna or St. Anna system. There is no indication in available literature as to how the sheet-lines of the two systems were matched with the old revised sheets which had already been shifted erratically. One can assume that the sheets with inconsistent positions were not simply fudged cartographically, but were subject to compromising shifts.

By the comparison of available coordinates and scaled positions, it can be determined which of the sheets belong to the Vienna system and which belong to the St. Anna system, and which ones were subjected to displacement. Such an investigation would require considerable cartometric work, and was omitted in this study because the larger portion of the area concerned is already covered by the new topographical survey at 1:25,000 (Hungary) and 1:20,000 scale (Czechoslovakia), as well as by the Hungarian stereographic 1:25,000 revised sheets. In the compilation of any large scale map in the future these new maps should be utilized. The old 1:25,000 sheets of the Third topographical survey will be used only in the areas not covered by the new survey; therefore these old sheets need to be carefully investigated prior to their utilization in the compilation of a new map.

It should be mentioned that a letter from the Army Survey Office of Vienna (Heeresvermessungsstelle Wien) of April 22, 1940, to the National Survey Office (Reichsamt für Landesaufnahme) describes the regriding of Austro-Hungarian maps at 1:25,000 and 1:75,000 scale and concludes that the positions of sheet-corners in this area by reason of empirical adjustment are so inaccurate as to disagree as much as 70 meters. (File No. 661.0894).

(4) B o s n i a a n d H e r z e g o v i n a:
In 1878 the Austro-Hungarian Army occupied Bosnia and Herzegovina which prior to that time had been provinces of the Turkish Empire. The Military Geographic Institute started the survey of the occupied territory in 1879. Because there are some deviation from the standard survey practice established in the rest of the Monarchy, a brief explanation of the survey in Bosnia and Herzegovina will be given in this paragraph.

The triangulation started in 1879 with a first order chain which extends between the 35° and 36° meridian through the central part of the province and includes the base line at Sarajevo measured in 1882. In the North the first order chain was attached to these stations of the first order net in Slavonia:

356 Kučerina (of Dubica base extention net)
360 Maksimov Hrast
362 Kasonja
363 Lipovica,

and in the South to the following stations of the Dalmatian first order chain:

341 Tmor
343 Rogo
345 Ostra Glavica
348 Sniježnica
350 Orjen.

For all these stations the geographic positions referring to the Vienna University can be found in part II of "Positions Rechnungen" (Protocol 290 B). In 1883 - 1885, the first order net was extended from Sarajevo east and southeast to the Serbian and Montenegro boundary.

Bosnia and Herzegovina prior to that time had no survey and no reliable maps; therefore it was planned to start with the cadastral survey as early as 1880. The occupied province still was in a stage of resistance and since survey parties needed the protection of small combat units the K.u.k. Military Geographic Institute was charged with the execution of the cadastral survey; consequently the cadastral survey was planned and executed in such a manner that its complet utilization in the topographical survey was assured in advance.

In order to provide the cadastral and topographical survey with a sufficient density of trig points (1 trig point on each 25 square kilometers) the 2nd, 3rd and 4th order triangulation started in 1879, i.e. before the completion of the first order net. This triangulation, usually covering a region which during the next year has to be surveyed by the cadastral survey, started individually from the first order stations belonging to the already mentioned first order chains which surround Bosnia and Herzegovina from the North, West and South. In each region the triangulation was adjusted preliminarily and immediately used in the detail survey.

For the first and second order stations, which formed the so called "main net", the geographic positions of the Vienna system were computed from different starting points in different regions. These geographic positions are the basis for the "uniform graticule system" in Bosnia and Herzegovina. (The geographic positions of Bosnia and Herzegovina are not listed in "Positions Rechnungen", Protocol 290 B compiled in 1889. File No. 661.0895.)

Triangulation of Bosnia and Herzegovina comprise:

Base line Dubica	
Base line Sarajevo	
First order stations	30
Second order stations	136
Third and fourth order trig points	2094
T o t a l	2260 trig points,

of them 54 churches, mosques and monuments.

The cadastral survey of Bosnia and Herzegovina is unique for the entire Monarchy, since it is in position completely identical with the topographical survey. The cadastral sections are cut in the "uniform graticule system". The polyhedric sheet of $15'_{\phi} \times 30'_{\lambda}$ at 1:75,000 scale is divided into 16 cadastral sections at 1:12,500 scale, 64 cadastral sections at 1:6,250 scale and 256 sections at 3,125 scale which were used only in the survey of closed settlements. In order to meet the cadastral requirement the spheroidal Soldner coordinates with the origin at center of each 1:75,000 sheet for all lower order stations of Military triangulation were computed. The cadastral survey was completed in 1885. Reduced by pantograph to 1:25,000 scale it served as base for the topographical survey.

In 1944, the Germans transformed the Soldner coordinates, with the origin at the center of each 1:75,000 sheet, into Yugo Red. Gauss-Krueger coordinates (File No. 658.0394).[108] It should be remembered that the sheets were positioned on geographic positions of Vienna University system computed from preliminary adjusted regional nets with different starting points used in computation meanwhile the Yugoslav triangulation represents a homogeneous, final adjusted net oriented on Hermannskogel datum. The linear conformal transformation was made by the sheets where, because of lack of a sufficient number of identical trig points, the transformation elements were derived from the differences between the Soldner and Yugo Red. Gauss-Krueger coordinates of 2 sheet corners and the central point of each sheet. In order to furnish the Yugo Red. G.K. coordinates needed in the comparison the geographic positions of sheet corners and centers in Vienna University system were transferred into the system of the Yugoslav triangulation by the application of corrections derived by Dr. Ledersteger for the purpose of the recasting of sheets. These corrected geographic coordinates were than converted into reduced Gauss-Krueger coordinates.

The comparisons of the reduced Gauss-Krueger coordinates of the Military triangulation of Bosnia and Herzegovina, obtained from this transformation, with the Yugo Red. Gauss-Krueger coordinates show at identical stations disparities up to 18 meters. The average values of disparities on each sheet were taken as blanket corrections which have to be applied to the transformed coordinates of stations belonging to the corresponding sheet. By application of these corrections the transformed coordinates should be in sympathy with Yugoslav triangulation in limit of ± 5 meters and would meet only artillery and cartographic requirements.

The corrections run as follows:

dN from + 7.00 m to - 6.51 m
dE from + 9.95 m to -13.70 m.

Since the plane table sections are positioned upon geographic positions of the Vienna University system computed from preliminary adjusted regional nets the sheet corners are not in sympathy with the adjusted K. und k. M.T. first order net but have displacements within limits of the above mentioned corrections.

d. Elevations: The Military Geographic Institute of the Austro-Hungarian Empire started precise leveling in

1873. A leveling datum at Molo Sartorio in the Harbour of Trieste was established in 1875. The elevation of the starting benchmark at the Custom Guardhouse, (where the tidal gauge constructed in 1869 is located) was defined from the observations of the tidal gauge within the period of one year (1875) to be:

+ 3.3520 meters

above the mean sea level of the Adriatic Sea (0.3780 below N.N.). The observations covering a period of 8 years (1875, 1876, 1879, 1901, 1902, 1903, 1904) show that the elevation of starting bench mark is:

$$3.2621 \text{ m} \pm 0.0099 \text{ m}$$

above the mean sea level, consequently the mean sea level determined in 1875, is too low by 0.0899 meters.

The precise leveling of the Austro-Hungarian Empire is based upon the value of sea level determined in 1875, which according to the new determination is 8.99 cm below the correct value of mean sea level of the Adriatic Sea, therefore elevations are for approx. 9 cm too high.[169]

The third topographical survey started 6 years prior to the establishment of the Trieste vertical datum. Consequently the elevations used in the third topographical survey are not uniform.

(1) In the larger area of the Monarchy (with the cadastral survey already completed and utilized in the topographical survey) the elevations shown on the 1:25,000 and 1:75,000 maps are based on the elevations of cadastral trig points. These elevations were determined by means of trigonometric leveling and refer to Adriatic Sea level. The starting value, in respect to the mean sea level determined in 1875, is unknown. The disparities fluctuate according to the regions of survey as for instance:

in the Environs of Vienna by	- 2 meters
in Czechoslovakia by	+ 1 to - 7 meters
in Carpatho-Ukraine by	-10 meters
in Tyrol and Carinthia by	- 1 to - 5 meters
in Bosnia and Dalmatia by	+ 3 to - 3 meters.

(2) In the areas where precise leveling had been completed at the time of topographical survey the trigonometric elevations of the Third toposurvey were tied to the precise leveling (Croatia and Slavonia, Southwest and Central Hungary). The elevations used in the III topographical survey of Bohemia, Silesia, Moravia and Western Slovakia were determined by means of trigonometrical leveling in 1875-1879. The cadastral trig station Kozihon near Mikulovo in

Moravia (sheet 4457) with elevation determined by precise leveling served as starting elevation. Due to the vertical traverses extending far away from the starting point Kozihon the elevations determined in trigonometrical leveling differ from the elevations of precise leveling determined later by + 1 m to - 7 m. In the same region primary cadastral elevations determined by trigonometrical leveling would differ from the elevations of precise leveling by + 4.9 m to - 8.2 m.[114]

(3) The reambulated (field revised) sheets of the Third topographical survey have elevations in sympathy with the precise leveling, because in the areas which had to be revised the precise leveling was completed prior to the reambulation.

This would explain the differences in the elevations which appear from the comparison of the map of III topo-survey with the map of IV topo-survey or with the maps of the new surveys made by successor states, as well as by the elevations of the triangulation records of the III Military triangulation and triangulations of successor states.

2. Topographical Survey:

a. Construction of plane table sheets: The topographical survey was executed at scale 1:25,000 by plane table method. For this purpose the large "graticule sheet" of $15'_\phi \times 30'_\lambda$ was divided into 16 plane table sheets to be used in the field survey. The division was made in such manner that the plane table sheets remain parts of the common projecting plane.

The basic graticule sheet of $15'_\phi \times 30'_\lambda$ was computed by formulae:

$$a = \frac{\Delta\lambda'' \cos \phi_0}{[2]}$$

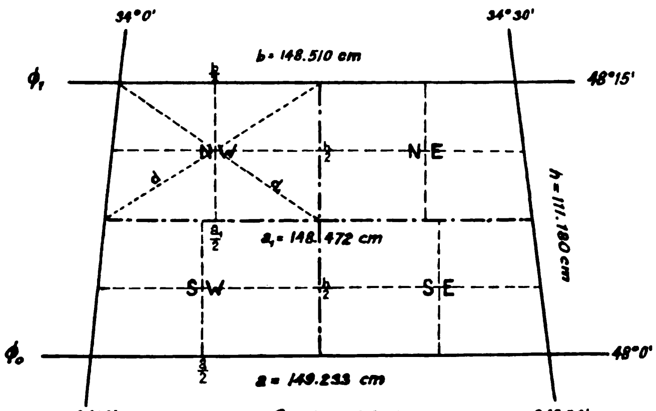
$$b = \frac{\Delta\lambda'' \cos \phi_1}{[2]}$$

$$h = \frac{\Delta \phi''}{[1]}$$

where $[1] = \log \dfrac{1}{M \sin 1''}$ taken for $\dfrac{\phi_0 + \phi_1}{2}$

$[2] = \log \dfrac{1}{N.\sin 1''}$

It was then divided into 4 "plane table sections" by halfing each linear value of meridians (h) and parallels (a,b) at the scale 1:25,000.



Scale 1:25,000

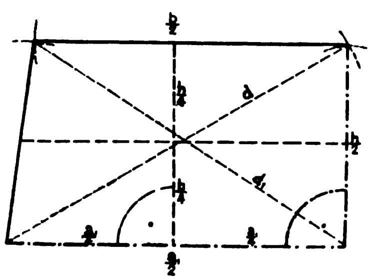
For the construction of recatangular trapezoidal plane table sections the elements:

$$\text{sides } \frac{a}{2}, \frac{a_1}{2}, \frac{h}{2}; \quad \left(a_1 = \frac{a+b}{2}\right)$$

$$\text{longer diagonal } d = \sqrt{\left(\frac{a}{2}\right)^2 + \left(\frac{h}{2}\right)^2}$$

$$\text{shorter diagonal } d = \sqrt{\left(\frac{a}{2} - \frac{b}{2}\right) + \left(\frac{h}{2}\right)^2}$$

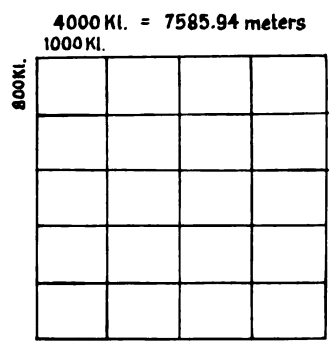
are given in the tables on page 377 - 380 of the Instruction for Military topographical survey (File No. B-661.2001 - IIa).[98]



The plane table section is then divided into 4 plane table sheets by halving $\frac{a}{2}$ and $\frac{h}{2}$ and by constructing a perpendicular at center of base $\frac{a}{2}$. By such division a graticule sheet of $15'_{\phi}$ x $30'_{\lambda}$ is divided into 8 rectangulars and 8 trapezoids.

b. <u>Incorporation of the cadastral planimetry into the uniform graticule system:</u> The Cadastral triangulation of the Austro-Hungarian Empire with its 10 different systems was computed in the Cassini projection. (See paragraph II/1 of this study.) The coordinate axes are formed by the intersection of the meridian plane and prime vertical plane with the tangent plane at the point of origin of each system. The southern direction of the meridian projection represents the positive direction of the abscissa and the western direction of the prime vertical projection represents the positive direction of the ordinate axis.

The Austrian mile grid based on the coordinate axes divides each system into square miles. Austrian mile = 4000 Klafters = 7585.94 meters. Each square mile represents one triangulation sheet and is subdivided into 20 cadastral sections at 1:2880 scale.



All cadastral sections of 1000 x 800 Klafters are positioned within the square mile grid; consequently the problem of incorporating the cadastral planimetry into the uniform graticule system would be solved if the cadastral square mile grid is constructed on graticule sheets of the topographical survey in sympathy with the geographic positions. For this purpose the geographic positions of such cadastral grid intersections (corners of cadastral sections) which are close to graticule sheet-corners were computed. This was achieved by using trig stations which are identical to both the military and the cadastral triangulations and for which geographic positions and cadastral rectangular coordinates have been computed, i.e. from two such trig points and the nearest grid intersection a a triangle was formed and the geographic position of intersection computed. The computed geographic positions of the grid intersections made it possible to fit the square mile grid into the uniform graticule system, i.e. to plot the sheet-corners of the cadastral sections on topographical plane table sections. By means of these plotted sheet-corners of cadastral sections the cadastral planimetry was pantographically reduced into plane table sections. Therefore it would be correct to state that the Austro-Hungarian maps at 1:25,000 and 1:75,000 scale framed into the theoretically projected uniform graticule system are in fact based on the geographic positions of the sheet-corners of the cadastral sections. (See Inclosure 9).

It is easy to comprehend in theory the incorporation of cadastral planimetry into the uniform graticule system, but the execution of this work involved many problems. It is well to remember the following facts (some of them already discussed):

(1) The geographic positions on which the uniform graticule system is based have interior tensions which vary as follows:

- (a) In the Vienna University system up to 30 meters,
- (b) In St. Anna system up to 40 meters,
- (c) In the areas of empirical adjustment up to 170 meters.

(2) Therefore, if the mean values are taken, the maximal extent of the displacement of the sheet-corners could be expected to be:

- (a) In the Vienna University system 15 meters = 0.6 mm at 1:25,000 scale
- (b) In St. Anna system 20 meters = 0.8 mm at 1:25,000 scale
- (c) In areas of adjustment 85 meters = 3.4 mm at 1:25,000 scale.

(3) The cadastral plane rectangular coordinates were computed from unadjusted or empirically adjusted triangulation.

(4) The assumed exact identity of MT stations with the cadastral stations used in the cadastral mapping is often questionable since the cadastral stations were provided with permanent markers 30-50 years after their establishment.

(5) The lack of a sufficiant number of the identical stations on some sheets necessitated a graphical transportation of the mile grid from the adjacent sheets.

(6) The disagreement along the junction lines where the cadastral planimetry from the maps belonging to different cadastral systems was pantographed on the same plane table section.

All these irregularities resulted in a great deviation of the Third topographical survey from the standards of a normal survey. The differences which arose under the described circumstances can be reduced but cannot be eliminated except by a completely new survey. In the majority of cases they were reduced graphically along with the construction of the cadastral mile grid and the reduction of planimetry on the plane table sheets. Hence the interior inconsistency of Austro-Hungarian maps at 1:25,000 and 1:75,000 scale.

Available literature contains no chapters discussing the Austro-Hungarian mapping that would explain the difficulties which occurred in the positioning of the cadastral grid and in the pantographical reduction of cadastral planimetry in the plane table sections. These remain the secrets of the Computing Bureau and of the Map Construction Branch at M.G.I. In addition to a map analysis showing the defects of individual sheets and of the map as a whole, the Instructions for military topographical survey contain some explanations which significantly question the accuracy of Austro-Hungarian Maps; for instance:

(1) If the distances from the mile grid line given by Cadaster for the trig points already plotted by geographical positions are drawn perpendicularly to the direction of the mile line and if their ends do not plot in a straight line then the mile line should be drawn in a "mean position" in order to "satisfy" all requirements. (Pg 25, Part II of the Instructions for Military topographical survey.)

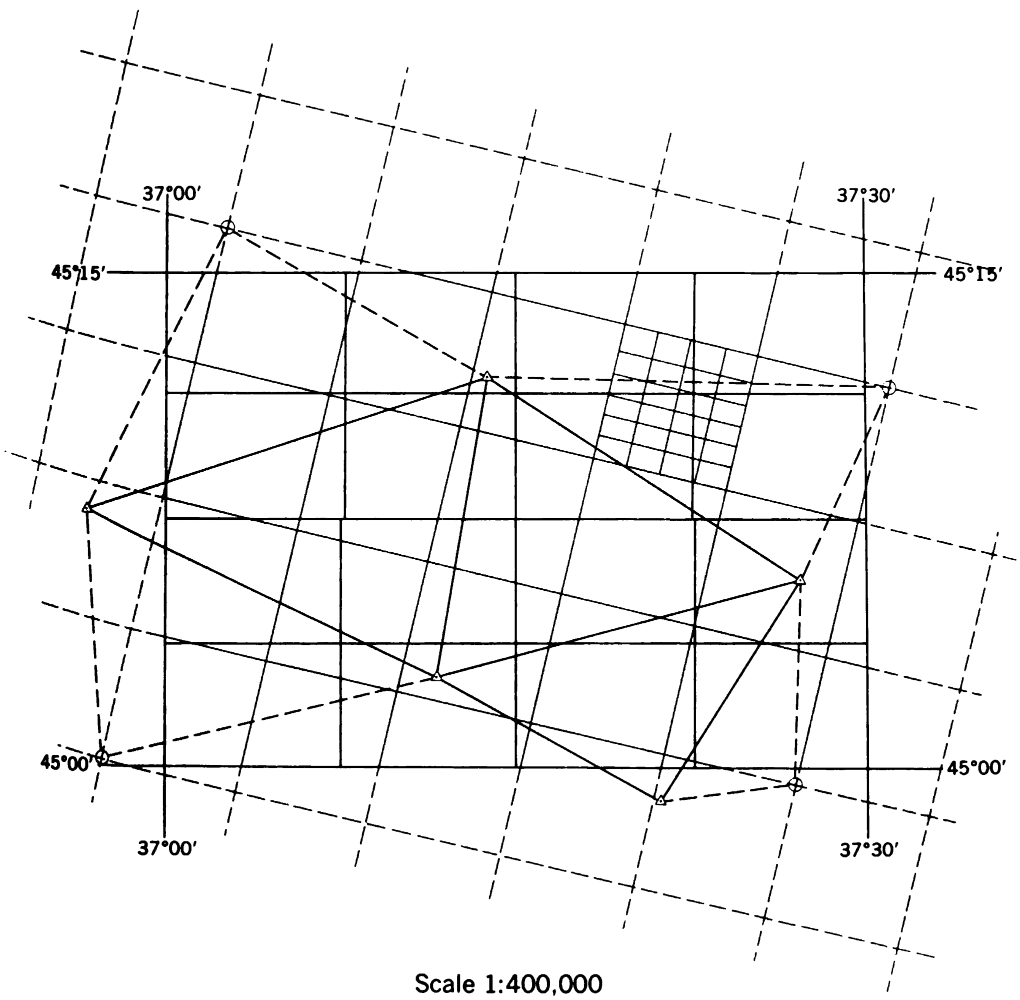
(2) In spite of all the care taken, in the compilation of the plane table sections some parts especially those without trig points, are shifted in position. Such parts should be in blue lines (at map revision) corrected to the true position only if the extent of displacement is larger than 3 mm. (Pg. 359, Part II of the Instructions for M.T.S.).

(3) The position of cultural features should be checked from all trig stations and other accurately determined stations. On the plane table sections with cadastral planimetry the displacement should not exceed 1 mm. Of course, the parts "surveyed at home", the inaccurately surveyed parts, and the parts which had changed in the course of time could not be considered accurate within the limits of 1 mm. (Pg. 345, Part II of the Instructions for M.T.S.). [99]

(4) Because in many cases such differences along the boundaries of communities were revealed by the pantographical reduction of the cadastral planimetry it was impossible to place the communities geometrically in such position that the boundaries would match. (Pg. 77, Mittheilungen des K. u. k. M.G.I., Vol. I, File No. B-661.2000/I.)

Inclosure 9

CONSTRUCTION OF CADASTRAL SQUARE MILE GRID ON GRATICULE SHEET



Scale 1:400,000

c. The detail survey: The execution of the Third topographical survey in respect to the survey of detail also was not uniform over all the Monarchy. The standard procedure of the topographical survey was only partially applied in those regions, where cadastral planimetry, old 1:28,800 maps, plans of private property survey or forest maps were utilized. Hence in general there are three types of survey:

- Topo-survey based on cadastral planimetry,
- Topo-survey by utilization of old 1:28,800 maps,
- Topo-survey based on sparse triangulation.

There are some variances also within each of these types, especially within the second. Although the larger portion of the Monarchy is covered by detail survey based on cadastral planimetry, a brief review of the execution of the third or normal type of detail survey, based solely on sparse triangulation would be needed in order to evaluate the methods applied, and the completeness and accuracy of the map.

(1) Topographical survey based on sparse triangulation started with the development of graphical triangulation; the purpose was to provide within each plane table section a sufficient number of stations and fixed points needed in the detail survey.

(a) Graphical triangulation: To develop the graphical triangulation within a plane table section (approx. 280 km^2) at least three trig stations were given. Starting from these by the method of intersection a net of graphical triangulation was developed, including 60 - 100 graphical stations as well as prominent points such as belfries, chapels, smokestacks, field crosses etc. Graphical triangulation was executed either on the large plane table at 1:25,000 scale or on the detail plane table at 1:50,000 scale. In the latter case it was later reconstructed on the plane table sheet at 1:25,000 scale and of course, the graphical error was doubled.

(b) Trigonometric leveling: Along with the horizontal determination of graphical points, vertical angles were measured and by means of trigonometrical leveling the elevations of points were determined. The elevation of each graphical point was determined either within a vertical traverse which was included and adjusted between two trig stations or as an average value of three forward observations from three stations with previously established elevations.

(c) Survey of detail: In the Third topographical survey measurement of distances by stadia (tachymetry) was not yet in use. Therefore in open areas the detail points were determined mostly by intersections from graphical stations. Additional points needed in the drawing of planimetry were determined by the polar method where the distances were either measured by pacing or estimated up to 300 paces. The ends of long straight lines, such as highways, railroads, canals were determined by intersection and these straight lines were then utilized in determination of detail points either by alignement or by the orthogonal method where the ordinates were paced or estimated.

In the towns and in compact villages the prominent objects, such as churches, towers, smokestackes were determined by intersection; the periphery, the outskirts and main streets were surveyed, the interior, particulary the side streets, were sketched holding the plane table on the hand.

Smaller forests were encircled by the survey, the entrances and exists of roads determined and then the interior was sketched on the hand.

Large forest regions were also encircled by the survey with the entrances and exists of the roads, rivers, streams, fire lines precisely determined. In the interior a sufficient number of tree-signals, especially on the summits of the main ridges, near the crossroads, confluences and clearings was determined in graphical triangulation, other summits, knolls and prominent rocks were intersected in the detail survey of the surrounding area. Along the main roads, main ridges and streams compass traverses tied to the tree-signals were made where the distances were measured by pacing. The areas confined by the survey of periphery and by traverse lines, within which were certain intersected points (summits, knolls, rocks) were then sketched on the hand.

Along with the survey of planimetry (cultural and drainage features and vegetation outlines) the elevations of the detail points important for the correct expression of the shape of relief were measured. The elevations of the intersected points and of the detail points in the open areas were determined by trigonometric leveling; meanwhile in the forests the elevations of the traverse stations and of detail points were determined by barometric leveling. On the basis of these elevations the relief was expressed by slope-lines, form lines and hachuring. In this manner only measured parts were drawn as well as the strips along the ridges, streams, roads where the compass traverses were measured. By a careful study of the relief by the observation from the opposite side (slope, ridge) the drainage lines, slope-lines and form lines were corrected and then the characteristic of an entire part was represented by hachuring.

On the large plateaus covered by woods, where a side study was impossible, the areas confined by surveyed strips were filled by the sketching on the hand.

In the large regions of karst the prominent ridges and elevations important for the orientation and larger depressions were surveyed, as well as the strips along the roads; other areas were sketched in such a manner that the general characteristic was expressed and the orientation made possible.

In order to increase the production the topographers were encouraged to construct the planimetry and to express the relief on base of a minimal number of the measured points, as well as for a large application of sketching on the hand. (Sketching with the plane table in the hand, oriented by compass, and by use of pacing and estimation of distances.)

This would be completely understandable if in the Third topographical survey of the areas surveyed without use of cadastral planimetry for the plane table sheet of 68 km^2 (average surface) the following norms were achieved:

1 Topographer in summer period of 6 months.

Type of terrain	TP	Graph. points	Detail points	Elevations	Days	km^2 in 6 months	Pl. tab. sheets
Plain	3	15	450	50 - 150	35	350	5.1
Hills	3	25	700	300 - 400	49	250	3.7
Mountains	3	20	600	200 - 300	72	170	2.5

The contour lines with the interval of 20 meters index contours of 100 meters, auxiliary contours of 10 and 5 meters) were constructed during the winter period in the office; they were not drawn in the field. The drawing of contour lines based upon the sparse number of elevations and on the drainage lines, slope lines, form lines and hachures made in the field. The elevations of points were determined with the following accuracy:

graphical points	± 1 meter
detail points	± 3 meters
barometric points	±10 meters

In the new survey based solely on the sparse triangulation the topographers were advised to use the plans of private property survey and the forest maps. At that time such plans and maps were made for the large property holdings of the nobility and are to be found in the offices of estate and forest administration. The plans or maps at larger scale were condensed and incorporated in the plane table sheet. For this purpose a certain number of points shown on the plan or forest map was graphicaly intersected on the plane table sheet. A parallelogram grid which facilitated the reduction was constructed upon these identical points on the plane table sheet and on plan or map. These private surveys were made in various scales and with varying accuracy. Forest maps of the klafter system usually were compiled at the scale 1:5760 or 1:11,520 meanwhile the metric system was also used in survey of the forest maps at 1:5000 or 1:10,000 scale. Forest maps are based on compass-traverses tied to the cadastral triangulation or to locally determined trig points. Usually forest maps show property boundaries, roads and trails, permanent objects, wood lines and clearings as well as the forest subdivision delimited by fire lines or roads and trails. There were no uniform standards for the execution of private property surveys; consequently also the accuracy varies. In general the cadastral standards were used for the plans, but the forest maps were surveyed with lower accuracy. With very few exceptions the relief was not represented on the private plans and forest maps.

(2) Topographical survey based on the cadastral planimetry: In the regions where the topographical survey was based upon the reduced cadastral planimetry the graphical (plane table) triangulation was either omitted or only partially developed. Usually the positions of a smaller number of stations were determined graphically, the vertical angles were measured, and the elevations were computed. From these stations the position of cadastral planimetry was checked and the elevations of intersected and detail points were determined.

The reduced cadastral planimetry often was plotted in erroneous position and the extents of displacement varied. In addition to irregularities discussed in paragraph 2/b on page 33 the extent of displacement was influenced by the reduction, plotting, duplication and distortion of paper due to changes of atmospheric condition.

In such cases the cadastral planimetry should be shifted into agreement with the intersected positions of cultural features. Such shifts would be only locally possible and in many cases, particularily in the areas of adjustment, were subjected to compromises.

In the areas belonging to large property holdings, especially in the large forests, the trails, paths, small streams, springs, ravines and clearings (unless such features represent the property lines) were omitted or merely sketched in the cadastral survey; therefore these features must be included in new topographical survey. Also the areas with vast changes of cultural features, river-channels and woodland must be surveyed anew because cadastral maps had became obsolete. Large forest regions, because of very sparse cultural features shown on the cadastral maps, ordinarily would require the development of plane table triangulation and a complete detail survey. Normally the reduced cadastral planimetry was revised only in the field and brought up to date with new cultural features. While revising and completing the planimetry, the topographers observed the vertical angles and computed such elevations as were needed in the topographic expression of the relief. The accuracy as well as the number of determined elevations were the same as in the new survey based solely on sparse triangulation. The drawing of contour lines was accomplished in the office during the winter time.

The topographical survey of Bosnia and Herzegovina (1880-1887) is completely identical in position with the cadastral survey. (See paragraph (4) on page 26-28). The cadastral sections are cut within the uniform graticule system based on the military triangulation common to both, cadastral and topographical survey. Therefore the reduction and plotting of the cadastral planimetry on topographical plane table sheets was accomplished without difficulty. The topo survey of Bosnia and Herzegovina should be considered as the best within the Third topographical survey of Austro-Hungarian Empire, with the exception of a few northwestern sections surveyed in 1880 without cadastral planimetry (See Enclosure 6) and those large forest regions into which the topographers dared not penetrate because of the danger of meeting guerilla units.

The average norms of production achieved by 1 topographer in the summer period of 6 months are as follows:

Type of terrain	Days used for 1 plane table sheet	Plane table sheets surveyed.	Km^2 surveyed in 6 months
Plain	20	9.0	612
Hills	28	6.4	435
Mountains covered by woods	38	4.7	320
Karst and high mountains	49	3.7	252

(3) <u>Topographical survey by utilization of the old 1:28,800 map:</u> In Central and Southern Hungary the enlarged and recasted 1:28,800 sheets of the Second topographical survey were utilized in order to maintain the progress in the survey since no complete cadastral survey was available. The utilization had certain variances:

(a) In the area surveyed in 1881 and 1882, the recasted prints in faint blue colour were composed (as already discussed in paragraph (3a) and then revised in the field. The blue colour when exposed to atmospheric conditions either dissolved or turned green. This green colour would reappear in the photography and needed to be erased from the manuscripts. Due to the extensive displacement of the planimetry as shown on the recasted blue lines in relation to the positions of plotted trig points the manuscripts were often subjected to excessive erasures; therefore in the surveys of following years the blue lines were no longer used.

(b) In the area surveyed in 1883 and 1884, the useful planimetry and form lines of the old 1:28,800 sheets were pantographically enlarged into 1:25,000 plane table sections and then revised in the field. In some sections graphical triangulation was developed as for a completely new survey. On the base of interesected points the enlargements of the old survey on transparent paper were then copied in the new survey. The parts of the old map which did not agree with the features on terrain were covered by a new detail survey. In certain areas records of private cadaster were used as discussed on pages 37-38.

The average norms of production achieved by 1 topographer in the summer period of 6 months are follows:

Type of terrain	Days used of 1 plane table sheet	Plane table sheets surveyed	Km^2 surveyed in 6 months.
a - Survey 1881 and 1882			
Plain	26	6.9	469
Hills with many details	32	5.6	383
b - Survey 1883 and 1884			
Plain with woods and swamps	28.5	6.3	428
Hills with many details	33.5	5.4	367
Middle Mountains	30.5	5.9	401

The time periods according to provinces surveyed in the Third topographical survey of the Austro-Hungarian Empire are as follows:

Transylvania	1853 (1869) - 1873
Tyrol and Vorarlberg	1869 - 1872
Salzburg	1871 - 1872
Carinthia	1871 - 1877
Styria	1872 - 1878
Lower Austria	1872 - 1878
Bucovina	1873
Upper Austria	1874
Galicia	1874 - 1876
Hungary	1875 - 1884
Silesia	1876
Moravia	1876 - 1877
Littoral	1877 - 1878
Carniola	1877 - 1878
Bohemia	1877 - 1879
Croatia and Slavonia	1878 - 1881
Dalmatia	1880 - 1884
Bosnia and Herzegovina	1880 - 1887.

3. Reambulation (instrumental field revision) of 1:25,000 manuscripts.

The previous discussion about the geodetic foundation and the execution of the Third topographical survey demonstrated the variances of the control used, of the survey material utilized, of the methods applied and of the accuracy achieved in various epochs and in different regions covered by this survey. This discussion convincingly showed a complete lack of uniformity. It is selfevident that the plane table sheets with the reduced cadastral planimetry represent a topographical survey of much higher precision than those sheets with sparse plane table triangulation and cultural features sketched on the base of pacing and distance-estimations. Furthermore, the survey of the early years accomplished by inexperienced topographers using primitive instruments was obviously less accurate than the survey of the last epoch made by experienced topographers with improved instruments. Consequently there would be various degrees of the field revision between the inclusion of supplementary cultural features and a resurvey.

a. The primary goal of the field revision initiated in 1885 was to bring up to date the 1:25,000 map of the Third topographical survey by supplementing the cultural features. The secondary goal was to establish the uniform standard for accuracy and completeness of the map in the various regions and for the different epochs. Moreover there existed at that time a demand expressed by certain civilian authorities for a 1:25,000 map which would satisfy not only military requirements but also the need for provisional study of road, railroad and canal constructions.

The realization of these goals was thwarted by the too rapid tempo of field revision dicated by the military necessities. In order to complete the reambulation in the shortest possible time the territory in the order of its importance from the military point of view was divided into these three categories:

(1) The regions along the international boundaries (presumptive battlefields) and important operational routes, where all details should be revised.

(2) The regions suitable for military operations (possible battlefields), rolling areas, hilly land, valleys and settled areas, where only the details of military importance should be revised and supplemented.

(3) Mountains and extensive forest regions; in general the areas without settlements and seldom frequented, where only such inaccuracies should be corrected as would be perceptible in the 1:75,000 map.

b. Considering the geodetic control and other basic data used in the original topographical survey the following improvements of the 1:25,000 map were accomplished by field revision (reambulation):

(1) The triangulation was resurveyed and densified by additional trig points:

1885 - 1890 in Transylvania,
1887 in Istra,
1891 - 1894 in Northwest Hungary (Slovakia),
1893 in Moravia,
1894 in Southeast Hungary (Vojvodina).

The blue and brown lines provided by the plotted trig points were then used in the field revision.

(2) The triangulation, particularly the cadastral triangulation, was attached to the precise leveling:

1885 in Tyrol and Vorarlberg,
1885 - 1890 in Transylvania,

1887 - 1890 in Bucovina,
1888 - 1892 in Galicia,
1892 - 1893 in Bohemia, Moravia, Silesia, Lower Austria and Hungary (Slovakia).

Starting from the stations with the elevations determined by precise leveling, the elevations of a certain number of trig stations were determined by trigonometrical leveling and then the elevations of all other trig points recomputed by use of the old observations. For the field revision the topographers were provided with the elevations of trig points in sympathy with precise leveling. (Precise leveling at that time was not yet finally adjusted.)

(3) In the Third topographical survey of Tyrol and Transylvania (as already mentioned on pages 6-7) old rectangular sheets of Cassini projection were used. These rectangular sheets were recasted into uniform graticule sheets; consequently in the field revision the blue lines of the polyhedric graticule sheets were used.

(4) The cadastral planimetry pantographically reduced on transparent paper was given to topographers to be fitted on the blue lines of the sheets originally surveyed without cadastral records. The planimetry was plotted in the field along with the checking of cultural features. The additional planimetry of the revised cadaster on the blue lines of the sheets surveyed by use of cadastral records was likewise plotted in the field.

c. The field work started with the reconnaissance of the area. In case of sparse triangulation during the reconnaissance 5-8 signals in the area of one plane table sheet were erected and determined in position by graphical intersection. From the trig stations and intersected points the positions of cultural and relief features were then checked by sights and by measurement of vertical angles and in cases of disagreement were properly corrected. In the corrections of the position of cultural features it was a general rule that the completeness and the local agreement (the relative position) are more important than the correct position; therefore in the case of a systematical displacement (shift) of the cultural features within 3 mm the correction was not applied. A new and better topographical expression of the relief was in general not the concern of the field revision. Some local corrections were made in cases of falsely expressed parts of the relief or where the relief had to be brought into agreement with the newly-surveyed railroads, roads and other points of military importance.

The elevations of the 1869 - 1872 topographical survey were resurveyed and corrected if they differ:

in the rolling areas 2 and more meters,
in the mountains 5 and more meters.

The sheets of this survey were also supplemented by newly-determined spot elevations. All measurements of elevations started from points with elevations based on the precise leveling. The manuals of vertical angles of intersected points and spot elevations of the survey of 1873 and of later surveys were still available; therefore only the starting points of the vertical traverses were reobserved from the stations with the elevations in sympathy with the precise leveling. The elevations of other points were corrected by the differences obtained on starting points.

The hypsometry was reconstructed and new contours drawn only in the cases where complete vertical control of the original plane table sheet was in error. Partial corrections were made in such cases where in certain parts of the plane table sheet the differences between the newly determined and the old elevations were so large as to require a considerable shift of the contours. The reconstruction of hypsometry and drawing of contour lines was again not accomplished in the field, but in the office.

The revised blue lines of such plane table sheets where many corrections were made were inked in the office during the winter season. In these manuscripts only such parts of the relief were hachured where the correct expression of the relief would require the hachuring; other parts of the relief were expressed only by contours. The steep and uniform slopes were represented only by 100 m contour lines. The blue lines of such plane table sheets, where only a small number of corrections occured, were not inked but the corrections and supplemental features were copied in the old manuscripts.

It was planned in advance that the norms of production in the field revison would be at least doubled in respect to the original survey. This norm was scarsely reached in the plains and high mountains. Meanwhile the field revision in the rolling areas and hills, with many details, required approximately the same number of days as the previous new survey. This tends to show that the 1:25,000 sheets in such areas were supplemented with many details and also that the expression of planimetry and relief was improved.

The average norms of production achieved by 1 topographer in the 6 months summer-period are as follows:

Type of terrain	Days used for 1 plane table sheet	Plane table sheets surveyed	Km^2 surveyed in 6 months
Plain	17.6	10.2	694
Hills with many details	42.1	4.3	292
Middle mountains covered by woods	34.4	5.2	354
Mountains	40.0	4.5	306
High mountains	29.9	6.0	408

Of 2780 plane table sections comprising the 1:25,000 map of Austro-Hungarian Empire only 860 (36.1 % of surface of the entire Monarchy) plane table sections were reambulated. The reambulation covered the following provinces:

Tyrol and Vorarlberg	1885 - 1889
Transylvania	1888 - 1894
Galicia	1892 - 1896
Bucovina	1894 - 1895
Istria and Croatian Coastland	1908
Bosnia and Herzegovina	1907 - 1913
Bohemia (strip along German boundary)	1910 - 1913
Slavonia and South Hungary	1913

(See Inclosure 2).

d. The survey and reambulation in Transylvania:

At this point it is well to mention certain particularities of the topographical survey and reambulation carried out in Transylvania, which was at that time an autonomous princedom of the Monarchy. The topographical survey in order to cover the territory of the princedom had already been initiated in 1853, i.e. prior to the "provisional instructions" which in 1860 introduced the measurement of elevations of the detail points and drawing of contours. Only a small portion of Transylvania was surveyed by old standards without contour lines; the largest part was surveyed in 1869 - 1873, by standards prescribed in the "provisional instructions". In order to preserve the continuity of the survey there were retained:

the old 1:28,800 scale, and
the old sheet lines of Cassini projection;

rectangulars with dimensions:

24 x 16 Zolle = 9600 x 6400 klafters

or

63.216 x 42.144 cm = 18,206.2 x 12,137.5 meters,

and surface:

220.978 square kilometers.

The sheet lines were parallel to the coordinate axes (prime vertical and meridian) of the origin Sibiu (Hermannstadt) Observatory with:

$\phi = 45^\circ\ 50'\ 28''.95$
$\lambda = 41^\circ\ 46\ 39.00$
$\alpha = 359^\circ\ 16\ 33.78$ to Presbe.[101]

The topographical survey was based solely on sparse triangulation with an average density of 3 trig points to 221 square kilometers (1 rectangular sheet). The records of the cadastral survey were not utilized. By plane table triangulation a net of about 50 graphical stations was developed and from graphical stations about 1250 detail points were intersected. These 1300 determined points (6 points to 1 km^2), about 800 of them with elevations, served as a skeleton of the planimetry and of the relief. The average norm achieved by 1 topographer in 6 months was 228 km^2 (1 quadrangle + 7 km^2). Because Transylvania is a mountainous area covered by large forests and because cadastral records were not utilized in the survey, the number of measured points as well as the norm achieved are a sufficient proof that the 1:28,800 map of Transylvania represented the worst part of the Third topographical survey. Therefore at the outset of the reambulation of the sheets of the Third topographical survey it was decided to incorporate the map of Transylvania into the uniform graticule system and to improve it by reambulation.

The reambulation started in 1888 and was completed 1894. The area of about 56,000 km^2 was covered by 208 plane table sections (832 plane table sheets). The rectangular sheets of Cassini projection were recasted in the uniform graticule sheets. The procedure was the same as already discussed in the paragraph (3,b) on page 20 with the exception that the composing of enlarged fragments of 1:28,800 map occured on a glass plate. The 1:25,000 polyhedric plane table sections composed in this manner were photographed and blue lines printed. Because the old triangulation (about 750 trig points) was of inadequate density and because a large number of markers had already disappeared, the triangulation of Transylvania in 1885 - 1890 was resurveyed and densified by the additional 1200 points. Along with this work the elevations of trig points were brought into sympathy with the precise leveling. The trig points (together about 1950) were plotted on the blue lines which were then reambulated in the field. Approximately 9 trig points were plotted on a plane table section (1 trig point to 30 km^2).

The cadastral planimetry was only partially utilized in the reambulation, because the cadastral survey was not yet completed. The entire planimetry of 200 cadastral communities and the planimetry of the forest regions of 338 cadastral communities were pantographically reduced on plane table sections. In addition to these records of official cadaster the records of private cadaster were utilized. With the above-mentioned exceptions the reambulation was carried out in the same manner as in other provinces.

The connection of recasted and reambulated sheets of Transylvania with the sheets in Hungary was not achieved satisfactorily, as already pointed out in paragraph (3,b) on pages 23-24.

The average norm achieved by 1 topographer in 6 months was:
1 plane table sheet reambulated in 41 days:
4.4 plane table sheets or 300 km^2 reambulated in 6 months.

Considering the inadequacy of the survey of the basic 1:28,800 map enlarged to 1:25,000 scale, the fact that cadastral material was only partially used, and the large average norm achieved in the reambulation, the reambulated sheets of Transylvania would be less complete and accurate than those in other parts of the Monarchy surveyed by the utilization of cadastral planimetry. Scaled positions disagree up to 150 meters. The detail compared with the new Hungarian 1:50,000 map show considerable differences either in cultural features or in the relief.

e. Maybe some contribution for a better evaluation of the 1:25,000 manuscripts of the Third topographical survey will be made by the following statement:

Major-General Otto Frank, Commander of the Military Geographic Institute in his article "Landesaufnahme und Kartographie" (Topographical survey and Cartography), published in the Mitteilungen des K.u.k. M.G.I. Vol. 24, page 66, made this statement about the Austro-Hungarian 1:25,000 map surveyed in 1869 - 1886 and its field revision: "A rectification of the 1869 - 1886 topographical survey immediately after its completion was planned and for the execution of the rectification a correct rule was established: 'To provide the survey-material which would satisfy only military requirements'. A rectification of the mentioned survey which will meet the technical requirements would be inconceivable. Such a rectification would primarily require new accurately surveyed vertical control, new drawing of contours, thence a new topographical expression of the relief, which would mean almost a new survey".[44]

In the same article Gen. Frank proposed a new topographical survey at 1:10,000 scale with 1 trig point and approximately 100 measured elevations to 1 square kilometer, and the topographical expression of the relief only by contours to be drawn along with the survey in the field. The article was published in 1904, but from that time up to the present the requirements in the military mapping have become much more rigorous.

IV. The Fourth Topographical Survey 1896 - 1914 (Präzisionsaufnahme).

The Austro-Hungarian Military authorities in 1885 concluded that the 1:25,000 map of the Third topographical survey was inaccurate to such a degree that it could not be sufficiently improved by reambulation to meet the military requirements of that time. Hence, the Military Geographic Institute in 1896 initiated a new topographical survey of much higher precision. For the first time in the history of Austro-Hungarian mapping quality was given priority to quantity, and stereophotogrammetry in this survey was extensivily applied, particularily in the high regions of the Alps. World War I and the consequent disintegration of the Austro-Hungarian Empire prevented the completion of the IV Topographical survey.

Altogether there were surveyed 480 plane table sheets comprising only 5.0 % of the Empire territory, covering parts of the provinces, Tyrol, Carinthia, Carniola and Littoral (See Inclosure 10).

1. Geodetic foundation:

   a. The ellipsoid of Bessel was retained in the fourth topographical survey.

   b. The polyhedric projection was also retained. In the survey of 1896 - 1902 the sheet bounded by meridians and parallels of 15' in latitude and 30' in longitude was still used as the projecting plane. After 1902, in order to reduce the distortion, each plane table sheet of 3'45" in latitude and 7'30" in longitude (1/16 part of the graticule sheet $15'_{\phi} \times 30'_{\lambda}$) was used as an individual projecting plane.

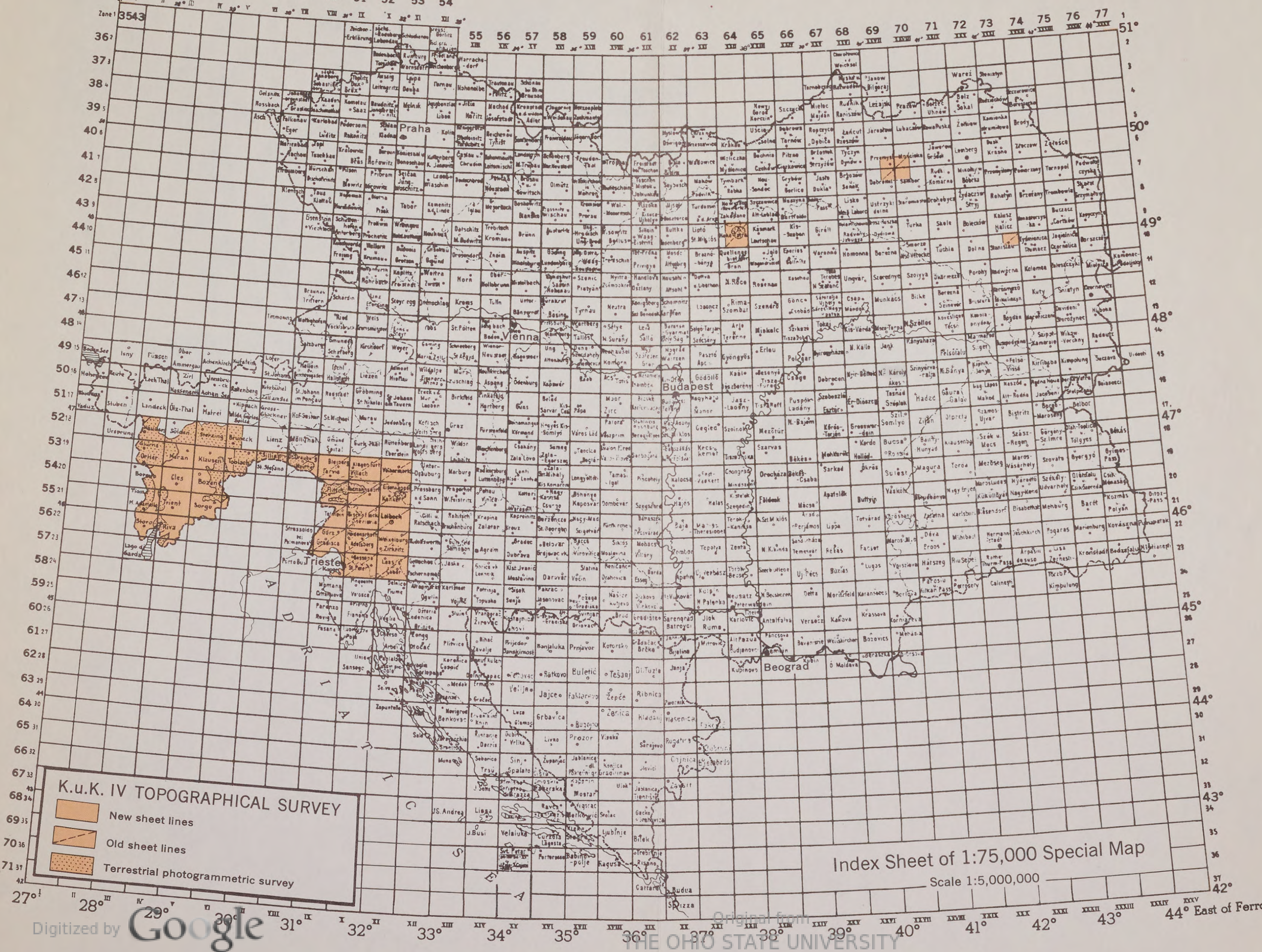
   c. Triangulation: Since a uniformly adjusted first order net, oriented at Hermannskogel datum did not yet exist at the outset of the Fourth topographical survey, the topographical survey executed in the years 1896 till 1902, still was based on geographic positions of the positions Rechnungen. (M.G.I. Protocol 290 A and B).

      (1) The 1:25,000 plane table sheets covering the parts of provinces Carinthia, Carniola and Littoral (east of meridian 30° 30' east of Ferro) are based on geographic position as of Vienna University system.

Inclosure 10

INDEX SHEET

OF THE IV TOPOGRAPHICAL SURVEY OF AUSTRO-HUNGARIAN EMPIRE



An average difference of geographic positions of Vienna University system from GPs of Hermannskogel datum in this area would be:

$$\Delta\phi = +1''3$$
$$\Delta\lambda = -5.3$$

The 3rd order triangulation executed for the purpose of the IV Topo-survey, into which were included those cadastral trig points for which markers were found, was in 1900 - 1904, (after its utilization in topo-survey) tied by means of a sparse 2nd order net to the uniformly adjusted first order net oriented on Hermannskogel datum. It was then adjusted and recomputed. Such inverse development of triangulation in this area plus the fact that some of the 3rd order points at the time of the execution of the 2nd order triangulation had already been lost, produced an irregularily developed net which can not be considered satisfactory for all the area surveyed. The part of this triangulation (1:200,000 sheets Trieste and Ljubljana) was published in 1906 in "Die Ergebnisse der Triangulierungen" Vol. 4, File No. B-661.3300/V.4.

(2) The plane table sheets in Tatra (former Hungary, now Slovakia) and in Galicia are based on geographic positions of St. Anna System.

(3) The plane table sheets in Tyrol are based on preliminary adjusted III Military Triangulation oriented on Hermannskogel datum with:

$$\phi_A = 48^\circ\ 16'\ 15''29 \pm 0''04$$
$$\lambda = 33^\circ\ 57'\ 41.06 \text{ East of Ferro}$$
$$\alpha_A = 107^\circ\ 31'\ 41.70 \pm 0''18 \text{ to Hundsheimer Berg.}$$

d. Elevations: The elevations determined by means of trigonometric leveling are based on the elevations of precise leveling (1873-1898) with the vertical datum Molo Sartorio in Harbour of Trieste. (See chapter III/1d on page 28-30).

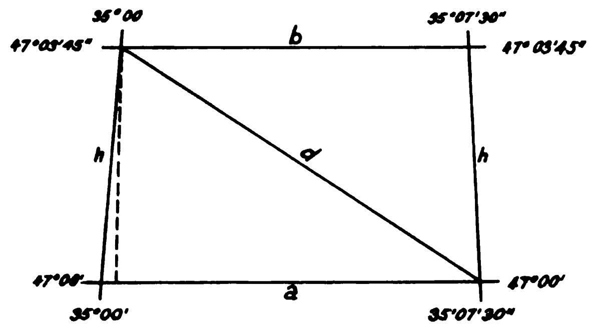
The required accuracy of elevations of trig points was ± 0.5 m.

2. Topographical Survey:

a. Construction of plane table sheets:

(1) In the survey carried out from 1896 till 1902, the old plane table sheet-lines as described in chapter III/2a on page 30-32 were used. (See Inclosure 10).

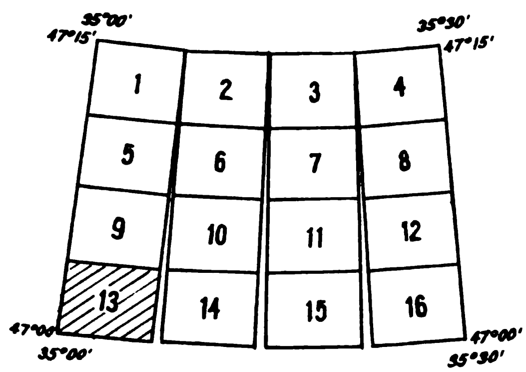
(2) Because a plane trapezoid, regarded as projection of a $15'_{\phi}$ x $30'_{\lambda}$ spheroidal trapezoid, show at 1:25,000 scale already a considerable distortion, therefore since 1902 one sixteenth part of the $15'_{\phi}$ x $30'_{\lambda}$ sheet, i.e. each plane table sheet of $3'45''_{\phi}$ x $7'30''_{\lambda}$ was used as an individual projecting plane.



The sheet lines were computed by formulae used in the computation of basic graticule sheet $15'_{\phi}$ x $30'_{\lambda}$ (See page 30)

$$d = \sqrt{a \cdot b + h^2}$$

The plane table sheets at 1:25,000 scale within the 1:75,000 "special map" sheet have numbers 1 - 16 as shown on the sketch.



b. <u>Incorporation of cadastral planimetry</u>:

The method of incorporation of cadastral planimetry into the uniform graticule system, as discussed in chapter III/2b, page 32-35 found its complete application also in the Fourth topographical survey.

In order to improve the accuracy of the incorporation of cadastral planimetry into the topographical survey a 3rd order triangulation was initiated in 1896 to furnish for each plane table sheet at least 3 trig points (after 1900 at least 10 trig points) with the elevations determined in sympathy with the precise leveling. The primary purpose of this 3rd order triangulation was the inclusion of cadastral trig points into the Military triangulation. It was planned in advance to reobserve only some of the cadastral trig points and to use cadastral observations in the recomputation of the majority of points. This plan was rejected "because only a small number of cadastral markers and other reference points which would confirm the identity of cadastral stations were found; therefore almost all selected cadastral trig points were newly marked and not only elevations, but also positions newly determined". (Mittheilungen des K.u.k. M.G.I. 1896 Vol. XVI pg.9). Consequently only a small number of trig points identical to Military and Cadastral triangulation existed; hence, the same difficulties as in the III Topo-survey remained in the IV Topo-survey in respect to an exact incorporation of cadastral planimetry into plane table sheets.

c. The detail survey:

The Fourth topographical survey was carried out generally in the same manner as the Third topographical survey (See chapter III/2c, 35-41). Therefore, at this time only new factors will be discussed.

(1) In all plane table sheets the cadastral planimetry was pantographically reduced.

(2) As a consequence of the required greater accuracy, the following new standards were prescribed:

(a) Triangulation:

In 1896 - 1898		3 trig points on plane table sheet,
in 1898 - 1903		10 trig points on plane table sheet,
after	1903	15 - 20 trig points on plane table sheet.

(b) Graphical points: 20-50 graphical points determined by plane table triangulation within each plane table sheet. On the sheets with 10 or more trig points plotted, only trig points can be used as stations in graphical triangulation.

(c) Elevations: On each plane table sheet the following number of elevations had to be determined:

In Plain	300 - 600 or 4 - 9 to 1 km^2.
Middle and High Mountains	800 - 1200 or 12 - 15 to 1 km^2.
Hills	1200 - 1500 or 15 - 22 to 1 km^2.

(d) Accuracy by which the elevations should be determined:

Trig points	± 0.5 m,
Graphical points	± 1.0 m,
Detail points up to	± 3.0 m
Barometric points up to	± 10.0 m.

(e) Accuracy of photogrammetrically determined points at 1:25,000 was established:

in position ± 7 m.
elevation ± 2 m.

(f) On the plane table sheet the following number of spot elevations has to be plotted:

In Plain	150 - 200,
Mountains	200 - 250
Hills	250 - 300. [99]

(3) The stadia method of distance measurement (Tachymetry) was introduced. Hence in the detail survey the polar method found greater application, pacing was reduced, the estimation of the distances permitted only to 100 meters. In the compass traverses the distances were measured by stadia and only lees important cultural features, particularly in the forests, still were sketched on the hand by use of pacing.

(4) In the mountains of Tatra, Julian Alps, Dolomites and particularly in high glacial regions of Alps in Tyrol terrestrial photogrammetry was used in the IV Topo-survey.

(a) In the first epoch from 1896 - 1905 the photographs made by phototheodolite were utilized in the survey of high mountainous regions. By method of so called "plane table photogrammetry" the positions of the points were constructed from photographs (photographical intersection) and plotted on the plane table sheet; the elevations of points were computed by formula:

$$H = h . \frac{D}{d}$$

where h = vertical distance between the point and the line of horizont on the photograph (ordinate).

D = horizontal distance from the station to the point in the field.

d = distance between station and horizontal projection of the point on picture trace.

On the basis of points determined by this method and by looking at photographs the cultural features and the contours were drawn. This method of compilation was very slow and required 16 work hours for the plotting of 30 points together with the computing of elevations. The compilation produced by means of plane table photogrammetry was supplemented by the topographers in the field.

(b) In 1905 the plane table photogrammetry was replaced by stereo-photogrammetry where the stereocomparator facilitated mechanical plotting of points and scaling of the elevations from the stereo-model. The cultural features and contours then were drawn by looking at stereo-model as in the field.

(c) In 1908, the invention of the stereoautograph by Capt. von Orel of the Military Geographic Institute of Vienna made the stereo compilation, including the drawing of contours, completely mechanical. In 1911, the stereophotogrammetric surey in the area of Bruneck (Tyrol) covered 560 km^2 of $11\frac{1}{2}$ plane table sheets with a total surface of 770 km^2. The stereophotogrammetric survey was generaly confined to upper regions of the area surveyed. Because it was not convenient to survey photogrammetrically the deep and narrow valleys they were surveyed by plane table method along with the supplementing and completing of the regions compiled by stereautograph. [81]

It is worthy of mention that the von Orel's stereoautograph in 1911 was improved by Zeiss and reconstructed as a large photogrammetric machine capable to utilize in the photogrammetric compilation also aerial photography. (Not yet used at that time). By this stereoautograph model 1911, considered in the mapping circles of that time as a wonder of technique, there were compiled the last few plane table sheets of the never completed IV Topographical survey of the former Austro-Hungarian Empire.

(5) The norms achieved by 1 topographer in the summer period of 6 months are:

without stereocompilation
0.65 - 1.5 of plane table sheet = 45 - 105 km^2;

if a large area was covered by stereocompilation
1.25 - 2 plane table sheets = 87 - 140 km^2.

(6) Also in this survey the hypsography still was constructed in the office during the winter time. The contour lines compiled by stereoautograph in order to emphasize the geomorphological character of the relief suffered in the final drafting small shifts and polishing. The contour interval remained the same as in Third topo-survey - 20 meters.

(7) Four plane table sheets were joined in a plane table section $7'30''_\phi \times 15'_\lambda$. These original manuscripts were inked in six colours and represent a piece of topographical art in respect to drafting, shape of symbols and combination of colours.

The plane table sections have on the margin ticks of a kilometer grid with the origin at center of the $15'_\phi \times 30'_\lambda$ (1:75,000) sheet.

As in the Third topographical survey the map at 1:25,000 scale never was published. For military as well as for civilian needs the original manuscripts of plane table sections were photostated and printed as black or brown copies.

SECTION C

AUSTRO-HUNGARIAN
SPECIAL MAP AT 1:75,000 SCALE

C. AUSTRO-HUNGARIAN SPECIAL MAP AT 1:75,000 SCALE

I. General information and coverage.

In discussing the Austro-Hungarian special map at 1:75,000 scale and cartographic material utilized in its compilation (1:25,000 topo-manuscripts) it should be emphasized at the outset that this study was written with present standards in mind. Considering the mapping standards and reproduction technics and facilities of that time, the 1:75,000 special map and other maps which were compiled from it by K. und k. Military Geographic Institute represent an excellent piece of work, famous the World over. Nevertheless it is even at the present time difficult to comprehend how the K. und k. M.G.I. topographers in the III Topographical survey of the Austro-Hungarian Empire produced manuscripts as accurate as they are, measuring, as they did, merely up to 9 detail points and 6 elevations per square kilometer, and how they achieved an average norm of 400 km^2 in six months.

After numerous conferences held in the years 1868-1872 by delegates of War, Agriculture and Railroad Ministries, General Staff and Military Geographic Institute, finally a decision was made to replace the old 1:144,000 special map in Cassini projection by a new special map at 1:75,000 scale. It was decided that:

> "the new special map in the passable terrain should include everything that would facilitate or hinder the movement and the action of the armed services or grant to them proction;
>
> it should be a reduced copy of the newly-surveyed 1:25,000 plane table sections".

Because there was no intention to publish a map at 1:25,000 scale, the topographical survey at this scale was carried out solely for the purpose of compilation of the "special map"; therefore the special map at 1:75,000 scale represents the official Austro-Hungarian tactical map of the largest scale.

By virtue of the Emperors decree of 1872, there was established a division for compilation of 1:75,000 map at K. und k. Military Geographic Institute. This division consisted of about 70 cartographers and cartographic draftsmen, military and civilians, and was responsible for compilation and drawing of the map as well as for the education and training of the new personnel.

The total coverage of the Monarchy was planned by 715 sheets. The map was extended over the territories of neighbouring countries and at the time of the disintegration of the Monarchy comprised 832 sheets.

II. The construction, compilation and reproduction of special map.

The map is constructed in polyhedric projection, officially called "uniform graticule map system". The polyhedric sheet of $15'_{\varphi}$ x $30'_{\lambda}$ was considered such a small surface of the Earth that at the scale of the map (1:75,000) the curvature can be ignored without causing considerable distortion, hence the spheroidal trapezoid replaced by a plane trapezoid the sides of which correspond to the natural lengths of the 15' meridian and 30' parallel arcs. The meridians and parallels framing the sheets are constructed as straight lines but they really should be arcs, where the curvature of the 15' meridian arc (0.045 m) is negligible; meanwhile the curvature of the 30' parallel arc expressed in the distance between the chord and the arc at center of parallel arc (15') amounts to 30.32 meters at 47^{o} of latitude, i.e. in the center of the Monarchy. This at the scale 1:75,000 represents 0.4 mm. Consequently in the construction of sheet-lines for the topographical survey the curvature of the parallels should be taken into consideration; but regarding the paper deformation of printed map in the construction of sheet-lines of 1:75,000 special map actually it was ignored.

The 1:75,000 graticule sheet is composed of four 1:25,000 plane table sections. The composing was made at the 1:60,000 scale to which the 1:25,000 plane table sections were photographically reduced and blue-lines printed. The reduced blue-lines of the plane table sections were fitted into sheet-lines of the graticule sheet and served as a base on which the manuscript of 1:75,000 sheet was drawn. First the cultural features were drawn and the lettering made; then the relief was expressed by hachuring according to the Lehmann's scale and 100 m contour lines. Because of the rule that the special map should be a reduced copy of the plane table sections there was a very limited generalization of the cultural features as well as of the relief. Except for the omitted 20 m contour lines and some unimportant buildings in the compact settlements, the 1:75,000 map includes almost everything shown in the 1:25,000 plane table sections; therefore the 1:75,000 map is overloaded with details.

The drawing of the manuscripts, which served for direct reproduction, was done in black ink. From 1872 till 1906, the manuscripts were helioengraved into copper plates used in the printing of the map by litographic press. The map was printed only in black colour. In 1906 experiments were begun in order to reproduce the 1:75,000 map in colours; therefore two colour separations were drawn, i.e. cultural features and the relief. The drainage and the woodlines were inked directly on the plates. Only six sheets in colours were printed prior to disintegration of the Monarchy. The reproduction occurred photolithographically and the sheets were printed by offset rotary press bought in 1910.

III. Supplementing with additional information.

In order to keep the special map up to date the "Evidence section" (Map intelligence) collected from civilian and military authorities as well as from private sources all additional information, particularly the traces of the newly constructed roads and railroads and the corrections of geographical names. The offices of the province and district civil engineers were bound by duty to furnish the Evidence section of the K. und k. Military Geographic Institute each year with all information concerning the supplementing of the special map. The Evidence section plotted the supplementary records into correction sheets. The supplemental information then regularily appeared in the newly-printed sheets. Evidence section was also responsible for the collection of the foreign maps and mapping information of neighbouring countries used in the special map compilation of the regions accross the boundaries of the Monarchy. It should be emphasized that the plane table sections at 1:25,000 scale were not supplemented by the information collected by Evidence section. The plane table section remained in the stage of original survey or reambulation.

IV. Revision of the special map.

At the outset of the IV Topographical survey in 1896 the reambulation of the 1:25,000 plane table sections - the largest source for the improvement of the 1:75,000 special map - was abandoned, but the need for a better map which would include contemporary information remained. The new topographical survey covering within 17 years only 5% of the Empire's territory or 0.29% in a year, and would need by such progress almost 340 years to cover the entire Monarchy, was an insignificant source considering the quantity (surface). This situation in the Austro-Hungarian mapping, considering that a map in respect to cultural features after 20 years became obsolete, imperatively required an accelerated map revision. The special map revision started in 1897, and was replaced in 1906 by the reambulation of the plane table sections at 1:25,000 scale. The intention of the map revision was to improve the map along with its comparison with the corresponding terrain by supplementing and correcting the cultural features. The expression of the relief ordinarily would not be corrected. The corrections of the features already shown in the map occurred only if the situation drawn in the map had no similarity to that in nature. Because every change in the map would require the correction in the copper plate - very slow and expensive work - only unavoidable corrections were made in the map revision. Consequently in the map revison the elevations were not corrected in order to bring them into sympathy with the precise leveling.

The map revision of the Austro-Hungarian special map should be considered a semi-instrumental check of the map where surveying instruments, a light reconnaissance plane table with the sight alidade, compass and aneroid-barometer were used. The majority corrections were made by sketching with the plane table in the hand, walking, on horse back, or in the plain on a wagon. The plane table was placed on the tripod and the survey made only in the cases where the new roads, railroads or larger parts of settlements had to be included in the map.

For the map revision a sharp print of the sheet was made. On the print exact sheet lines and the subdivision on 4 plane table sections were constructed and black-inked, then the sheet was photographically enlarged to 1:50,000 scale. For each plane section ($\frac{1}{4}$ of 1:75,000 sheet) a separate brown copy at 1:50,000 scale on the drafting paper was printed and then revised in the field by an experienced topographer. The supplemental features and the corrections on the brown copy were inked black; the features which should be omitted were covered by cobalt blue ink. The corrections of the geographic names (nomenclature) and spot elevations were made on the tracing paper.

The average norm achieved by 1 topographer in 6 months was:

3.3 plane table sections = 860 km^2.

Altogether there were revised 100 sheets (400 planetable sections) or 16.8% of the sheets covering the entire Monarchy. (See Inclosure 2.) At this rate of progress it would require about 80 years to revise the 1:75,000 map of the Austro-Hungarian Empire.

Along with the revision of the 1:75,000 special map the topographers included the supplemental records and the corrections into 1:200,000 general map.

V. Various editions of the special map.

The special map at 1:75,000 scale was not published uniformly. There were three editions constructed and compiled independently. The drafting shows small changes in various epochs of publication because standard symbols changed according to the sample sheets of 1872, 1882, 1888, 1894, 1905, and 1913.

1. The first edition was based on the Third topographical survey and was drafted according to the sample sheets of 1872 and 1882. The relief expressed with sufficient contrasts in the hachuring produces a plastic effect contributing to a better legibility of the map. The rather heavy hand-lettered nomenclature (geographical names) as well as cultural features still hover above the black hachuring. Altogether there were published 714 sheets completed in 1872 - 1889.

2. The second edition comprising 212 sheets was based on the reambulated 1:25,000 plane table sections and the 1:75,000 sheets revised in the field as well as on the Fourth topographical survey. It was drafted according to the sample sheets of 1888, 1894 and 1905. This edition contains more details and gives a better expression of the cliffs. However the drafting in this edition is too heavy. The contrasts in the hachuring are too small; therefore a monotonously black effect of the relief into which the hand lettering of the nomenclature and the drafting of the cultural features sunk. The map is heavily overloaded with details and, particularly in the mountainous regions is barely legible. Undoubtedly the second edition compared with the first edition shows quite a large topographical improvement, but the general cartographic expression of the topography, the balance among the hachuring, the symbols and the hand lettering, as well as the ratio between the light and shade are less successful.

3. The third edition based solely on the plane table sheets on the Fourth topographical survey was published in four colours: cultural features black, relief brown, drainage blue and woodland green. The relief is expressed as in the first and second edition by the combination of hachuring and 100 m contour lines, the rocky regions still without contours. The hand lettering of the names is smaller particularly of the names of tne relief features. In respect to accuracy and completeness the third edition of the special map represents the best tactical map of the former Austro-Hungarian Empire. Its planimetry would be plotted by almost the same graphical accuracy as the

European maps published in the epoch between two World Wars, for which the following standards were prescribed:

horizontal control plotted by an error no larger than....± 0.1 mm

orientation points and points of plane table triangulation by an error no larger than................± 0.2 mm

detail points in the open terrain by an error no larger than..............................± 0.5 mm

detail points in the covered terrain (forest) by an error no larger than..............................± 1.0 mm.

Its main deficiency is the expression of the relief by combination of hachuring and 100 m contour lines. The relief should be represented by 20 m contours as in original survey, without superflous hachuring. A few combined sheets along the Serbian boundary published during World War I show Austro-Hungarian territory in black print and Serbian territory in colours with the relief expressed by 20 m contour lines. Although the standard symbols and the expression of the relief did not undergo any considerable changes the reproduction in the colours made the map much prettier and easily legible. Only 6 sheets were published.

4. From the sheets or parts of the sheets of the 1:75,000 special map there were combined a large number of garrison maps ordinarily published with the drainage in blue and the woodland in green colour. The 1:75,000 special map served as base in compilation of many tourist and other maps at 1:50,000, 1:75,000 and 1:100,000 scale. In the time prior to World War I the Austro-Hungarian special map, as the French 1:80,000 map (published 1817-1878), was very famous. The experiences of World War I revealed its deficiencies and drastically reduced its fame.

VI. Remarks :

1. Warfare and the Map.

The Armies have been using the maps for more than two centuries. The Napoleonic Wars gave a special impulse to the use of geographic maps in warfare; consequently, in the European Armies mapping services were created, of which many are known as Military Geographic Institutes. It was the military who though the XIX century in Europe as well as in the colonies was responsible for the largest part of the geodetic and topographic surveys. In these surveys the military aspects dominated; particularly at their outsets the scientific purposes were not considered and many times also technical requirements were ignored. There was solely one goal: - to produce a military map. This military map should include all such information of the area concerned which the military leaders need for the planning and execution of movement, combat, accommodation and supply. The enormous technical progress in the last century largely influenced the application of strategical and tactical principles in warfare; therefore the nature of warfare changed and consequently also the requirements for the military maps. In order to avoid the lack of adequate maps in any future war, the nature of the warfare together with the corresponding changes which would affect the standards of the mapping have to be considered in advance within limits of possibility and also proper measures should be undertaken at the time. The Austro-Hungarian military authorities passed up the proper time for such considerations; hence the single tactical map of the Monarchy - 1:75,000 special map - trailed far behind the requirements imposed by the changes of warfare in World War I.

2. The special map as a tactical map.

The 1:75,000 special map is a typical marching map compiled in order to furnish the information needed in the orientation in the field. Its completeness, scale, manner of compilatiom and expression as well as accuracy would satisfy the necessities for a map in such tactical activities as the:

movement (with exception in high mountains)
accommodation, and
supply.

Meanwhile the nature of combat in World War I required a tactical map more complete, more accurate and at larger scale. The drum fire of the massed artillery of all calibers, the precise flat fire of the infantry heavy weapons, machineguns and guns and quite vertical fire of mortars forced the combat units to rivet into soil. Hence large fortifications of the field, semi-permanent, and permanent types were built. The front stabilized and the furious war of movement degenerated into positional war. The artillery, pulled behind the natural shelters and into fortifications, ordinarily acted by the indirect fire. The method of the indirect firing was applied already in the Russo-Japanese War in 1904-1905 by the artillery, but in World War I also heavy machineguns in some cases fired indirectly. The successful conduct of indirect fire requires a large scale map of great accuracy. In lack of such a map Austro-Hungarian artillery during the World War I used the 1:75,000 special map with changing success.

3. The maps used in topographical preparation by artillery.

In order to make the indirect fire possible the elements of firing data:

distance gun - target (range),
direction gun - target (deflection), and
difference of the elevations gun - target (altitudes)

must be determined either analiticaly by the computing from direct observations and meansurements or graphically be taken from the map. The maps were used prior to World War I by fortress artillery. The environs of a fortress was topographically surveyed at 1:10,000 or 1:25,000 scale and the elements, at that time still for direct fire (the range and altitudes), were then taken from the map which was divided into battery-sectors. In World War I the movable artillery ordinarily used the firing data taken from the map; therefore, the inadequacy of maps was revealed.

The normal scale of the topographic maps used in the movable artillery is that at 1:25,000 scale, but in case such a map does not exist maps at scales up to 1:100,000 scale had been used.

a. The standards prescribed for the horizontal accuracy of the topographical surveys carried out in the period between two World Wars are as follows:

The error of plotted trig points should be no larger than..± 0.1 mm;

the error of plotted orientation points (towers, belfries, smokestacks, crosses, monuments etc) should be no larger than..............................± 0.2 mm;

the error of plotted detail points not visible from a long distance (bridges, crossroads, corners of woodland, confluences, etc.) should be no larger than..± 0.5 mm;

the error of plotted detail points in the woods should be no larger than..............................± 0.1 mm.

Meanwhile the testing works made in order to establish the accuracy of topographical manuscripts of the surveys carried out between the two World Wars showed that the orientation points and the sharply-shaped detail points of the planimetry are plotted by a probable error of ± 0.3 mm. The corresponding values in the terrain to the graphical accuracy of plotting in respect to the various scales are shown in the following table:

Scale of the map	Max.error of scale ± 0.1mm	TPs plotted by ± 0.1mm	OPs plotted by ± 0.2 mm	DPs plotted by ± 0.5 mm	Probable error of plotting ± 0.3 mm
1: 25,000	2.5 m	2.5 m	5 m	12.5 m	7.5 m
1: 50,000	5 m	5 m	10 m	25 m	15 m
1: 75,000	7.5 m	7.5 m	15 m	37.5 m	22.5 m
1:100,000	10 m	10 m	20 m	50 m	30 m

Considering these characteristics of the accuracy of topographical manuscripts if in the artillery topographical preparation the starting points are taken from the map and the other points: positions of base piece, targets, observation posts, reference points etc. determined by means of artillery instruments (compass, goniometer, panoramic telescope of the piece, range finder) the probable error of positions of determined points will be that of detail points = 0.5 mm of the map scale, i.e.;

on the 1: 25,000 map ± 12.5 m
on the 1: 50,000 map ± 25 m
on the 1: 75,000 map ± 37.5 m
on the 1:100,000 map ± 50 m.

b. Meanwhile the requirements of the instructions for topographical preparation in artillery in movable war are:

(1) The points: battery positions, base pieces, base points, reference points, observation posts, targets should be determined in position with probable error not larger than ± 15 meters.

(2) The directions should be determined by probable error not larger than 3 mils.

(3) The contour lines should be drawn with such accuracy that the mean square error of the vertical displacement should not exceed the value obtained by formula

$$Eh_m = \pm (1 + 10 \tan\alpha) \text{ meters;}$$

where:
1 and 10 are constants;*
α = slope angle.

* Formula for the error of contours established by Prof. Dr.Carl Koppe:
Vertical error $E_h = \pm(c + k \cdot \tan\alpha)$ meters,
Horizontal error $E_p = \pm(c \cdot \cot\alpha + k)$ meters.

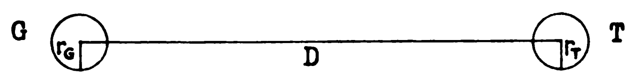
The contour interval should be for:

1: 25,000 map 5 and 10 meters,
1: 50,000 map 10 and 20 meters,
1: 75,000 map 20 meters, and
1:100,000 map 40 meters.

4. <u>The accuracy of firing data determined from the map</u>.

In order to establish the adequacy of the topographical maps at scale 1:25,000 up to 1:100,000, to be utilized in the artillery topographical preparation in movable war, the accuracy of elements of firing data if taken from these maps has to be analyzed.

a. Determination (reading) of the distance from the map: In order to simplify the case, the elliptical shape of error of plotting will be considered as a circle.



If the distance (range) G (gun) - T (target) is plotted in the map by probable errors which have the radius r_G and r_T then the error of determination of distance (range) G - T from the map would be:

$$E_D = \sqrt{r_G^2 + r_T^2}$$

Regarding that the points G and T were plotted by errors of 0.3 mm or 0.5 mm we have following combinations:

(1) Both points are plotted by errors of 0.3 mm;

$$E_D = 0.3\sqrt{2} = 0.42 \text{ mm.}$$

In this case the error of the determination of the distance from the map would be:

10.5 m if 1: 25,000 map is used,
21. m if 1: 50,000 map is used,
31.5 m if 1: 75,000 map is used,
42. m if 1:100,000 map is used.

(2) One point plotted by error of 0.3 mm other by 0.5 mm;

$$E_D = \sqrt{(0.3)^2 + (0.5)^2} = 0.6 \text{ mm.}$$

In this case the error of the determination of the distance from the map would be:

15 m if 1: 25,000 map is used,
30 m if 1: 50,000 map is used,
45 m if 1: 75,000 map is used,
60 m if 1:100,000 map is used.

(3) Both points are plotted by error of 0.5 mm;

$$E_D = 0.5\sqrt{2} = 0.7 \text{ mm.}$$

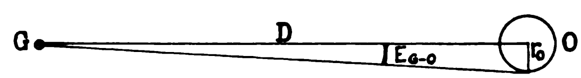
In such case the error od determination of the distance from the map would be:

17.5 m if 1: 25,000 map is used,
35 m if 1: 50,000 map is used,
52.5 m if 1: 75,000 map is used,
70 m if 1:100,000 map is used.

The absolute error E_D, if the expansion of paper is ignored, does not depend of the length of the distance G - T.

The relative error $\frac{E_D}{D}$ decreases proportionally to increasing distance.

b. Determination of the direction (deflection) from the map: If the direction gun (G) - (O) orientation point (base point) has to be determined, according to the sketch



the error of the direction G - O would be

$$\tan E_{G-O} = \frac{r_O}{D}$$

In respect to the small angle tangent can be replaced by the angle expressed in the angular units used in the artillery - mils, hence

$$E_{G-O} = \frac{r_O}{0.001\ D}$$

This formula could be applied only in case the point G is plotted without the positional error. All points should be considered to be plotted with certain errors; therefore the error of direction, depending on the plotting errors of points and on the distance between the points, would be expressed:

(1) In the general case where points are plotted with different errors:

$$E_{G-O} = \frac{\sqrt{r^2 + r^2}}{0.001 \ D}$$

(2) In a special case where points are plotted with the same error $r_G = r_O = r$

$$E_{G-O} = \frac{r\sqrt{2}}{0.001 \ D}$$

Using these formulae the probable errors of direction (deflection) shown in the table below were computed for the distances 1-20 cm in respect to the maps at 1:25,000, 1:50,000, 1:75,000 and 1:100,000 scale:

Distance on the map in centimeters.	Corresponding distances on the terrain in meters				Probable error of direction	
	1:25,000	1:50,000	1:75,000	1:100,000	r_G=0.3 mm r_O=0.5 mm	r_G=r_O 0.3 mm
1 cm	250 m	500 m	750 m	1000 m	58 mils	42 mils
2	500	1000	1500	2000	29	21
3	750	1500	2250	3000	19	14
4	1000	2000	3000	4000	15	10
5	1250	2500	3750	5000	12	8
10	2500	5000	7500	10000	6	4
15	3750	7500	11250	15000	4	3
20	5000	10000	15000	20000	3	2

The table shows that the direction (deflection) can be determined with sufficient accuracy if the distance G - O is longer than 15 centimeters on the map or on the terrain longer than:

3750 m if 1: 25,000 map is used,
7500 m if 1: 50,000 map is used,
11250 m if 1: 75,000 map is used,
15000 m if 1:100,000 map is used.

c. Determination of the difference of elevations (altitudes) between the gun and target from the map: In most cases neither gun nor target would be placed on a point which would be a trig point, leveling point or a spot elevation; therefore the elevations of the gun and target have to be determined by interpolation from the contours. On the contemporary maps with relief expressed by contour lines (with contour interval corresponding to the scale of the map) drawn with a vertical error not larger than that expressed by formula

$$E_{h\ max.} = \pm (1 + 10 \cdot \tan \alpha) \text{ meters}$$

the maximal error of the determination of the elevation depending on the size of the angle of sloping would be within limits from 1 to 11 meters. For the following angles of sloping it would amount:

α	$E_{h\ max.}$ in meters:
0°	1.00
2°	1.35
5°	1.87
7°	2.23
10°	2.76
20°	4.64
30°	6.77
40°	9.40
45°	11.00

Practically the permissible error will be within the limits of a contour interval of 10 meters used in the mapping at 1:25,000 and 1:50,000 scale. Consequently the mean square error in the interpolation of the elevations permitted by artillery would be equal to the maximal vertical error in the drawing of the contours tolerated in the contemporary mapping at 1:25,000 scale. By the theory of errors the maximal error is three times larger than corresponding mean square error

$$E_{max.} = 3E_m^{*}$$

therefore some countries have more liberal standards prescribed for the accuracy of the drawing of contours in the military maps than the value expressed by formula $E_h = \pm (1 + 10 \cdot \tan \alpha)$ meters. For instance:

* Symbols used in some Artilleries:

E = probable error,
E_1 = average error,
E_2 = mean square error
E_3 = maximal error.

$$E = \frac{5}{6} E_1 = \frac{2}{3} E_2 = \frac{2}{9} E_3$$

(1) G e r m a n y:

1:5000 scale "Topographische Grundkarte".

$$E_{h2} = \pm (0.4 + 5 \cdot \tan\alpha) \text{ meters,}$$

$$E_{h3} = \pm (1 + 15 \cdot \tan\alpha) \text{ meters.}$$ [55] [83]

1:25,000 scale Prussian plane table sheets.

$$E_{h3} = \pm (1.5 + 15 \cdot \tan\alpha) \text{ meters,}$$ [181]

1:25,000 scale new German plane table sheets tested in 1937

$$E_{h3} = \pm (1.8 + 10 \cdot \tan\alpha) \text{ meters.}$$ [138]

(2) C z e c h o s l o v a k i a :

1:20,000 scale topographical map.

$$E_{h3} = \pm (1 + 10 \cdot \tan\alpha) \text{ meters.}$$ [17]

These standards for the accuracy of drawing of contours in professional circles were criticized as too rigorous, especially for the areas with low slopes. The Germans carried out the field check of 1:5000 map in two regions and the records published in 1926 and 1929 show that contours were drawn with greater accuracy than was prescribed, i.e. $E_{hmax} = \pm (0.48 \pm 4.05 \cdot \tan\alpha)$ meters and $\pm (0.57 + 5.01 \cdot \tan\alpha)$ meters. [33] [55]

The accuracy of contour lines undoubtedly depends on the number of measured elevations. The contour lines in the German 1:5000 topographical map, until it was surveyed by plane table method, were constructed on base of 500 - 1400 measured elevations within 1 square kilometer and in the Prussian plane table sheets on base of 80 - 400 spot elevations per 1 square kilometer. [55] [83]

The contours of Czechoslovakian 1:20,000 topographical map were drawn on base of 15 - 100 spot elevations; therefore Czechoslovakian formula $E_{h3} = \pm (1 + 10 \cdot \tan\alpha)$ meters for the sheets which were not compiled by stereoautograph or stereo-planigraph appears to be very rigorous.

It should be mentioned also that such accuracy of drawing of contours can be achieved only in the topographical surveys of 1:25,000 scale and larger, as well as a field check in order to test the accuracy of contour lines is applicable only to the original manuscripts or by a careful consideration of expansion and deformation of paper and matching of colours to the maps which are direct copies of original manuscripts; at a smaller scale map compiled from reduced manuscripts of original survey with already generalized expression of the relief the test of the accuracy of contours, though theoretically possible, would be meaningless.

It would be of interest to compare the Russian standards for the accuracy of contour lines prescribed in the topographical instructions of 1943 with already mentioned standards.

(3) U.S.S.R. :

The maximal vertical error of contours permitted in Russian mapping:

α	contour interval	1:25,000 map 5 m.	1:50,000 map 10 m.	1:100,000 map 20 m.
$0^\circ - 2^\circ$	$\frac{1}{4}$	1.25	2.5	5
$2^\circ - 5^\circ$	$\frac{1}{2}$	2.5	5	10
$5^\circ - 7^\circ$	$\frac{3}{4}$	3.75	7.5	15
$7^\circ -$	1	5	10	20

[26]

The table shows that the Russian standards represent a flat interpolation of the contour interval values applied to the four steps of slopesteepness. Compared with the German and Czechoslovakian standards Russian standards are very liberal.

(4) Austro-Hungarian Empire:

In 1907, the K. und k. Military Geographic Institute surveyed the military training grounds at Hajmasker (Hungary) and Alt Benatek (Bohemia) with a total surface of 184 km^2. The survey executed by plane table method at 1:10,000 scale was experimental in character because it included the test of the adequacy of plane table method for this large scale. For this purpose the triangulation was densified with 3rd and 4th order trig points to a density of 1 trig point per 3 km^2, and the areas were covered by spirit leveling lines. The cadastral planimetry was pantographically reduced into plane table sheets and carefully checked. The detail was surveyed by 100 - 1000 detail points per 1 km^2, all having measured elevations. The contour interval used on the flat land was 1 m, on steeper slopes 5 m. As the result of the testing the accuracy of contours was expressed by the following mean square error

$$E_{h2} = \pm (0.2 + 5 \cdot \tan \alpha) \text{ meters;}$$ [139]

A value derived from the largest errors would be expressed by formula

$$E_h = \pm (0.8 + 7 \cdot \tan \alpha) \text{ meters,}$$ [139]

which is more favorable than the maximal error

$$E_{h3} = \pm (0.8 + 15 \cdot \tan \alpha) \text{ meters}$$

given by Prof. Hammer.[83] [139]

The corresponding 1:25,000 plane table sections of the Third topographical survey were compared with this 1:10,000 experimental topographical survey of higher accuracy. The numerical values resulting from this comparison were not published. Instead only this general statement was made: "In the plane table sheets at 1:25,000 scale of the Third topographical survey

- due to the scarcity of measured elevations many of the less prominent features of the relief were omitted:

- in the forest regions the undulation of terrain as well as the low spurs were either omitted or inaccurately expressed;

- in hilly land the ridges ordinarily were shown as too flat and to wide and slopes too narrow and too steep." [139]

By reason of the fact that the contours in the plane table sections of Austro-Hungarian topographical survey were drawn:

- in III Topographical survey on base of 1-5 measured elevations per 1 km^2;

- in IV Topographical survey on base of 4-22 measured elevations per 1 km^2;

it is evident that they can not meet the standards of accuracy required by artillery for determination of altitudes. In the light of the standards for accuracy of contour lines used in contemporary mapping the contours by which the relief in Austro-Hungarian topographical surveys at 1:25,000 scale was expressed could be rated very close to form lines.

Within all the Austro-Hungarian topographical survey at 1:25,000 scale an accuracy of contours sufficient to meet the artillery requirements is to be found only in the parts of the plane table sheets in Tyrol and Carithia surveyed in Fourth topographical survey by terrestrial photogrammetry.

d. The accuracy of the firing data determined from a map undoubtedly shows that only a topographical map at 1:25,000 scale would completely satisfy the requirements of the artillery in a movable war if compiled by the following standards:

- orientation points, points of plane table triangulation plotted with probable error not larger than $\pm$ 0.2 mm;

- other detail points plotted with probable error not larger than $\pm$ 0.5 mm;

- contour lines drawn with accuracy where the mean square error of the vertical displacement should not exceed the value obtained by formula

$$E_{h2} = \pm (1 + 10 \cdot \tan \alpha) \text{ meters};$$

In this case the length of the orientation line used in the determination of deflection should exceed 3750 m.

The 1:50,000 topographical map in the compilation of which the same standards of accuracy were applied would satisfy the artillery requirements only in cases where the length of the orientation line used in the determination of deflection exceed 7500 m.

It should be noted that this accuracy would be reduced to a half if the irregular expansion of paper is considered or three or more time in case the firing data have to be determined graphically from two or more joined sheets which are not provided with a fire control grid.

5. The deficiences of the special map.

The Austro-Hungarian special map at 1:75,000 scale, as already mentioned, has to be considered as a reduced copy of the plane table section surveyed at 1:25,000 scale. Summarizing previously discussed points:

- various basic data used in the III and IV topographical survey,

- different methods of survey applied,

- trifling number of surveyed points and elevations,

- enormous surface surveyed by 1 topographer in a period of six months, which is six times larger than the present norm,

- various aspects by which the survey, reambulation and map revision were executed within a half century,

- complete lack of uniformity of the entire map,

it could readily be concluded that the Austro-Hungarian special map does not meet the standards prescribedfor a map to be successfully used in the topographical preparation of artillery. Moreover, one half of this map represent the sheets compiled from the III topographical survey executed in 1869 - 1887, which were never revised; the other half are sheets compiled from reambulated plane table sections of III topographical survey, revised special map sheets at 1:50,000 scale and of plane table sections of IV topographical survey prior to 1914 (See Inclosure 2); hence this map should be considered obsolete. The successor states replaced the special map by their own maps as follows:

Austria	1: 50,000, map
Czechoslovakia	1: 50,000, 1: 75,000 maps,
Hungary	1: 50,000, 1: 75,000 maps,
Italy	1: 50,000, 1:100,000 maps,
Poland	1: 50,000, 1:100,000 maps,
Romania	1:100,000, map,
Yugoslavia	1: 50,000, 1:100,000 maps.

These maps largely were compiled of reambulated Austro-Hungarian topographical survey, revised special map and smaller part of the new topographical surveys carried out by successor states. In World War II some 1:75,000 sheets of the maps of Czechoslovakia, of Hungary and of 1:50,000 sheets of the map of Austria still were unrevised old sheets of Austro-Hungarian special map.

The main deficiencies of the 1:75,000 special map could be summarized as follows:

a. Completeness: The third topographical survey as well as its reambulation were carried out differently by the division of territory into three categories in respect to the importance from the military point of view; hence the regions along international boundaries and important operational routes (presumptive battlefields) were surveyed more accurately and well filled in by details, the regions suitable for military operations, rolling areas, hilly land, valleys and settled areas (possible battlefields) were surveyed some what less accurately and do not include so much detail; meanwhile the mountainous, extensive karst and large forest regions were merely sketched and are incomplete. Hence the map is not uniform in respect to completeness and accuracy. Furthermore the reambulated and newly surveyed plane-table sections were used only in the compilation of newly constructed sheets of the second and third edition marked "2. Ausgabe" and "3. Ausgabe"; however the partially corrected sheets marked

"Teilweise berichtigt bis..." included as part of the reambulation and new survey only additional important cultural features and those obtained by the Evidence section (Map intelligence). For instance: The 1:75,000 sheet 5269 Kiralyhego-Biharrosa (Transylvania) compiled from plane table sheets of the 1869-70 topographical survey is marked partially corrected to 28. VI. 1913, and was published in 1913. The Third topographical survey in this area was executed on base of sparse triangulation without use of cadastral planimetry. The reambulation of the III Topographical survey in this area was completed in 1892-93. The 1:75,000 sheet, published in 1913, compared with the plane table sections reambulated in 1892-93, shows that in mountainous and forest regions of the southern part the trig points, spot elevations, forest roads, trails and settlements as well as newly expressed relief shown in 1:25,000 reambulated plane table sections were not included into 1:75,000 sheet. This is not an isolated example but it represented a general practice.

The fallacy in the accepted classification of regions into three classes, i.e. presumptive and possible battlefields and seldom-frequented mountainous areas was clearly demonstrated by the type of warfare practiced in World War I. Rejecting the accepted idea that seldom-frequented mountainous areas were of little comparative importance the positional war, not detered by any type of terrain, dug deep entrenchments and built concrete positions in the most remote ridges of the Carpathian Mountains and in the rocky summits and glaciers of the Tyrollian, Carnic and Julian Alps. Strategic roads, railroads and cable ways were constructed and the heaviest mortars of 42 cm caliber were placed on heights up to 2500 m. There was a general demandfor an accurate large scale map because it was needed so badly for artillery fire and for planning of fortifications and communication lines. Thanks to the Austro-Hungarian General Staff and its complete lack of imagination about the perspectives of a future war there were no adequate maps, particularly not in these "seldom-frequented areas of third class importance".

The original 1:25,000 plane table sections (manuscripts) were provided with a kilometer grid with the origin in center of 1:75,000 sheet, photostated and printed in order to satisfy the urgent need for a large scale map. Surveyed for the purpose of compilation of 1:75,000 special map, quite inaccurately positioned, with considerable distortion in construction of polyhedric sheet lines, with large interior discrepancies because of an inadequate number of surveyed points, with contour lines constructed in the office on the basis of a negligible number of measured elevations, this map was a poor substitute for an artillery map. Because of these deficiencies plus the fact that each four plane table sheets have a different origin the grid is no better than a reference grid.

The incompleteness and inaccuracy of 1:75,000 map in mountainous and extensive forest regions, compiled from topographical survey consisting mostly of sketching, made the map untrustworthy in orientation and minimized its value also as a marching map.

b. Scale: For a long period of time in the Austro-Hungarian Army the pace (1 pace = 0.75 meters) was used as the unit of length measurement. The range of the guns and rifles was determined in paces. This was the main reason that the 1:75,000 scale was adopted in 1872. Nevertheless, certain military circles considered the 1:75,000 scale as the best for a tactical map, complaining at the same time that the 1:100,000 scale is too small. Such an opinion as well as a facilitated utilization of the 1:75,000 sheets, inherited from the disintegrated Austro-Hungarian Empire, led the Czechoslovakian and Hungarian military authorities later to retain the 1:75,000 scale. Modern warfare rejected this opinion because a compromising scale of 1:75,000 cannot satisfy the need for a tactical map at 1:100,000 scale used by larger units particularily as a device for orientation and the need for 1:50,000 tactical map used ordinarily by smaller units and particularly in the regions of high mountains where the 1:50,000 scale would permit inclusion of all details needed in orientation; as well as in the case if the 1:25,000 map does not exist partially meet the artillery requirements for use of the map in firing preparation. The tactical map at 1:75,000 scale practically disappeared from modern military mapping because there is need for 1:50,000 scale and for 1:100,000 scale tactical map.

c. Legibility: The military map has to be compiled and drafted in such a manner that it can be read in a moving car, tank, airplane, on horse back, and by day light under a tent without use of a magnifying glass. In order to obtain such a degree of legibility:

(1) The contents have to be carefully selected in respect to the degree of military importance and only such a quantity of selected features included in the compilation which would be in accordance with the scale of the map. Such cartographical selection generally would require an omission

of some features shown in the topographical manuscripts, particularly in the well settled areas in order to assure the legibility of the map quite a considerable number of features must be omitted. There is no place in a tactical map at 1:100,000, 1:75,000 and also 1:50,000 scale for all trails in the field or rolling areas, for all sheds, fences and hedges in the settled areas. The map will not lose any important features by their omission but should gain considerably in clearness and legibility.

(2) The selected features have to be expressed, regarding the natural size and degree of importance by such size, shape and colour of symbols as would provide maximal legibility. In this expression the similarity to the corresponding objects in nature as well as the aesthetics should in no case be ignored.

(3) The nomenclature (place names) represents an important factor in the solution of the problem of map legibility. An inadequate selection of the quantity of names, of the type, size and graduation of the lettering can detract from the legibility and aesthetic appearence of an otherwise good map. The graduation should guarantee that the objects of greater importance attract at first glance the attention of map readers. The combined factors of shape, size and graduation of the lettering should make the nomenclature serve as a fine screen through which the appearence of the relief and cultural features would remain undisturbed.

The Austro-Hungarian 1:75,000 map was published in three editions with many partially corrected sheets. The various editions were described and evaluated in respect to completeness and legibility in chapter V,pp. 58-59, but still such a general conclusion in respect to legibility should be made:

The 1:75,000 map reproduced only in black colour, overloaded by details in the plain and settled areas, with the relief expressed by combination of hachuring and 100 m contour lines is hardly legible, particularly in the mountainous areas. In order to make the nomenclature more legible the hand-lettering was made too large and too heavy, which together with the expression of the relief and overabundance of cultural features produces a dark monotonous map which fails considerably to meet the legibility requirements of a military map.

d. Accuracy: The 1:75,000 special map was compiled from 1:25,000 plane table sections of the III Topographical survey, reambulated plane table sections, and 30 sheets from plane table sections of the IV Topographical survey. Each 1:75,000 sheet is composed of four 1:25,000 plane table sections. Consequently, all previous statements concerning the accuracy of topographical surveys and reambulation included in chapters: III-2b, p. 33; III-2c (1), pp.35-36; and IV-2c, pp.51-52 remain valid for 1:75,000 map. Obviously, considering the scale the graphical effect would be reduced to one third.

(1) Composition: In the Third topographical survey as well as in the first part of the Fourth topographical survey (1896-1902) each individual 1:75,000 sheet of $15' \times 30'$ was considered to be a projecting plane; since the four 1:25,000 plane table sections lie in the same plane, because 1 special map sheet of $15' \times 30'$ at 1:25,000 scale is supposed to be simply cut into four symmetrical rectangular trapezoids, the composing of the 1:75,000 sheets theoretically should not cause any distortion. Meanwhile in the scaling of geographic positions of identical points from the sheets at 1:25,000 and 1:75,000 scale disparities arise which largely exceed the limits of graphical error for plotting and scaling. Comparisons of scaled positions of 74 trig points show:

average disparity $\Delta\phi = \pm 1''.0$
$\Delta\lambda = \pm 1.1$

maximal disparity $\Delta\phi = + 3''.7$
$\Delta\lambda = + 2.3$

Comparisons similar to these were made by Military Geographic Institute of Yugoslavia (See File No. 658.0488). There were compared 80 first order stations scaled from 1:25,000 and 1:75,000 sheets. In these comparisons the following values were obtained:

average disparity $\Delta\phi = \pm 2''.0$
$\Delta\lambda = \pm 2.1$

maximal disparity $\Delta\phi = - 7''.2$
$\Delta\lambda = - 9.5$

It should be noted that in these comparisons the stations:

S. Andrija I $\Delta\phi = -14''.4$ (+ $2''.6$)
$\Delta\lambda = + 0.5$ (+ 0.3)

Maglić $\Delta\phi = +11''.2$ (+ $2''.2$)
$\Delta\lambda = + 9.7$ (+ 2.4)

were scaled erroneously. The values obtained in the comparisons of this study are given in parenthesis. In addition to making errors in scaling the Yugoslavs apparently did not consider the following facts concerning the basic data used in Austro-Hungarian mapping:

The triangulation used in the Third topographical survey (1869-87) is identical with the trig points plotted on the 1:75,000 sheets of the first edition. The triangulation net was gradually resurveyed, densified, and adjusted. At the time of resurvey many markers of the primary net had already been lost and new stations had been established near the location of the old stations; therefore the same name and a corresponding elevation on a map of later edition does not necessarily mean that the station used in the compilation of the second edition (for which there were utilized 1:25,000 reambulated plane table sections) or in compilation of the third edition (for which the plane table sections of the Fourth topographical survey were used), would be identical with the station used in the first edition. The reports discussing the resurvey of triangulation nets show that in some regions 50% and more of the old markers had disappeared. The 1:75,000 sheets of the second edition compiled from the reambulated plane table sections show a certain number of omitted trig points which were plotted in the first edition of the 1:75,000 map, as well as a large number of new trig points. Consequently, it is of primary importance in such comparisons to use these 1:25,000 plane table sections from which the sheets of the 1:75,000 map were compiled; i.e. plane table sections of the III Topographical survey should be compared with the sheets of the first edition of the special map, reambulated plane table sections with the sheets of the second edition of the special map, and plane table sections of the IV Topographical survey with sheets of the third edition of the special map.

In the comparisons made in this study where all mentioned particularities of the Austro-Hungarian mapping, as well as the paper deformation of printed maps, were considered, the differences between the positions scaled from the 1:75,000 map and those from the 1:25,000 plane table sections would still amount too:

average value	$\Delta\phi = \pm$	$1''.0$	(30.9 m)	= 0.4 mm	at 1:75,000;
	$\Delta\lambda = \pm$	1.1	(23.0 m)	= 0.3 mm	" "
maximal value	$\Delta\phi = +$	3.7	(114.4 m)	= 1.5 mm	" "
	$\Delta\lambda = +$	3.3	(69.0 m)	= 0.9 mm	" "

The linear values given in parenthesis correspond to the latitude 47° 30' - center of the Monarchy. The magnitude of these differences exceed the maximal errors of plotting 0.1 mm and scaling 0.2 mm, for 1:75,000 map estimated total ± 0.3 mm (theoreticaly ± 0.22 mm) and apparently require an explanation.

At this part it should be noted also that the scaling of positions from 1:25,000 plane table sections can not be accomplished with a greater accuracy than ± 0.5 mm. There are no original manuscripts available but only greatly distorted photostated or printed copies with sheet lines that are partially invisible and therefore ordinarily need to be reconstructed. Considering the scale, this error would be within the limits of the accuracy ± 0.3 mm by which a position can be read from 1:75,000 map.

The differences obtained in comparison of sheets covering a large area are not systematical but are erratic in nature meanwhile if observed within one 1:75,000 sheet they would be systematical in each plane table section, which fact undoubtedly shows a poor composition of the 1:75,000 sheets where the reduced 1:25,000 plane table sections without exact size often were forced to match 1:75,000 sheet lines.

The difficulties for an accurate composition of the map would continue insofar as the paper used in drawing of the manuscripts and colour separations has not been replaced by a stable material. The blue lines on which the colour separations are drawn are considered to be on size at the time of their print if the dimensions differ from the computed values by not more than ± 0.3 mm. In modern map-composing the blue lines are immediately mounted on aluminum plates covered by paper on which the sheet lines and control were plotted. The pasting has to be made by matching the plotted positions of trig points, each section or patch having at least 3 trig points. Considering the linear expansion and local deformations of paper as well as inexact scale in photography, an absolute matching of the control is quite impossible. There will remain empty strips and overlappings have to be cut amongst the patches. If these strips and overlappings also remain within the permitted limits of 0.3 mm the relation among the trig points would be already distorted in respect to the relation among the trig points plotted in plane table sheets. At the time of the Austro-Hungarian mapping the manuscripts were pasted on linen and blue lines on cardboard; the photolithographical reproduction of the blue lines was less accurate and the size of the reduced blue lines of the plane table sections differed up to 1 mm and more. Nevertheless, in many regions there was no control of such a density that two or more trig points with the geographic positions were available for each plane table section, because cadastral trig points were graphically included into plane table sections; therefore, the reduced plane table sections were fitted into sheet lines of the 1:75,000 map with a dubious accuracy. Many times the composition was done simply by matching the external sheet lines. In such a case the strips which appeared alcng the internal sheet lines were fudged cartographically. Apparently, the positions scaled from such 1:75,000 sheets would not agree with the positions scaled from the plane table sections. This deficiency greatly reduced the accuracy of the 1:75,000 map and particularly limited its utilization in the preparation of firing data by the artillery. Actually, during World War I, the 1:75,000 map was used by field artillery, but satisfactory results were obtained only in cases where the map locally agreed with the terrain features.

(2) Sample: Sheet 5663 Topolya emphatically demonstrates the defectiveness of composition of the Austro-Hungarian 1:75,000 map (See Inclosure 1I). The "Positions Rechnungen" M.G.I. Protocol No. 290 A, Part I includs the geographic positions of the following 3 trig points located in sheet 5663:

194 Kula Telečka (Puszta Kula)

Positions Rechnungen:	ϕ = 45° 46' 43″49	λ = 37° 00' 27″93
Scaled 1:75,000 sheet: $\Delta\phi$ =	+ 0.97 = + 29.90 m;	$\Delta\lambda$ = +1.04 = + 22.46 m
1:25,000 " $\Delta\phi$ =	+ 1.31 = + 40.44 m;	$\Delta\lambda$ = +0.77 = + 16.63 m
1:75,000 - 1:25,000	ΔN = - 10.54 m	ΔE = + 5.83 m.

195 Bajmok, Church

Positions Rechnungen:	ϕ = 45° 58' 03″96	λ = 37° 05' 27″92
Scaled:1:75,000 sheet: $\Delta\phi$ =	- 0.73 = - 22.53 m;	$\Delta\lambda$ = -1.03 = - 22.37 m
$\Delta\phi$ =	+ 0.19 = + 5.86 m;	$\Delta\lambda$ = +1.95 = + 41.97 m
1:75,000 - 1:25,000	ΔN = - 28.39 m	ΔE = - 64.34 m.

199 Topola (Akasztofalva)

Positions Rechnungen:	ϕ = 45° 46' 27″94	λ = 37° 17' 47″63
Scaled:1:75,000 sheet: $\Delta\phi$ =	± 0.00 = ± 0.00 m;	$\Delta\lambda$ = +6.94 = + 149.90 m
1:25,000 " $\Delta\phi$ =	+ 0.34 = +10.49 m;	$\Delta\lambda$ = +3.26 = + 70.42 m
1:75,000 - 1:25,000	ΔN = -10.49 m	ΔE = + 79.48 m.

Comparing the computed length of sides and the length scaled from 1:75,000 and from the 1:25,000 maps corrected for expansion of paper we have:

Side 194 Kula Telečka - 195 Bajmok, Church

Positions Rechnungen: 21,981 m
Scaled from: 1:25,000: 21,875 m + 106 m = 21,981 m; ΔS = + 0.00 m
1:75,000: 22,035 m - 42 m = 21,993 m; ΔS = + 12. m = 0.16 mm

1:25,000 scale:
coefficient of paper expansion = 0.1945 mm/km = 4.86 m/km;
21.875 x 4.86 = 106.31 m

1:75,000 scale:
coefficient of paper expansion = 0.0252 mm/km = 1.89 m/km.
22.035 x 1.89 = 41.65 m.

Side 194 Kula Telečka - 199 Topola

Positions Rechnungen: 22.464 m
Scaled from: 1:25,000: 22.390 m + 84 m = 22.474 m; ΔS = + 10 m = 0.4 mm,
1:75,000: 22.560 m + 0 m = 22.560 m; ΔS = + 96 m = 1.3 mm.

1:25,000 scale:
coefficient of paper expansion = 0.1505 mm/km = 3.76 m/km
22.390 x 3.76 = 84.19 m.

1:75,000 scale: coefficient of paper expansion = 0.

In this case the reduced 1:25,000 plane table sections were fitted into the 1:75,000 sheet by matching of the external sheet lines. Hence the positions of trig points were shifted and the side 194 Kula Telečka - 199 Topola extended for 86 m. The 1 - 1.3 mm wide strip along the internal sheet lines was cartographically tied. The width of the strip at 1:25,000 scale would amount to about 3.5 mm; therefore this cartographical fudging is readily shown by the comparison of detail. It should be noted that similar defects occured in the composing of the 1:100,000 sheets of the Yugoslav map covering the western part of the country which prior to 1918 was a part of the Austro-Hungarian Empire.

In order to better understand the degree of deficiency in respect to completeness, legibility and accuracy of the Austro-Hungarian 1:75,000 map and particularly its limited value as a tactical map, the 1:75,000 map should be compared with the contemporary Austrian map at

1:50,000 scale. (See comparisons in the pamphlet "Entwicklung des Kartographischen Institutes und der staatlichen Kartenherstellung nach dem Umsturz"; File No. B-661.2018).

VII. The maps compiled from 1:75,000 special map.

The 1:75,000 special map served as basic cartographic material in the compilation of the following military-operational and synoptical maps covering the territories of the Austro-Hungarian Empire and of neighbouring countries which were published by the K. und k. Military Geographic Institute.

1. The general map of Central Europe at 1:200,000 scale.

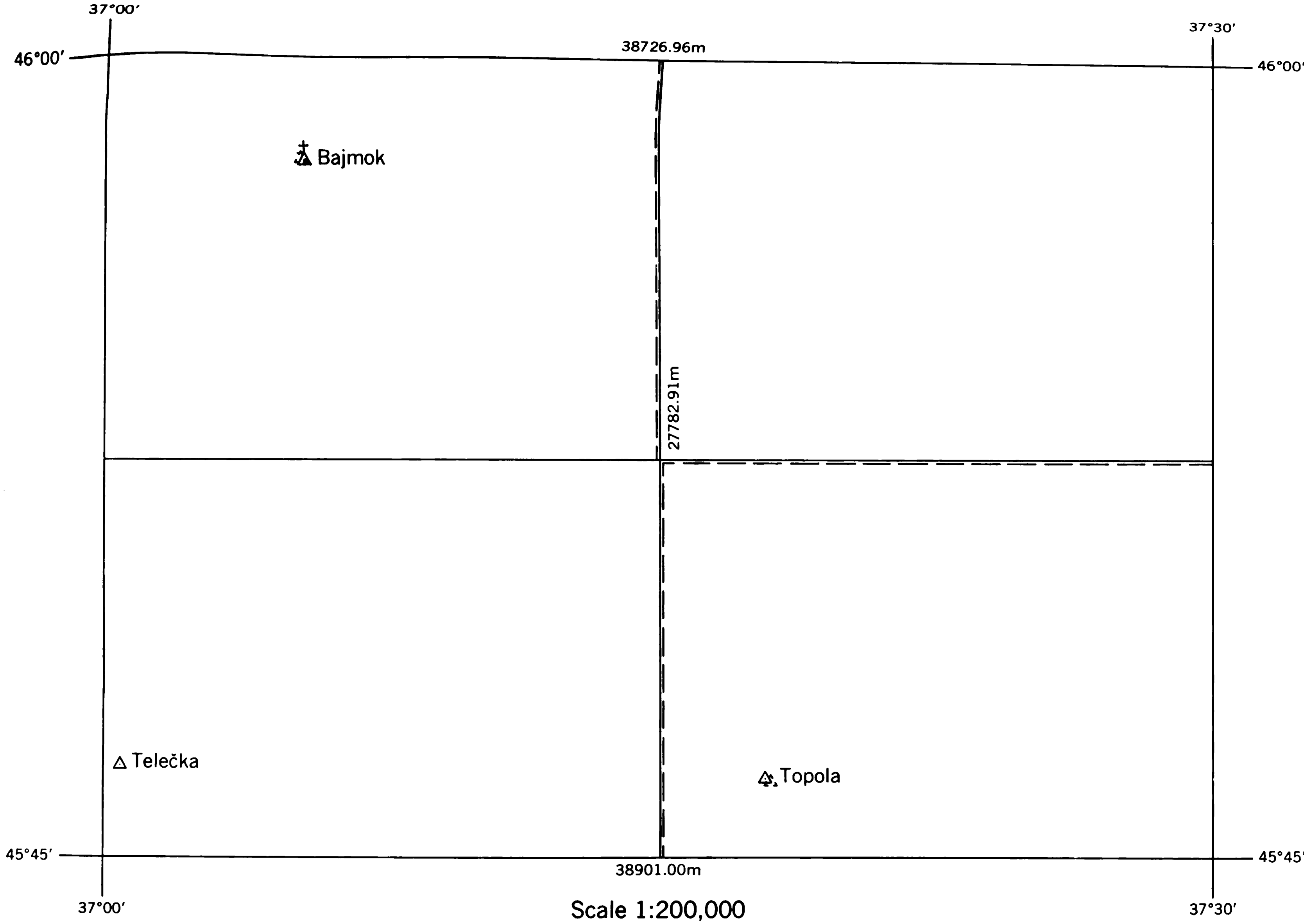
The preparations and studies for this Austro-Hungarian operational map began in 1879, but the compilation started in 1885. At the beginning of compilation it was projected by 282 sheets to cover the area of Central Europe between the 24° 30' and 48° 30' East of Ferro meridians and between 38° 30' and 53° 30 parallels. Up to 1918 there were published 266 sheets.

The polyhedric sheets of one degree in latitude and longitude are cut in the "uniform graticule system" of the special map in such a manner that full degree meridians and parallels intersect at the centers of the sheets each composed of 8 sheets of 1:75,000 map.

The compilation and drawing were carried out at 1:170,000 scale (some sheets at 1:200,000 scale) to which the 1:75,000 sheets were photoreduced. Since a cartographic manuscript for each sheet was not compiled the color separations were drawn upon the blue lines of the photoreduced original cartographic material. The cartographers carried out the generalization of the contents along with the drawing of color separations. For the relief a manuscript with generalized shapes of the terrain was prepared and on base of it the color separation drawn. The relief was expressed by hachures except in the sheets covering the Balkans where it was expressed by the combination of 100 m contours and shading. Because within the period of compilation (1885-1918) the topographical symbols and handlettering of toponymy underwent many changes an exact uniformity in the compilation and drawing was not preserved. In the period after 1900 for some sheets covering Balkans, Galicia and Poland (former Russian territory) more reliable cartographic material was obtained, therefore 45 sheets were recompiled and published as second edition. A few sheets appeared even in the third edition.

Inclosure 11

5663



Scale 1:200,000

Surveyed 1881

Published 1884

The sheets were reproduced by process of helio-engraving with transfer from copper plates to lithographic stones and printed in four colors i.e., cultural features, graticule, marginal information, and nomenclature in black; hydrography in blue, relief in brown and woodland in green tint.

The 1:200,000 general map of Central Europe undoubtedly represents the best cartographic work of the K. und k. Military Geographic Institute. Despite such deficiencies as not uniform compilation and drawing, too crowded place names in dense settled areas and relief expressed only by hachuring it was considered the best operational map the European armies had in World War I. The completeness and reliability of the sheets covering Balkans often were criticized. Since the compilation of these sheets was based on various foreign maps and upon such intelligence material as sketches, itineraries and descriptions the producers of the poor cartographic material deserve the criticism rather than the K. und k. Military Geographic Institute which used the best available material. The general map has an artistic appearence and very good legibility. One serious observation should be made in respect to the native Czech, Slovene and Croatian toponymy which in the sheets covering the Austrian part of the Monarchy was completely germanized and in the sheets of Littoral and Dalmatia even italianized.

2. Synoptical map of Central Europe at 1:750,000 scale, constructed in Bonne projection.

The synoptical map of Central Europe constructed in projection of Bonne consists of 45 sheets. The sheets are uniform quadrangles with the sheet lines not conciding with graticule.

The map was published in 1882-1886. The compilation was based upon the photoreduced 1:75,000 sheets and for the part covering the neighbouring countries upon the sheets of 1:300,000 general map of Central Europe. The compilation and drawing of color separations was carried out at 1:500,000 scale. The relief is expressed in hachures, the nomenclature is handlettered. The reproduction was carried out by process of helio-engraving with the drainage engraved directly in the stone. The map was printed in four colours, i.e. cultural features, sheet lines with marginal information and nomenclature in black; first and second class roads in red; relief in brown and hydrography with appropriate names in blue color.

This map represents a uniform cartographic work and was during World War I extended to the West. Combined sheets were published together as synoptical maps of various battlefields. The successor states Czechoslovakia and Hungary published this map for their regions and changed merely the nomenclature and marginal information. Supplemented with new information and brought up to date it is still reproduced by Freitag and Berndt as a synoptical map of successor states.

The 1:750,000 synoptical map was also published with the relief expressed in hypsometrical tints. This edition was not completed and consists only of 12 sheets covering Bohemia and Galicia and parts of Tyrol and Vorarlberg, Transylvania and Bosnia. Furthermore 6 sheets with hypsometrically expressed relief were published together as the oro-hydrographical map of Carpathians.

3. The synoptical map of Central Europe at 1:750,000 scale constructed in Albers projection.

In 1895, Col. Prof. Dr. Heinrich Hartl published his discussion about the application of equal-area conical projections in the mapping of Central Europe. Col. Hartl introduced the Albers conical projection which was adopted by K. und k. Military Geographic Institute for the new 1:750,000 synoptical map of Central Europe.

The new synoptical map had to cover the area between the meridians 21° 30' and 53° 30' East of Ferro and between the 40° 30' and 53° 30' parallels. The sheets with dimensions $3^{\circ}_{\phi} \times 4^{\circ}_{\lambda}$ are composed each of 12 sheets of the 1:200,000 general map (or 96 sheets of 1:75,000 special map). The parallels are circular arcs and meridians straight lines constructed in sympathy with the graticule system of special map, but the sheets are extended over this graticule and form quadrangles of equal size with overlapping strips. In order to compose more sheets together the overlapping strips have to be cut off.

The compilation and drawing of the planimetry was carried out at 1:600,000 scale and of the relief at 1:750,000 scale. The basic cartographic material used in the compilation were 1:200,000 sheets of the general map. Up to disintegration of the Monarchy of the projected 40 sheets only 12 sheets covering the area south of 49° 30' parallel were compiled and published, i.e. sheets: E-6 Innsbruck, H-6 Debreczen, E-7 Milano, F-7 Trieste, G-7 Banja Luka, H-7 Orsova, I-7 Bucuresti, K-7 Odessa, G-8 Kotor, H-8 Skoplje, I-8 Adrianople and K-8 Constantinople.

The map has two editions which differ in the expression of the relief. The sheets of first edition show the relief expressed by hypsometric scale with 12 tints. In the sheets of second edition the relief is expressed by the combination of 500 m contours and shading.

The reproduction was carried out by process of helio-engraving. The sheets were printed in five basic colours (plus hypsometric tints) i.e. cultural features, sheet lines with marginal information, nomenclature and elevations in black; first and second class roads in red; relief in brown, hydrography with pertaining names in blue; and woodland (shown only in second edition) in green colour.

The compilation of this excellent synoptical map after World War I was discontinued.

4. The K. und k. Military Geographic Institute published in the period from 1839 to 1918, numerous maps at various scale and for various military and civilian purposes which compilations were based upon the basic maps i.e. 1:25,000 topographical manuscripts, 1:75,000 special map, 1:200,000 general map and 1:750,000 synoptical map. Many of these maps, for instance garrison maps environ maps, province maps and battlefield maps, are merely direct reproductions of these basic maps, where the sheets of basic maps were joined together and in the reproduction some colors added and special information included.

The K. und k. Military Geographic Institute was considered as the World's largest cartographic enterprise. It is beyond the scope of this study to discuss all of its numerous and successful activities in the field of Cartography.

SECTION D

SUCCESSOR STATES
AUSTRIA, CZECHOSLOVAKIA, HUNGARY, ITALY AND YUGOSLAVIA

D. THE MAPS OF SUCCESSOR STATES

After the disintegration of the Austro-Hungarian Empire the successor states in the period between the two World Wars partially covered the inherited territory by new topographical surveys. The surveys were utilized in the compilation of the various maps which replaced the Austro-Hungarian maps. The successor states have not yet completed topographical surveys covering all the territory inherited from the Monarchy; therefore a certain number of sheets of the various maps published by surveying and mapping agencies of the successor states still are based on the Austro-Hungarian topographical survey. In this chapter particular attention will be given to the new topographical surveys and to the maps compiled from the new surveys. (See Inclosure 12).

Since the topographical surveys of the successor states are based upon the triangulations attached to the first order net of the III K. und k. Military triangulation and upon the elevations in sympathy with the elevations of the Austro-Hungarian precise leveling referring to the vertical datum Trieste, Molo Sartorio (1875), brief discussions of the III K. und k. Military triangulation and of the precise leveling in the Austro-Hungarian Monarchy are included in this chapter.

The III K. und k. Military Triangulation.

It should be remembered from the previous discussions that the uniform graticule system of the Austro-Hungarian mapping is based upon the II K. und k. Military triangulation and upon the chains of degree survey executed in 1862 - 1898, (Transylvania, Bosnia and Hercegovina, Dalmatia) with the preliminary geographic coordinates referring either to Vienna University or to Arad, St. Anna datums. (Positions Rechnungen M.G.l. Protocol 290 A and B.)

1. In 1862, the Austro-Hungarian Empire became a member of the Commission for the Central European degree survey initiated by Prussian Lt. Gen. Baeyer. The Commission planned to cover Central Europe by a large triangulation carried out by all member-states uniformly. This triangulation together with an adequate number of astronomically determined positions should serve as a basis for determination of general shape of the Earth as well as curvatures of its European surface. The first order net of the III K. und k. Military triangulation in general results from the degree survey which started in 1862 and consists:

   a. of 17 base lines with extention nets as follows: [97]

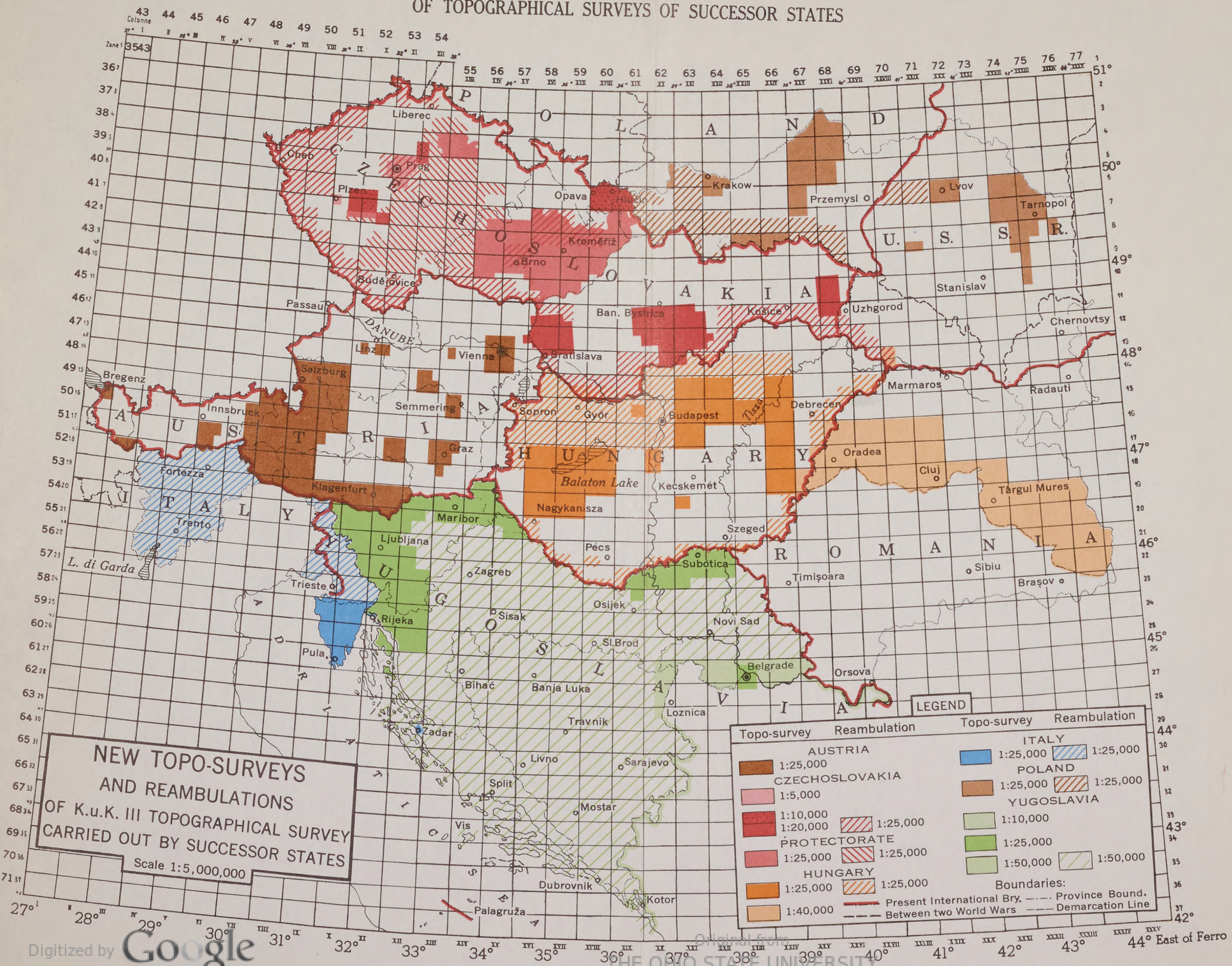
      Tarnow (1849) 5972.501 m ± 1/2,000.000

      Hall (1851) 5671.317 m ± 1/740.000

Inclosure 12

INDEX SHEET

OF TOPOGRAPHICAL SURVEYS OF SUCCESSOR STATES



Wiener Neustadt (1857)	9484.065 m ± 1/700.000	
Maribor (Kranichsfeld 1860-1875)	5697.405 m ± 1/4,200.000	
Josefov (Josefstadt 1862)	5257.266 m ± 1/850.000	
Shkoder (Scutari 1869)	3061.191 m ± 1/300.000	
Sinj (1870)	2475.474 m ± 1/1,600.000	
Linz (Kleinmünchen 1871)	3163.475 m ± 1/1,800.000	
Cheb (Eger 1873)	4188.306 m ± 1/840.000	
Rădăuti (Radautz 1874)	4621.087 m ± 1/2,000.000	
Dubica (1878-79)	2949.419 m ± 1/1,700.000	
Sarajevo (1882)	4061.409 m ± 1/1,800.000	
Budapest (1884)	4248.059 m ± 1/2,100.000	
Braşov (Kronstadt (1886)	4130.141 m ± 1/2,000.000	
Vršac (Versecz 1895)	4022.655 m ± 1/1,800.000	
Szatmar-Nemeti (1897)	3898.154 m ± 1/2,400.000	
Tarnopol (1899)	4445.212 m ± 1/1,700.000	

The base lines were measured by the Austrian base apparatus consisting of compensated stell and brass bars.

b. of 1377 triangles with 717 stations which in two closed nets cover only the northwestern part of the Monarchy and Transylvania; meanwhile the largest central part remains simply striped by chains. The average side of triangle is 30km and the maximal 125km.

The observations were carried out by the directional method in 12 positions of horizontal circle. Generally the signals were observed and only in cases where the sides were longer than 40km were the heliotropes used in the observation. In order to attach the old triangulations to the new first order net the stations, where it was possible, were established above the old centers of the II. K. und k. Military triangulation and of the Cadastral triangulation. It should be noted that such coincidences seldom succeded. The newly established stations were marked by a subsurface marker consisting of a stone plate having a zinc bolt with engraved cross at the center and by surface marker, usually about an one meter high stone or masonry monument which in the observation served as a theodolite-post. The identity with the old stations is stated in the description of stations published in the "Ergebnisse der Triangulierungen". The directions were observed by theodolite of Starke and Kammerer (diameter of horizontal plate 26 cm, magnification of telescope 40X, microscope reading 2") with an accuracy expressed by the mean error of angle m_a computed from the error of closure of 1285 triangles, published in the Volume I and II of the Ergebnisse der Triangulierungen, by formula of Ferrero:

$$m_a = \pm\sqrt{\frac{[f^2]}{3\,n}} = \pm\sqrt{\frac{3234.56}{1285.3}} = \pm\ 0.''916 \qquad [176]$$

c. In its first adjustment for the purpose of the International Geodetic Association this triangulation was adjusted by the method of least squares. In the adjustment the triangulation was not considered as a whole but it was decomposed into 59 separate nets, including 17 base extention nets. The adjustment was carried out without imposed base and polygonal conditions. The lengths of 16 measured base lines were ignored and the scale of Josefov (Josefstadt) base line carried by the attachment of net to net through triangulation. The disparity between the length of the base lines computed from Josefov base line through the triangulation and the measured base lines reached its maximum at the base line of Rădăuti (Radovec, Radautz) and amounts to:

$$0.257868\ m = 1/17{,}920$$

If the results of this adjustment published in the "Astronomisch - geodatische Arbeiten des K. und k. militar - geographischen Institutes" would be evaluated by the value of mean correction derived from the sum of the corrections in the adjustment applied to the 3276 observed directions, than the mean correction of the observed direction is expressed by:

$$v_m = \pm\sqrt{\frac{[v^2]}{n}} = \pm\sqrt{\frac{1387.97}{3276}} = \pm\ 0.''651$$

Evidently this rigorous adjustment without imposed conditions did not produce the uniform coordinates so badly needed for the topographical as well as cadastral survey of the entire Monarchy; hence a second adjustment was carried out.

2. The empirical adjustment by the method of Adolf Weixler: In this adjustment the results from the previous adjustment by the method of least squares were partially utilized and the partial nets were tied together into loops and empirically readjusted by satisfying the base and polygonal conditions which were ignored in the first adjustment. The base condition was satisfied partially in a graphical adjustment of the exit sides by changing the rigorously adjusted angles of the base extention nets; hence the adjustment would affect not only the chain connecting two exit sides, but also both extention nets. Introduction of two more conditions and the empirical recomputation changed the results of the primary adjustment and produced the positional disparities of the points up to 7 m and a change in azimuths of the sides up to 8". These differences were removed by:

- changing proportionally the length of the sides,
- changing the length of the chains in the loops,
- rotating of the entire chains or only sections,
- or by the combination of the change of length of the sides and rotation. [180]

The first order net is oriented on first order station 103 Hermannskogel determined astronomically in 1892 with:

$\phi = 48^\circ\ 16'\ 15''.29 \pm 0''.04$

$\lambda = 33^\circ\ 57'\ 41''.06$ East of Ferro geodetically derived from the new Vienna Observatory, located at a distance of 5.3 km.

$\alpha = 107^\circ\ 31'\ 41''.70 \pm 0''.18$ to Hundsheimer Berg. [93]

The first order station Hermannskogel listed by number 112 has in Vienna University system, used in the Austro-Hungarian mapping, the coordinates:

$\phi = 48^\circ\ 16'\ 16''.49$

$\lambda = 33^\circ\ 57'\ 35''.36$ [101]

The geographic coordinates resulting from this empirical adjustment were computed on Bessel ellipsoid and are published in Volumes I and II of the Ergebnisse der Triangulierungen as final coordinates of the first order net of K. und k. Military triangulation.

The Weixler's empirical adjustment evidently distorted the results of primary adjustment by the method of least squares, but on the other hand produced homogeneous coordinates for the entire Monarchy. The mean correction of the one observed direction derived from the sum of corrections applied in this adjustment to the 3276 observed directions amounts to:

$$v_m = \pm 0.''839$$

and is only 0.''188 larger than that obtained from the adjustment by the least squares method.

3. In 1901-1908, in the western part of Carinthia, in Tyrol and Vorarlberg and additional 56 first order stations were determined. This net consisting of 92 triangles was along the sides connecting the stations 146 Hohe Gehren, 148 Rettenstein, 149 Reissrachkopf, 151 Ankogel, 154 Staffberg, and 163 Golica attached to the first order net published in the "Ergebnisse der Triangulierungen". The net was adjusted in four partial nets by the method of least squares and geographic coordinates were computed, but not published. Consequently the entire first order net of the K. und k. Military Geographic Institute (III K. und k. Military Triangulation) without base nets consists of 1377 triangles and includes 773 stations.

4. Into the entire first order net there were included 14 Laplace stations and 80 astronomic stations having only latitude and azimuth determined. These astronomical data served merely as a check and were not utilized in the first and second adjustments of the net in which only geometrical conditions were satisfied.

The precise leveling of the Austro-Hungarian Monarchy.

The precise leveling in the Austro-Hungarian Monarchy was initiated by the second meeting of the Geodetic Association of Central Europe on October 7th, 1867, in Berlin. The permanent commission for the Central-European degree survey at this meeting defined the standard for the accuracy of precise leveling as:

> "probable error normally should be no larger than ± 3mm/km; and in no case should exceed ± 5mm/km". [109]

The precise leveling carried out by the K. und k. Military Geographic Institute started in 1873, with the observation of the leveling line Trieste-Ljubljana-Celje-Maribor. In 1914, prior to World War I, with some lines reobserved it was nearly completed but not finally adjusted.

1. As leveling datum there was adopted the mean sea level of the Adriatic Sea defined in 1875, from the one year observations of the automatic tidal gauge constructed in 1869 at the Custom Guardhouse on Molo Sartorio in the Harbour of Trieste. From the 1875 observations the determined elevation of the starting benchmark is:

$$+ 3.3520 \text{ meters}$$

above the mean sea level of the Adriatic Sea (0.3780 m below N.N. Amsterdam). Later observations (1875-1904) show that the sea level determined in 1875, is 8.99 cm below the correct value of the mean sea level of the Adriatic Sea. (See chapter III-1-d, pp. 28-30).

Beside the permanent tidal gauge (mareograph) in Trieste along the Adriatic coast additional permanent tidal gauges at Pula, and Dubrovnik and temporary (2 years observations) automatic tidal gauges at Rijeka, Senj, Zadar, Rogožnica, and Sestrice near Hercegnovi were established and tied to the precise leveling net.

2. The observations were carried out by Starke & Kammerer leveling instruments (8 instruments and 8 rods) with telescope having 27-33 magnification and sensitivity of the spirit level 5" (3"5 - 6"7) for 1 Paris line (2.25583 mm). [92]

The 3 meters long "selfreading" level rods, used in the observations, with H profile were made of dry fir wood with 1 cm interval graduation painted in black and red oil colours on both sides of the rod. The rods were compared with normal meter and results of comparisons included in the adjustment of the differences of elevations.

In the observations the method of observing from the center with fore and back sights and three wire reading was applied. The length of sights should be about 60 m and only in special cases longer than 80 m. The sections of about 2 km were leveled in both forward and backward directions. Generally the precise leveling was run along the railroads and roads.

3. The precise leveling net covering the entire territory of the Monarchy consists of 23,000 km of duplicate level lines and includes 16,652 permanent benchmarks. It is subdivided into 81 loops and 309 duplicate level lines. Two types of permanent benchmarks were placed along the leveling lines i.e. at intervals of 3-4 km into walls of buildings (general public buildings) or into stone monuments, if no buildings along the line exist, there were placed brass conical bolts; and at intervals of 0.5-1.5 km stone pillars with engraved cross in a rectangular on upper surface of pillar were established, or the same marks were chiseled into the upper surface of trig marks, kilometer stones, walls of bridges and culverts etc.

In geologically stable areas there were established the following seven basic benchmarks.

1	No. 374 Ruše (Maria Rast) near Maribor, Slovenia, Yugoslavia	H = 295.5957 m
2	No. 1359 Fortezza (Franzensfeste) South Tyrol, Italy	H = 736.5473 m
3	No. 2919 Lišov (Lischau) near Budějovice, Czechoslovakia	H = 565.1483 m
4	No. 6020 Žilina-Vrutky(Sillein-Rutka), Slovakia, Czechoslovakia	H = 371.0012 m

5 No. 7529 Trebušani (Trebusa), Carpathoukraine, USSR H = 367.6209 m

6 No. 9427 Turnu Rosiu (Rothenthurm) Pass, Romania H = 359.6277 m

7 No. 11257 Nadap, southwest of Budapest, Hungary H = 173.8385 m

The elevations of basic benchmarks resulted from preliminary adjustment of three partial nets carried out in 1896-1899. [92]

4. The precise leveling of the Austro-Hungarian Monarchy was connected with the precise levelings of all neighbouring countries. The mean differences of these connections are:

A-H - Germany	= + 0.38 m
A-H - Switzerland	= + 0.46 m
A-H - Italy	= - 0.03 m
A-H - Russia	= + 0.68 m
A-H - Romania	= + 0.21 m

Serbian leveling is attached to the Austro-Hungarian.

5. A preliminary adjustment of the precise leveling was made in 1896-1899, prior to the completion of observations over all the territory of Monarchy. The adjustment was carried out in three partial nets, i.e. western net, northeastern net and southeastern net which together include 69 loops with 275 duplicate level lines with a total length 18,280 km and 12,391 benchmarks covering the territory of Monarchy except the provinces Bosnia and Herzegovina, Dalmatia and district Lika-Krbava of Croatia. From the results of the adjusted partial nets the accuracy of the Austro-Hungarian precise leveling would be defined as follows: [109]

Western net: mean square error	± 4.1 mm/km (prob. error ± 2.7 mm/km)
Northeastern net: mean square error	± 5.3 mm/km (prob. error ± 3.5 mm/km)
Southeastern net: mean square error	± 5.8 mm/km (prob. error ± 3.8 mm/km)

The records of the precise leveling of the Western, Northeastern and Southeastern net are published in the vol VIII, X and XIV of "Die Astronomisch-geodätischen Arbeiten des K. u. k. Militär-geographischen Institutes" respectively.

6. After 1899, the works on precise leveling in the Austro-Hungarian Monarchy continued and up to 1914 an additional 4720 km of duplicate level lines were measured and 4261 permanent bench-marks established. These additional 12 loops of precise leveling mostly cover the provinces Dalmatia, Bosnia and Herzegovina and the western part of Croatia and consist of 34 duplicate level lines. The records of these additional loops are published in the volumes XX. XXI, XXII, XXV, XXVII, XXIX, XXXII and XXXIII of the "Mitteilungen des K. u. k. Militär-geographischen Institutes (1900-1913).

7. The precise leveling in the Austro-Hungarian Monarchy does not meet the standards of accuracy established in 1867, by the permanent commission for the Central European degree survey, i.e:

> probable error normally should be not larger than ± 3mm/km; and in no case should exceed ± 5 mm/km.

For instance the loop LXIX Reghin-Brasov-Sighisoara-Reghin in Transylvania with a length 507.3 km has an error of closure + 483.7 mm, hence the mean square accidental error per one kilometer of this loop, considered as the weakest in the entire net, would be

$$u_{F.q.} = \pm\sqrt{\frac{\phi^2}{F}} = \pm\sqrt{\frac{483.7^2}{507.3}} = \pm 21.5 \text{ mm/km}$$

consequently the probable error is:

$$u_F = \pm 0.67\, u_{F.q.} = \pm 14.4 \text{ mm/km.}$$

The mean square accidental error of the weakest loop on Yugoslav and Hungarian territory No. LXVII Celje-Hotinja vas-Nagykanisza-Zakany-Zagreb-Celje with a length 356.5 km and error of closure -230.0 mm is:

$$u_{F.q.} = \pm\sqrt{\frac{\phi^2}{F}} = \pm\sqrt{\frac{230^2}{356.5}} = \pm 12.2 \text{ mm/km;}$$

hence probable error would be

$$u_F = \pm 0.67 \times 12.2 = \pm 8.2 \text{ mm/km}$$

The mean square accidental error computed from 19 loops (7407.7 km) of the Austro-Hungarian precise leveling covering Yugoslavia is:

$$u^2_{F.q.} = + \frac{1}{n}\sum\frac{\phi^2}{F} = \pm\frac{1}{19}496.11 = \pm 26.11$$

$$u_{F.q.} = \pm\sqrt{26.11} = \pm 5.1 \text{ mm/km,}$$

consequently the probable error is:

$$u_r = \pm 0.67 \; u_{rq} = \pm 3.4 \text{ mm/km.} \quad [160]$$

Since the Austro-Hungarian precise leveling covering the territory of the western part of Yugoslavia was carried out from 1873 to 1909, and passed all stages of imrovement, the accidental mean square and probable errors computed above from 19 loops would satisfactorily express the accuracy of the precise leveling in the Austro-Hungarian Monarchy as a whole. This statement confirms also the results obtained in the adjustment of the three partial nets.

Considering the magnitude of the accidental mean square error ± 5.1/km and the lengths of level lines through which the elevations of benchmarks in various places of the former Monarchy from Trieste were determined it is evident that the preliminary adjusted elevations are determined with a mean error which accumulates up to ± 0.230 m. This error does not include the error

$$+ 0.0893 \pm 0.0099 \text{ m}$$

with which the elevation of the starting benchmark at Molo Sartorio in Trieste in respect to the mean sea level of Adriatic Sea was determined.

AUSTRIA

I. AUSTRIA

The Austrian Republic created in 1918, inherited from the territory of the Austro-Hungarian Empire the provinces Salzburg and Vorarlberg and larger parts of provinces Lower Austria, Upper Austria, Styria, Carinthia, Tyrol, and Burgenland with a surface of 83,833 km^2. These provinces mostly were covered by the oldest part of the K. und k. Military Triangulation and by the III topographical survey of which the largest part was surveyed in 1870-80, and only the provinces Tyrol and Vorarlberg in 1890 were reambulated, and the 1:75,000 map covering environs of Vienna and Linz in 1900-1902 was revised. Merely 5% of the surface of the Republic, in southwestern part of Carinthia, was covered by the IV topographical survey (1896-1914). The old Austrian Cadastral survey covering the territory of the Republic belonged to five systems and the Hungarian Cadastral survey in Burgenland had two systems i.e. together 7 various systems within the boundaries of the little Republic.

In order to solve this unfortunate situation in respect to the survey, the young Austrian Republic in January 1921, from what remained of personnal and equipment of the K. und k. Military Geographic Institute and of the Direction General of Austrian Cadaster, created two complementary agencies, i.e:

- The Federal Office of Standards and Survey (Bundesamt für Eich und Vermessungswesen) responsible for geodetic-astronomical and geophysical works, triangulation, cadastral survey, topographical survey and photogrammetrical survey with the attached Office of Standards; and

- The Cartographic Institute, former Military Geographic Institute (Kartographisches, früher Militärgeographisches Institut in Wien) responsible for cartographical and reproductional work. This agency was organized on a commercial basis.

With this reorganization all survey activities were centralized in the Federal Office of Standards and Survey which was together with the Cartographic Institute placed under authority of the Ministry of Commerce and Communications.

The general characteristics of the mapping activities and of the contemporary maps produced by the Federal Office of Standards and Survey and by the Cartographic Institute of the Republic of Austria could be summarized as follows:

1. Geodetic foundation:

   a. Ellipsoid of Bessel.

   b. Projection: Gauss-Krueger (Transverse Mercator) projection with 3^{o} zones; scale factor = 1; central meridians 28^{o}, 31^{o} and 34^{o} East of Ferro.

The meridian of Ferro was adopted as starting meridian because in the case of adoption of meridian of Greenwich four zones, with central meridians 9^{o}, 12^{o}, 15^{o} and 18^{o}, would be needed to cover the entire territory of Austria.

c. Triangulation: First order net of the III K. und k. Military triangulation (published in "Die Ergebnisse der Triangulierungen") partially reobserved and densified to which the new lower order triangulation was attached. Datum: Hermannskogel.

The first order net of the K. und k. Military triangulation covering the regions of the Republic of Austria consisted of 185 triangles (without base nets) including 82 first order stations located in the territory of the Republic and 25 stations in the boundary regions of the neighbouring states. The accuracy of observation of this net consisting of 185 triangles would be expressed by mean square error of a angle computed by formula of Ferro

$$m_a = \pm \sqrt{\frac{[f^2]}{3\,n}} = \pm 0\overset{''}{.}967$$

The error of closure larger than 3" have 12 (6.5%) triangles. The average length of the sides is 40 km, the maximal close to 80 km. [154] The base lines with the base nets pertaining to the first order net of the III Military Triangulation in Austria are:

Hall (1851)	5671.317 m ± 1/740,000.	Net	of	5	stations;
Wiener Neustadt	9484.065 m ± 1/700,000.	"	"	3	"
Linz (Kleinmünchen, 1871)	3163.475 m ± 1/1,800.000.	"	"	6	"
and on Yugoslav territory					
Maribor (Kranichsfeld 1860-75)	5697.405 m ± 1/4,200.000.	"	"	4	".

The eastern part of the net was observed in 1872-1884, meanwhile the western part consisting of 56 stations and 92 triangles extending over Tyrol and Vorarlberg west of the stations 146 Hohe Gehren, 148 Rettenstein, 149 Reissrachkopf, 151 Ankogel, 154 Staffberg and 163 Golica was observed in 1901-1908, but in the regions of Lower Austria, Northern Tyrol and particularly in Vorarlberg in the net are included also directions of the II Military triangulation observed in 1851-1854. The observations were carried out by directional method in 12 positions of horizontal circle using the Starke-Kammerer theodolits with microscopes. The directions belonging to the II Military triangulation were observed by method of repetition. The Schreiber's method in the observations of these net was not yet utilized.

The data of the eastern part of the net including geographic coordinates in 1901 were published in the Vol. I of the "Ergebnisse der Triangulierungen". The adjustment of four partial nets of the western part of the net covering Tyrol and Vorarlberg in 1915 were published in the Vol. XXIII of the Astronomic-geodetical Works (Astronomisch-geodätischen Arbeiten) of the K. und k. Military Geographic Institute. On the basis of these data the Federal Office of Standards and Survey computed, (but did not published), the geographic coordinates of the stations belonging to the western part of the net.

As in other successor states also in Austria there existed a need in the triangulation for a rapid development of the second third and lower order nets upon which the modern cadastral and topographical surveys would be based; therefore the above described first order net with all its deficiencies was adopted as a geodetic foundation upon which the new, uniform survey has to be based. Along with this adoption the following improvements were decided upon:

- All existing first order stations have to be marked with new permanent subsurface, surface and reference marks, strictly preserving the old places of the stations.

- Large triangles with sides longer than 50 km by means of inclusion of new first order stations should be decomposed into smaller triangles with maximal length of the sides 40 km.

- The large hole in the net along the Bavarian boundary in Upper Austria has to be filled by a first order net and the net tied with the Bavarian first order net.

- The entire first order net has to be gradually reobserved and the observations carried out by Schreiber's method with weight 24.

The new observations of the first order net were carried out with the greatest care and precision. The triangulation parties were equiped with Starke and Kammerer theodolites having microscopes reading 2"; after 1934, also with theodolites having microsceopes with optical micrometers (Wild III). Observed were only heliotropes or in the night reflectors.

The accuracy of observations computed from the error of closure of 65 newly observed triangles would be by formula of Ferrero expressed as follows:

$$m_a = \pm\sqrt{\frac{[f^2]}{3n}} = \pm 0\overset{''}{.}294 \qquad [154]$$

The maximal error of closure is 1"248. The reobserved and densified first order net consists of 159 first order stations of which 128 are on the territory of Austria and 31 on the territories of the neighboring countries. Since 24 old stations were dropped from the present first order net there are merely 58 stations identical with the K. und k. Military Triangulation. The measurement of 3-4 base lines is planned. To the first order net are attached exit sides of two modern base lines, i.e. Wien (1941) and Radovljica (Yugoslavia 1951). (See Inclosure 13). The second, third, forth and fifth order nets were developed from the reobserved and densified first order net. The fifth order net covers merely the southern part of the province Burgenland. Meanwhile the second, third and fourth order nets were recently extended over all territory of the Republic with an average density of one trig point per 6.5 km^2.

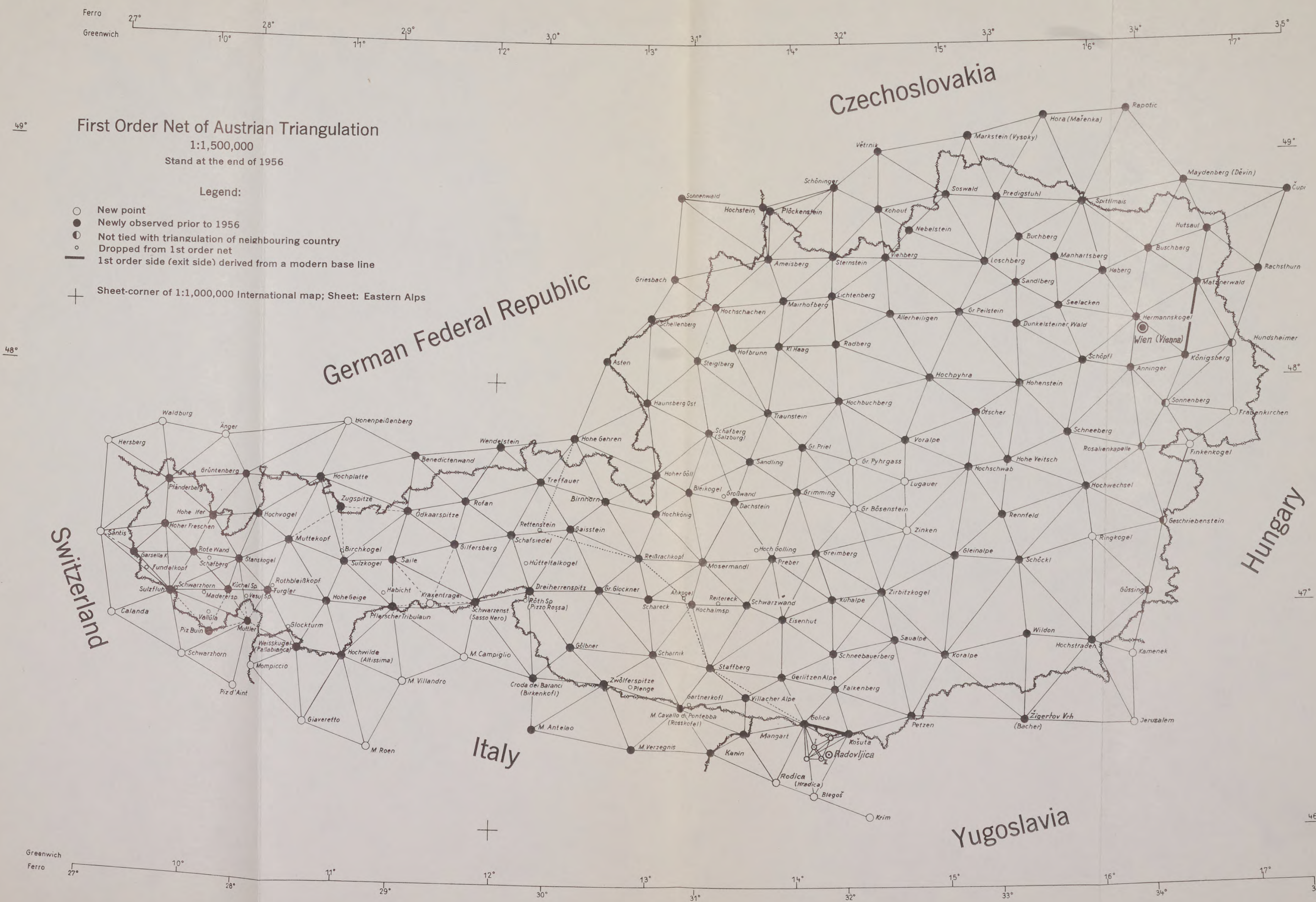
From the accuracy test of a larger part of the triangulation covering Lower Austria the following results expressing the accuracy of the individual nets were obtained:

Net	mean sq. error of direction after adjustment	mean positional error of trig point
2nd order	± 1"04	± 5.1 cm
3rd order	± 1.22	± 3.2 cm
4th order	± 1.44	± 3.1 cm
5th order	± 1.80	± 1.3 cm

In Upper Austria and Carinthia similar results to above mentioned in the accuracy test of the triangulation were obtained. [154]

d. <u>Elevations:</u> The elevations determined by means of trigonometric leveling are based on the precise leveling referring to the vertical datum Trieste, Molo Sartorio (determination 1875). The precise leveling net of former K. und k. Military Geographic Institute within the present boundaries of the Austrian Republic was carried out in the periods 1874-1880, 1882-1884, and 1892-1895, and consists of duplicate level lines established along the railroads including 763 1st order benchmarks. After 1921 this net was densified with new leveling lines established mostly along the roads and at present time consists of 6000 km duplicate level lines with 9700 benchmarks. The benchmarks are established at every 0.5-1 kilometer of leveling lines and, where possible, placed in the walls of public buildings such as churches, schools etc. In the observation the Zeiss III leveling instruments were used. The accuracy of the new leveling lines would be expressed by mean square error = ± 0.5 mm/km in respect to the accuracy of the old K. und k. leveling lines = ± 2.8 mm/km. To the leveling lines of high precision and precise leveling lines there were attached leveling lines of technical leveling. The precise and technical leveling nets are not yet completed. In 1956 there were established 660 km of precise leveling lines and 760 km technical leveling lines. In the determination of the elevations of trig points by means of trigonometrical leveling attached to the precise leveling there were

Inclosure 13



used only the shortest fourth and fifth order sides for which the zenith distances were observed.

2. Topographical survey:

The topographical survey is executed on plane table sheets of $3'45''_{\varphi} \times 7'30''_{\lambda}$. The cadastral planimetry is pantographically reduced into plane table sheets. Terrestrial stereophotogrammetrical survey based on triangulation and utilized in the compilation by stereoautograph provides the plane table sheets with 75 - 90% of relief expressed by contours. The contour interval changes gradually with the increasing steepness. Rolling areas and hilly land with slopes up to 10^{o} are expressed by contours with an interval of 5 m; middle mountains and slopes up to 20^{o} are shown by contours with 10 m interval; in high mountains a 20 m contour interval is used for slopes up to 65^{o}, steeper terrain is expressed only by 100 m contours. Contours are drawn also in gray shadowed cliffs. The plane table sheets compiled in this manner are then revised and supplemented in the field by topographers. In this revision the accuracy of contours is checked by measuring the elevations of 75 - 100 points to each 1 km^2. Since 1955 the terrestrial photogrammetry has been replaced by aerial photogrammetry. In the compilation from aerial photography 1:10.000 scale is used and the compiled sheets are photographically reduced to 1:25.000 scale and then field-revised by topographers.

Topographical survey is executed by the section "Landesaufhname" of the Federal Office of Standards and Survey. There are 6 parties equipped with Zeiss phototheodolites and 28 topographical parties. The stereocompilation is carried out with Zeiss-Orel Autographs Model 1911 and 1914. Aerial photography was used only in the map revision, for which purpose one plate photography was utilized and photographs rectified with Hugershoff's Semiautomatical Rectifier. In the aerial photography the Zeiss RMK 18 x 18 cm camera, f = 21 cm was used. Tests with aerial stereophotogrammetry have been carried out since 1935, but in larger scale aerial stereophotogrammetry was not applied until 1956 in which year for the first time a large area of 3187 km^2 was covered by aerial survey. The yearly capacity of 6 phototheodolite parties is about 1550 km^2. At the present time the new 1:25,000 topographical survey covers more than 40,000 km^2 (or about 48%) of the territory of Austrian Republic.

3. Maps:

a. The Austrian 1:25.000 map: Two plane table sheets are joined into one $7\frac{1}{2}'_{\varphi} \times 7\frac{1}{2}'_{\lambda}$ sheet of the Austrian 1:25,000 map constructed in Gauss-Krüger projection and reproduced in 6 colours (with glacial regions 7 colours). The map represents the original topographical survey, having the same standards in the expression of the relief as applied in the survey. The positions of exact identifiable points are plotted with an accuracy of ± 0.1 - 0.2 mm. The elevations are determined with an accuracy of ± 1 m. The map completely meets all technical requirements and could serve as a base for all general technical projects for which map should be used. The entire territory of the republic will be covered by 743 sheets. Till 1956 there were published 183 sheets covering 21,800 km^2 or 26% of Austrian territory and 1700 km^2 of the surface the neighboring countries. In 1956 there were published 36 sheets and 123 sheets are in work. (See Inclosure 12).

b. The Austrian 1:50.000 map: The 15' x 15' sheets of 1:50.000 are composed from 4 1:25.000 sheets and reproduced in seven colours (with glaciers in 9 colours). The contents of the 1:25,000 map included in the 1:50,000 map are somewhat generalized. The expression of the relief by contours is intensified by shading in two tones at vertical light. The sheets are numbered 1 - 213. Up to 1957 there had been published 58 sheets and 44 are in work.

c. The provisional Austrian 1:50.000 map: The regions not yet covered by the 1:50,000 map compiled from new survey still are represented on the provisional Austrian map which is actually a photographically enlarged copy of the old 1:75,000 special map with corrections and supplements included. [155]

d. Supplementing and revision of Austrian maps: The supplementing of Austrian topographical maps at 1:25,000 and 1:50,000 scale is carried out in evidence section of the Cartographic Institute. in order to bring the maps up to date there are used cadastral maps, aerial photography and other records from official and private sources. The map revision in the field is projected to be carried out in a period of 8-15 years after the completion of survey or last field revision. The map revision is the responsibility of the planning chamber of Federal Government (Plankammer) closely collaborating with the Cartographic Institute in the building of which it is also located. The revision in the field perform the officers topographers of the Army Survey Office (Heeresmess-stelle) which attended a two years topographical course. [111]

4. Austrian Private Cartography

The illegibility of the black 1:75,000 special map and very slow production of the new Austrian 1:50,000 topographical map encouraged private cartographical circles, particularly the Cartographic Enterprise Freytag and Berndt of Vienna to publish large and medium scale tourist maps. Among them the most outstanding is the 1:100,000 Tourist map of Austria, consisting of 44 sheets. The sheets are inconsistent and overlapping rectangulars with 5' graticule ticks plotted along the sheet lines. The cartographic material used in compilation are the sheets of 1:75,000 special map. Precisely speaking the sheets of this tourist map are redrafted sheets of 1:75,000 map supplemented with such tourist information as by colours marked tourist paths and trails and by red colour encircled tourist hotels and shelters. The sheets covering certain environs are composed of parts of 1:75,000 sheets and reproduced in five basic colours, i.e: cultural features, nomenclature and marginal information in black; hydrography with respective names in blue; woods in green; relief by combination of 100 m brown contours and gray shading. The tourist markings are added in the same colour as used in the field, i.e: red, violet, dark green and yellow. The map is very legible and with plastically expressed relief represents an excellent tourist map which military units could used as a good marching map.

In the same manner are published some sheets at 1:25,000 scale, i.e: Dachstein, Wienerwald and Goldberg und Ankogelgruppe, as well as the sheets Raxalpe, Semmering and Liesing-Voslau at 1:50,000 scale.

The Cartographic Enterprise Freytag-Berndt also published numerous synoptical maps representing various parts of the World at various scales.

The German and Austrian Alpine Unions (Deutscher und Oesterreichscher Alpenvereins) in collaboration published 29 sheets of 1:25,000 tourist map and 8 sheets of 1:50,000 tourist map. The sheets are inconsistent rectangulars covering various areas and at times overlap. The cartographic material used in the compilation were 1:25,000 plane table sheets of the Austrian, Bavarian and Italian topographical surveys. Some sheets are supplemented by the terrestrial photogrammetric survey. The reproduction in colours is not uniform and was carried out by the Cartographic Enterprise Freytag and Berndt of Vienna.

The 1:25,000 map of Stubaier Alps (Karte der Stubaier Alpen) consisting of two sheets covering about 1000 km² and published in 1937-39, represents a masterpiece of topography. The larger part of the map covers Austrian territory and was compiled from the terrestrial photogrammetric survey, meanwhile the part of Italian territory is compiled from the, 1:25,000 plane table sheets of the IV K. und k. topographical survey revised by Italians. The survey and compilation were carried out under the direction of Prof. Dr. Richard Finsterwalder with collaboration of Professors Dr. L. Fritz and Dr. O. Lacmann as well as H. Biersack, Ing. F. Ebster, Dr. O. v. Czikos and Dr. H. Sohm. The map was reproduced by Freytag and Berndt in 5 colours, i.e. sheet lines, cultural features, nomenclature, cliffs, deposits in black colour, hydrography in dark blue with light blue fill, contours in brown (in cliffs and deposits in black), glaciers in light blue shading with dark blue contours, forests with black circles and gray tint. The expression of the relief, including cliffs and glaciers by combination of brown, black and blue contours and gray and blue shading produce excellent legibility and an artistic appearence.

CZECHOSLOVAKIA

II. CZECHOSLOVAKIA

The Czechoslovakian Republic was created after the disintegration of the Austro-Hungarian Monarchy in 1918. The first Czechoslovakian Republic (1918-39) was composed of former Austrian provinces Bohemia, Moravia, Silesia and of the northern part of Hungary settled by Slovaks and Ruthemians (Slovakia and Carpatho-Ukraine) with a total surface 140.489 km^2; reduced by Nazis to Protectorate Bohemia and Moravia (1939-45) with a surface of 49,400 km^2; after World War II it emerged as the second Czechoslovakian Republic without Carpatho-Ukraine (12,613 km ceded to U.S.S.R) with a surface of 127,827 km^2. Consequently in discussing the mapping of Czechoslovakia a differentiation should be made in respect to the new survey activities of three separate epochs, i.e. the First Czechoslovakian Republic, the Protectorate and the Second Czechoslovakian Republic.

IIa. <u>The survey activities in the First Czechoslovakian Republic.</u>

The responsibility for the survey activities in the First Republic was divided among the following agencies:

The Triangulation Office of the Ministry of Finance (Triangulačni Kancelař ministerstva financi);

the Offices of Cadaster (Katastralni měřické uřady);

the Leveling Office of the Ministry of Public Works (Nivelačni uřad ministerstva veřejnych praci); and

the Military Geographic Institute (Vojenský zemepisný ústav), responsible for all survey activities concerning the military mapping of the country. Since all these agencies carried out various types of the survey according to the uniform instructions there was some overlapping in the works but all records could be utilized for the military purposes.

1. <u>Geodetic foundation:</u>

a. <u>Ellipsoid of Bessel.</u>

b. <u>Projection:</u> Křovák's oblique conformal conical projection of ČSR.

Starting meridian Ferro. Relation Greenwich-Ferro:

Ferro = 17°39'46".02 West of Greenwich. [87]

Meanwhile Č.S. Military Geographic Institute used the relation:

Ferro = 17°39'45".90 West of Greenwich. [10]

In order to solve the complex problem of constructing a projection adequate and uniform for the oblong territory of the Czechoslovakian Republic which lies obliquely with respect to the graticule Eng. Josef Křovák proposed the oblique conformal conical projection which must satisfy the following conditions:

- should be uniform and the most adaptable to the shape and surface of the ČSR considered as a part of the surface of Bessel ellipsoid;

- should be conformal and satisfy the requirements of all surveying agencies;

- deformation of angles in the triangles with the length of sides up to 5 km should be within limits of 1";

- linear deformation should be no larger than 1/10,000.

The solution of these imposed conditions was carried out in the following three steps:

(1) The spheroidal geographic coordinates in terms of Bessel ellipsoid are transformed to spherical geographic coordinates referring to Gaussian sphere having radius

$$r = \sqrt{MN} = 6,380\ 703.61 \text{ m}$$

with $49^{\circ}30'$ central parallel and basic meridian $42^{\circ}30'$ East of Ferro ($24^{\circ}50'13''.98$ East of Greenwich).

(2) The spherical geographic coordinates are transformed to spherical cartographic coordinates referring to Gaussian sphere having reduced radius by 0.9999, i.e.

$$r' = 6,380,065.54$$

and an arbitrary north pole P at the intersection of $42^{\circ}30'$ meridian East of Ferro with the $59^{\circ}42'42''.6969$ parallel. (Southwest of Helsinki in Finland). Consequently in respect to the arbitrary pole originate the cartographic meridians and parallels.

(3) The spherical cartographic coordinates are transformed into rectangular plane coordinates of the uniform cadastral system. For this purpose the reduced Gaussian sphere is projected on the surface of an oblique cone touching the sphere around the central cartographic parallel, having cartographic latitude $78^{\circ}30'$, with the vertex P' in the extended axis connecting center of the sphere C and the arbitrary pole P which with the rotation axis of the Earth closes the angle:

$$30^{\circ}17'17''.3031$$

The $78^\circ30'$ central cartographic parallel, the $48^\circ15$ spheroidal parallel and the basic meridian $42^\circ30'$ East of Ferro intersect in the point A having spheroidal geographic coordinates:

$$\phi = 48^\circ15'$$

$$\lambda = 42^\circ30' \text{ East of Ferro}$$

The pole of the cone P' located at the projection of the central meridian for:

$$r' \cdot \text{cotg } 78^\circ30' = 1,298\ 039.0046 \text{ m}$$

north of the point A is at the same time the origin of the rectangular plane coordinate-system constructed on the unfolded conical plane. The projection of the $42^\circ30$ meridian is considered X axis positive toward the south and perpendicular to the $42^\circ30$ meridian at P' as Y axis positive to the west, hence the entire territory of Czechoslovakia lies in the same quadrant of the projection and all X and Y values are positive.

In this conformal projection the meridians are expressed as straight lines, the cartographic parallels as concentric circles with the center P' and the geographic (spheroidal) meridians and parallels as curves of second degree. The curvature of the geographic meridians and parallels is so small that in the construction of 1:20,000 and 1:50,000 map sheets it could be ignored and meridians and parallels plotted as straight lines.

The magnitudes of the angular and linear distortion have no military significance. With the reduction of Gaussian sphere by ratio:

$$\frac{r'}{r} = 0.9999$$

the linear distortion on the surface covering the territory of Czechoslovalia remains within limits $\pm$ 1/10,000, i. e. along the cartographic parallels:

$$77^\circ15' = +\ 1/10,000$$

$$77^\circ45' = \pm\ 0$$

$$78^\circ30' = -\ 1/10,000$$

$$79^\circ15' = \pm\ 0$$

$$79^\circ45' = +\ 1/10,000$$

By introduction of the reduced Gaussian sphere in the distribution of the distortion an effect similar to that of secant Lambert projection was obtained.

The directions are distorted within the limits of ± 1".74.

The trigonometrical computations in Czechoslovakia were carried out in the plane of Křovák's oblique conical projection and the coordinates published as well as the grid on the Czechoslovakian maps are in terms of the uniform coordinate-system of the Křovák's projection, sometimes also called Czechoslovakian projection.

The transformation formulae are published in the Instructions for the Cadastral Survey (Návod jak vykonaváti katastrálni měřické práce) pp. 177-204. In order to facilitate the complicated computation in this projectioning which requires a transformation in three steps Křovák computed many tables. [124]

Since Křovák's oblique conformal conical projection officially was adopted in 1932, the Č.S. Military Geographic Institute in the triangulation and mapping prior to 1932 applied the conformal conical projection. In this projection the spheroidal surface is projected upon the surface of a secant cone along the 48°30' and 50°15' parallels. The system of rectangular plane coordinates constructed in the unfolded conical plane has its origin at the center of the southern sheet line of the 1:75,000 sheet 4260 Vsetin:

$$\phi = 49°15'$$

$$\lambda = 35°45' \text{ East of Ferro.}$$

In order to obtain positive coordinates within the entire area of the Republic a false origin, shifted 1000 km to the West and 500 km to the south, was introduced. The sheet lines and the grid of the Czechoslovakian maps up to 1932 are in terms of the conformal conical projection with two standard parallels. [16]

c. Triangulation: The Basic Cadastral Trigonometric Net.

(1) The first order net of the III K. und k. Military triangulation did not cover the entire territory of the Czechoslovakian Republic created in 1918; there are two large areas i.e. central part of the province Moravia and eastern half of Slovakia which were not covered by the first order net published in the Ergebnisse der Triangulierungen. The parts of the first order net of the K. und k. MT extending over the territory of the Č.S.R. consisted of 196 triangles (without base nets) including 121 first order stations of which 17 are located in the boundary regions of the neighbouring states. The average length of sides is 40 km, the maximal 92 km.

The base lines with base nets of the K. und k. III Military triangulation within the boundaries of Czechslovakia are:

Josefov (net of 6 stations).
Cheb (net of 4 stations)
Szatmar-Németi (Satu Mare, net of 4 stations). See page 85.

(2) These parts of the first order net of the K. und k. III MT were tied together with the new Cadastral triangulation observed 1920-26, which consists of 352 triangles and includes 204 first order stations. This new first order net of uniform cadastral triangulation covers the provinces Moravia, Silesia with district Hluchin and Slovakia, where also the K. und k. first order stations were reobserved. The average length of sides is 23 km. The observations were carried out 1920-24 by Schreiber's method with weight 24, after 1924 by Kolomaznik's method of angle measurements in all combinations with an average weight 36. In the observation the theodolites of Fennel, Breithaupt and Frič were used. After 1935, in the observation of 1st and 2nd order nets Wild theodolites were used. The accuracy of observations expressed by formula of Ferrero is:

$$m_a = \pm\sqrt{\frac{[f^2]}{3n}} = \pm\, 0''934$$

By means of the new cadastral first order net observed 1920-25, and covering the central part of the Republic there were joined together the part of the III K. und k. Military triangulation covering Bohemia (42 first order stations) with the part extending over the Carpatho-Ukraine (22 first order stations). This composite net consisting of 397 triangles with 1266 directions and including 237 stations was adjusted by the method of least squares as a homogeneous net in the oblique conical plane where 162 side and 559 normal equations were solved. The mean square error of a direction after adjustment is:

$$\mu = \pm\sqrt{\frac{[v^2]}{k}} = \pm\, 0''8105$$

where k = 559.

The scale, orientation, and position of the new net was derived from the net of 42 MT 1st order stations in Bohemia which for this purpose was recomputed in the oblique conical plane with the side Chmelová-Velky Choč projected on the cone and used in the computations as the starting side. Since in the station adjustment at the MT stations identical with the cadastral stations the newly-computed

MT directions were adjusted together with cadastral observed directions a uniform net oriented at Hermannskogel datum was established.

The recomputed coordinates of former MT stations would differ somewhat from their primary values; the difference is within the limits:

Westernmost station Kornberg $y = + 3.11$ m; $x = - 3.31$ m
Easternmost station Ineul $y = + 11.67$ m: $x = - 10.18$ m.

In 1926, the observations of the first order net covering Southwestern Slovakia were completed. This net consists of 59 triangles, 180 directions, and 31 newly-determined stations. The observations were carried out by an accuracy expressed by formula of Ferrero:

$$a_m = \pm \sqrt{\frac{[f^2]}{3n}} = \pm 0\overset{''}{.}608$$

The net was adjusted in 1927, by method of least squares solving 87 normal equations (59 triangle and 28 side equations) and along the sides connecting 11 stations attached to the main net. In this adjustment the coordinates, sides and azimuths for the 11 stations of junction obtained in the adjustment of the main net were held fixed. The mean square error of a direction after adjustment is:

$$\mu = \pm \sqrt{\frac{[v^2]}{k}} = \pm 0\overset{''}{.}8785$$

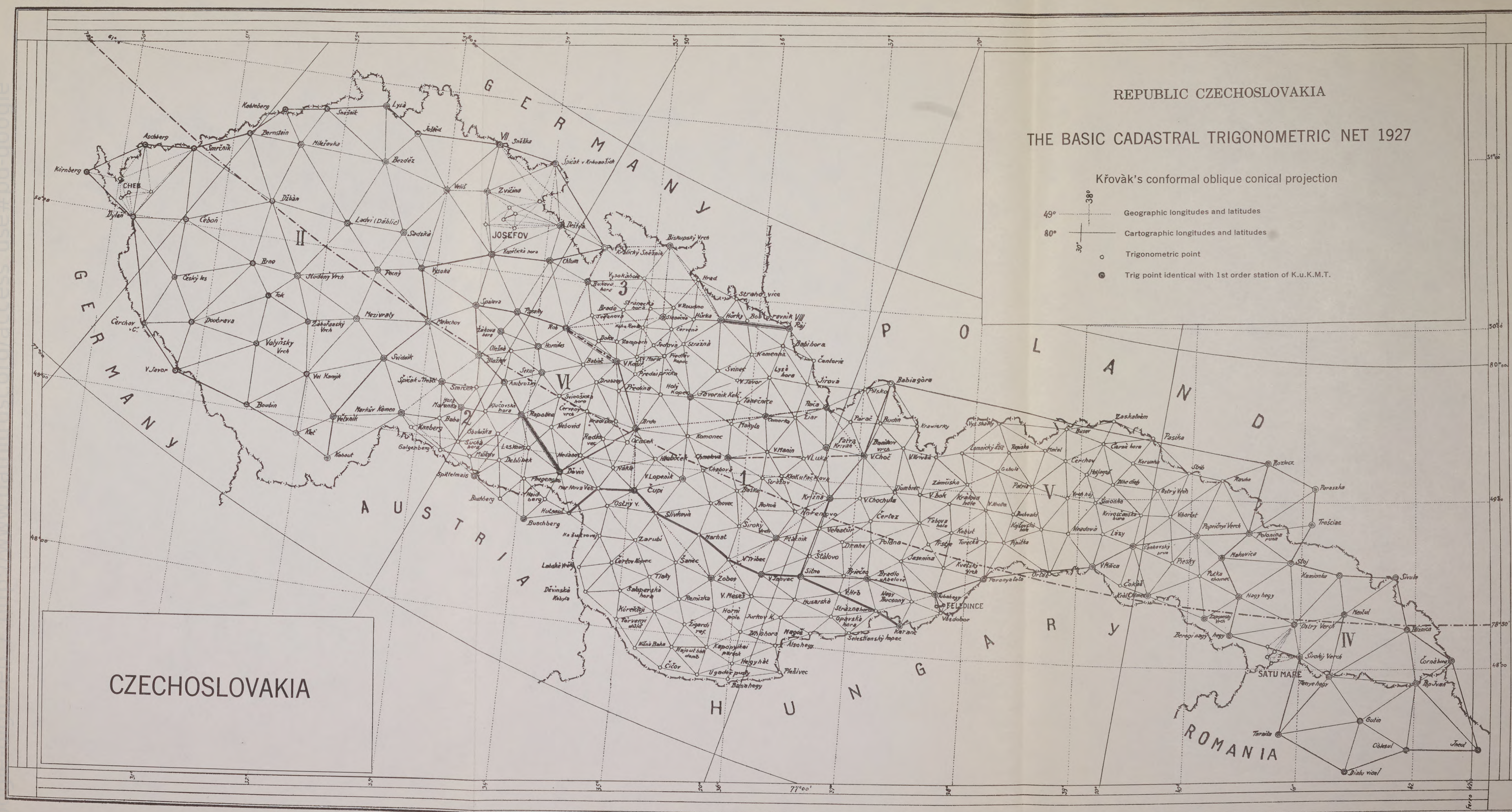
where $k = 87$.

Consequently the entire basic cadastral trigonometric net consists of 456 triangles with 1446 directions and includes 268 first order stations of which 107 are identical with the first order stations of the III K. und k. Military triangulation.[87] (See Inclosure 14).

In 1936, the base line at Feledince was measured and by means of an extension net consisting of 3 points connected with the first order net. The difference in the length of the exit side Võsdobor-Tubahegy computed from the measured base line in respect to the length of the same side which results from the adjusted first order net is 1/208,000. [88]

The basic cadastral trigonometric net was considered a provisional first order net established in order to provide a uniform geodetic foundation for the cadastral and military mapping.

Inclosure 14



(The territory of Č.S.R. was covered by the old cadastral triangulations with origins Gusterberg, Vienna St. Stephen Tower, Gellerthegy and Pschow, and K. und k. Military triangulations with coordinates referring to Vienna University, St. Anna and Hermannskogel datums.) In order to obtain a uniform density of the first order stations in Bohemia and Carpatho-Ukraine (MT net with large triangles) the basic cadastral triangulation up to 1939 was densified by an additional 100 first order stations. Meanwhile in 1931, a modern first order net, with measurement of new base lines was projected, for which orientation extensive astro-geodetic and gravimetric works started in 1936, with the measurement of the Feledince base line. (This first order net project was completed in 1956, and meets all contemporary scientific requirements.)

The basic cadastral trigonometric net was connected with the first order nets of Austria, Germany, Poland and Romania.

(3) From the basic cadastral trigonometric net there were developed 2nd, 3rd, 4th and 5th order nets of the Uniform Cadastral Triangulation. The observations were carried out by the directional method in 9, 6, 3 and 2 positions respectively. The average length of the sides are:

2nd order net	12 km
3rd order net	7 km
4th order net	4 km
5th order (detail) net	2 km.

The accuracy of the 2nd - 5th order nets would be expressed as follows:

Net	mean sq. error of direction after adjustment	mean positional error of trig point
2nd order	± 0.″8	± 5 cm
3rd order	± 1.0	± 3 cm
4th order	± 1.4	± 1 cm.

The density of the Uniform Cadastral Triangulation is 1 trig point to 3-4 km^2; in the regions were cadastral detail survey was carried out to 1-3 trig points per 1 km^2. [illegible]

Up to 1939, the following percentages of the projected Uniform Cadastral Triangulation had been completed:

2nd order net	60%
3rd order net	35%
4th order net	20%
5th order net	19%

The coordinates of trig points of the old cadastral triangulations (See Inclosure 1) and the coordinates of the K. und k. Military Triangulation were transformed (where it was possible) into rectangular plane coordinates of the uniform cadastral system (Křovák's oblique conical projection of Č.S.R).

d. Elevations: The precise leveling of Czechoslovakian Republic is based upon the following two basic benchmarks of the precise leveling of the Austro-Hungarian Monarchy:

No. 2919 Lišov (Lischau) near Budějovice H = 565.1483 m
No. 6020 Strečno (Žilina-Vrutky), Slovakia, H = 371.0012 m

with the elevations above the mean sea level of Adriatic Sea as defined in 1875, from the observation of the automatic tidal gauge at Molo Sartorio in the Harbour of Trieste. (See pp. 88-90). Considering the magnitude of the mean square error ± 5.1 mm/km of the Austro-Hungarian precise leveling and the lengths of leveling lines through which the elevations of the basic benchmarks Lišov and Strečno were determined the starting horizontal planes of the precise leveling of Czechoslovakia were determined with the mean errors ± 0.10 m, and ± 0.16 m respectively. The work on precise leveling in Č.S.R. begun in 1920, and in 1939, was close to completion. Altogether there were observed about 15,000 km level lines of high precision and precise leveling and 26,000 benchmarks were established at average interval of 0.4 km. The precise leveling net of the Austro-Hungarian Monarchy with 4876 km level lines covering the territory of Czechoslovakia was replaced by the new Czechoslovakian leveling nets, i.e. precise leveling net of the Ministry of Public Works covering Bohemia, Moravia and Silesia based upon Lišov and precise leveling net of the Military Geographic Institute covering Slovakia and Carpatho-Ukraine based upon Strečno.

The observations were carried out by the leveling instruments Zeiss III, Kern III and Wild III with invar rods. The maximal difference permitted between forward and backward measured duplicate level lines was 2.5 mm/km. The accuracy of observations of the leveling of high precision in the years 1927-29 would be expressed as follows:

probable accidental error $\eta = \pm 0.34$ mm/km
probable systematical error $\zeta = \pm 0.09$ mm/km
probable total error $\tau = \pm\sqrt{\eta^2 + \zeta^2} = \pm 0.35$ mm/km

The projected adjustment of the two leveling nets into a uniform leveling net based upon the benchmark Lišov prior to 1939 was not completed. The differences of the elevations at the benchmarks common to both nets vary from 23 to 82 mm. The average difference for which the elevations in Bohemia-Moravia are smaller than the elevations in Slovakia and Carpatho-Ukraine is 47.4 mm. [89]

The Leveling Office of the Ministry of Public Works was responsible for the precise leveling which was carried out by various agencies, mostly by Military Geographic Institute. The uniformity of works was guaranteed by the Instructions for the precise leveling published in 1921. To the level lines of the leveling of high precision and precise leveling (1st order and 2nd order lines of precise leveling) there were attached level lines of technical leveling.

The elevations of the trig points were determined by means of trigonometric leveling attached to the precise leveling. The accuracy of these elevations would be expressed by mean square error:

$$Eh_2 = \pm 0.05 \text{ m.}$$ [17]

2. Topographical survey.

a. In 1923, the Č.S. Military Geographic Institute initiated the topographical survey of the Republic which was carried out at 1:10,000 and 1:20,000 scale. In this survey, mostly executed by plane table method, the reduced cadastral planimetry and aerial photographs were utilized.

The plane table sheets used in survey prior to 1932 are trapezoids having graticule sheet lines with dimensions:

$$1{:}10{,}000 \text{ sheet } 1'52.5''_{\phi} \times 3'45''_{\lambda}$$

$$1{:}20{,}000 \text{ sheet } 3'45''_{\phi} \times 7'30''_{\lambda}$$

and 1 km grid of the conformal conical projection with two standard parallels. Since 1932 the plane table sheets are rectangulars cut in the uniform cadastral system (Křovák's conformal oblique conical projection) with dimensions:

$$40 \text{ cm}_N \times 50 \text{ cm}_E \text{ ;}$$

which correspond to 4 x 5 km/10,000 and 8 x 10 km/1:20,000. The 1:10,000 sheet comprises 16 sheets and 1:20,000 sheet 64 sheets of the cadastral map constructed in the same system. The sheet lines coincide with the 1 km grid plotted in the plane table sheets.

Topographical survey is based upon the uniform cadastral triangulation densified with the detail triangulation and in the large forest regions by numerical traverses carried out by Military Geographic Institute to a density of at least 1 point per 1 km^2, having coordinates and elevations. Consequently the plane table triangulation was reduced to a minimum. The cadastral planimetry was pantographically reduced into plane table sheets and along with the survey of the relief checked and completed by plane table method. In the areas with the obsolete cadastral survey aerial photography was utilized in the topographical survey.

The compilation at 1:10,000 and 1:20,000 scale was carried out by Orel-Zeiss stereoautograph and later by Zeiss stereoplanigraph. The photogrammetrically compiled manuscripts were revised in the field and supplemented by plane table survey.

The sheets including cities, large industrial regions, military reservations, and training grounds were surveyed at 1:10,000 scale, but normally the survey is carried out at 1:20,000 scale. The 1:10,000 manuscripts were reproduced in original scale and in the reduced 1:20,000 scale.

In the detail survey the method of plane table tacnymetry was applied. The topographer checked the position of the reduced cadastral planimetry and by supplementary measurements brought it up to date. The relief was expressed by contours with contour interval 10 m, 100 m index contours, and 5 m and 2.5 m auxiliary contours. (In the flat land surveyed at 1:10,000 scale there were used also 1 m and 0.5 m auxiliary contours). The contours were drawn immediately in the field. The details of the relief within the contour interval were expressed by hachures. The expression of the relief is based upon a maximum of 300 measured elevations in the survey at 1:10,000 scale and upon 15-100 measured elevations in the survey at 1:20,000 scale per 1 km^2.

The manuscripts were drawn in two colours i.e. planimetry, hydrography and vegetation in black and relief in brown colour.

At the outset of topographical survey used instruments of the former K. und k. Military Geographic Institute (plane table with tripod and telescopic alidade and altimeter with separate tripod) were gradually replaced by plane table equipment with telescopic alidade (Kippregel) of Frič.

According to the instructions for topographical survey the following standards were prescribed:

- measurements of distances at 1:10,000 scale up to 400 m and at 1:20,000 scale up to 800 m.

- maximal positional error of plotted detail points in open terrain ± 0.5 mm in covered terrain ± 1 mm.

- maximal error of elevations in the survey at:

1:10,000 scale = ± 0.50 m (in flat land ± 0.25 m).
1:20,000 scale = ± 1.00 m (in flat land ± 0.50 m). [16]

- maximal vertical error permitted in the drawing of contours

$$Eh_3 = \pm (1 + 10 \cdot \tan \alpha) \text{ meters.}$$ [17]

The average norm achieved by one topographer in 6 months in the topo-survey is:

at 1:10,000 scale 32 km^2
at 1:20,000 scale 80 km^2

Since the topographers had obtained plane table sheets already provided with dense triangulation and reduced cadastral planimetry or photogrammetric compilation, the norms achieved should be considered adequate.

The new topographical survey executed by Č.S. Military Geographic Institute covers 13.500 km^2 or 9.6% of the territory of the first Republic.

b. Reambulation of 1:25,000 manuscripts: The reambulation of the III. Topographical survey of the Austro-Hungarian Empire surveyed 1876-84 was carried out in a manner similar to that applied by the K. und k. Military Geographic Institute. (See page 43-44), with the exception that the contours of the corrected relief were drawn in the field. Along with the reambulation the correct native toponymy was collected and new classification of roads was made. The average norm achieved by one topographer in six months was 330 km^2. The reambulation carried out 1921-39 includes mostly the 1:25,000 manuscripts covering the regions along the German, Austrian and Hungarian boundaries with a surface 38,000 km^2 or 27% of the territory of the first Republic. (See Inclosure 12).

c. Revision of the 1:75,000 special map: The 1:75,000 special map was revised in 1897-1906, but the revision covered merely 17% of the territory of the Monarchy. These revised sheets of the 1:75,000 special map (2. Ausgabe) composed of reambulated 1:25,000 manuscripts and of revised 1:75,000 (37 sheets) covered 37,000 km^2 or 26.4% of the territory of the first Czechoslovakian Republic. (See Inclosure 2). In 1918 these sheets beside of those never revised were considered obsolete. Therefore the Č.S. Military Geographic Institute among its topographic activities gave the priority to the field revision of the 1:75,000 special map. This field revision was carried out in a manner similar to that of the K. und k. Military Geographic Institute. (See pp. 56-57); hence the map was not improved but merely brought up to date and provided with native toponymy. The average norm achieved by one topographer in 6 months was 1100 km^2. The revision included all sheets of the 1:75,000 special map covering the territory of the first Republic.

3. Maps:

a. Topographical map at 1:20,000 scale: This map is a reproduction of the manuscripts of the original topographical survey provided with the nomenclature, elevations and 1 km grid. The sheet corners - whole kilometers of the grid in terms of Křovák's conformal oblique conical projection are given with 0.''1 in geographic coordinates with the longitudes East of Ferro and Greenwich. The map was printed in four colours i.e. cultural features, handlettered nomenclature, vegetation except woodland, grid and marginal information in black; relief in brown; hydrography with names in blue, and woodland in green colour. Considering the manner and accuracy of compilation it would meet artillery as well as technical requirements.

b. Special map at 1:50,000 scale. The map is composed of 6 reduced plane table sheets with slightly generalized contents included into 1:50,000 sheet constructed in the Křovák's conformal oblique conical projection. The rectangular sheets 40 x 48 cm = 20 x 24 km are provided with 2 km grid. The relief is expressed by a combination of 20 m contours and shading. The sheets are printed in 5 colours, i.e. cultural features, handlettered nomenclature, grid and marginal information in black; relief with red contours and brown shading; hydrography with names in blue and woodland in green colour. The 1:50,000 sheets cover only the area covered by 1:20,000 sheets.

c. The map of Prague and environs at 1:5000 scale: The City of Prague and environs was surveyed in 1919-23 at 1:2880 scale. The survey was accomplished by Military Geographic Institute, Office of the City Public Works and Cadastral Survey. From this survey the map of "Great Prag" at 1:5000 scale consisting of 84 sheets was published. The 45.52 x 56.94 cm sheets (1200 x 1500 klafters = 2275.77 x 2844.72 meters) are rectangulars of Cassini projection. Sheet corner values are whole hundreds of Austrian klafters; therefore the sheets, which have the size of $1\frac{1}{2}$ Austrian cadastral section (800 x 1000 klafters) in the Northing and Easting, are cut in the Austrian Cadastral grid of Gusterberg origin with

$\phi = 48^\circ\ 02'\ 20.''50$
$\lambda = 31^\circ\ 48'\ 09.17$ East of Ferro;
$\alpha = 155^\circ\ 43'\ 16.4$ to Roderskogel ($-4'$ in error).

Actually in this survey the cadastral planimetry was supplemented with new features and the relief was expressed by contour lines. The contour lines with an interval of 1 meter are based on new spirit leveling which covers the Municipality of Prag. The map is printed in 3 colours: Cultural features black and gray, relief brown.

d. Czechoslovakian maps based on Austro-Hungarian survey: All other Czechoslovakian maps published by Military Geographic Institute are based upon the Third topographical survey of Austro-Hungarian Empire, and consequently burdened with its deficiencies. The blue lines of Austro-Hungarian sheets were improved by the reambulation of 1:25,000 plane table sections (27% of territory of the Republic), map revision of 1:75,000 sheets partially corrected and supplemented by the records of new survey, or map intelligence provided with native nomenclature and redrafted according to Czechoslovakian symbols. These are:

(1) 1:25,000 reambulated plane table sections of the Third topographical survey; relief expressed with 20 m contours, 100 m index and 10 m auxiliary contours in brown colour without hachuring. Until 1939 the reambulated plane table sections covered only 27% of the territory of the Republic. Altogether 182 sheets were published.

(2) 1:75,000 special map printed in 4 colours with 20 m contours, 100 m index and 10 m auxiliary contours; only 8 sheets published.

(3) 1:75,000 special map with 100 m contours and hachures and green printed woodland. The entire territory of the first Republic was covered by 189 published sheets. In the drawing of these sheets the symbols of the Austro-Hungarian special map published in 1913 plus Czech abbreviations were used. The special map sheets of both editions, black-green and in 4 colours are provided with grid of Křovák's conformal oblique conical projection superimposed in agreement with sheet corners. Because the inconsistent Austro-Hungarian sheet lines are not in sympathy with the III Military Triangulation (which is also the case with the new Uniform Cadastral Triangulation), this grid should be considered merely a reference grid. In the construction of the grid the corrections derived from the differences between the coordinates of Positions Rechnungen and those of the III Military Triangulation or Uniform Cadastral Triangulation were not applied to the sheet corners; therefore the scaled positions of the trig points did not agree with the coordinates published in the trig lists. Since the graphical compromising with the sheet lines based on different datums and erratic shifts carried out in the incorporation of cadastral planimetry into the uniform graticule system caused tensions in orientation of sheets which can not be eliminated from the plane table sections and the 1:75,000

sheets, and the relation: Austrian Cadastral Triangulation - Positions Rechnungen - III Military Triangulation in respect to the map can not be restored; therefore there is no mathematical remedy which would bring the sheet corners into sympathy with existing triangulation.

German editions of the Czechoslovakian maps at 1:25,000 and 1:75,000 scale were provided by D.G.K. (German Gauss-Krüger) grid in which construction the "comprehensible" disparities of sheet corner values were considered and somewhat better adaptation attained. Actually Germans by reason of the occupation of Austria in 1938 obtained all Austrian geodetic and mapping data, which enabled them to compute the D.G.K. coordinates of the old Austrian cadastral trig points with an accuracy of 2-4 m and then to construct the D.G.K. grid in agreement with the old cadastral trig points plotted in the Czechoslovakian 1:25,000 plane table sections and 1:75,000 sheets originated from the III Topographical survey of the Austro-Hungarian Empire. In this construction of the D.G.K. grid, Germans, insofar as possible, considered the relation: Positions Rechnungen - III Military Triangulation and according to the Planheft applied "conprehensible" corrections to the sheet corners. (They recasted the sheets to Hermannskogel datum). Meanwhile, the relation of the old Austrian Cadastral Triangulation to Positions Rechnungen remains unconsidered because graphical compromising with sheet lines and distortion of positions of cadastral points, caused by erratic shifts executed within the incorporation of cadastral survey into uniform graticule system, remains beyond mathematical consideration i.e. "incomprehensible". Hence, the D.G.K. grid based on old cadastral triangulation computed with an accuracy of ± 4 meters, but constructed in sympathy with graphically distorted positions of cadastral trig points in many cases plotted on the maps with a displacement of 100 or more meters could only locally serve its purpose; considered as a whole it evidently lacks the attributes of a fire control grid.

(4) 1:200,000 general map: The map consists of 38 sheets in construction and position identical with the sheets of the Austro-Hungarian 1:200,000 general map. The map was published in three éditions of which only the first preliminary edition was completed. The sheets of the Austro-Hungarian 1:200,000 general map constitute the basic cartographic material for the 1:200,000 general map of Czechoslovakia.

In the first edition consisting of 38 sheets the Austro-Hungarian 1:200,000 sheets were provided with the new international boundaries, native toponymy and supplementary information of Evidence section and reproduced in the same manner as the basic Austro-Hungarian sheets in four colours.

The second "final edition" consists of 26 sheets covering the areas of new topographical survey and reambulation of 1:25,000 manuscripts and boundary regions of neighbouring countries. The basic cartographic material for the sheets of second edition were preliminary sheets in which the records of the 1:20,000 topographical survey and 1:25,000 reambulation and of the newest foreign maps were included. The map was reproduced like the preliminary edition in four basic colours with the relief expressed by hachures; as the fifth colour red strips were added along the international boundaries

The third edition-"Normal International Aeronautical Chart" consists merely of 7 sheets. The sheets are redrafted 1:200,000 sheets of the preliminary and final edition with emphasis on the data important to airmen. With the publication of the seventh sheets the project was discontinued.

(5) 1:300,000 road and railroad distances map consists of 16 rectangular sheets reproduced in black colour.

(6) 1:500,000 synoptical map of Central Europe: The map was projected to consist of 20 sheets constructed in Lambert equal area projection with Greenwich as starting meridian; the sheets cut on graticule have dimensions 2° in latitude and 4° in longitude. The basic cartographic material in the compilation of this map were the revised 1:75,000 sheets. The sheets are reproduced in seven colours, i.e. graticule nomenclature, cultural features, except 1st-4th class roads in black; 1st, 2nd, 3rd and 4th class roads in red; relief expressed by combination of brown 100 m contours (50 auxiliary contours) and gray shading, hydrography with names in blue; woodland in green and international boundaries emphasized with violet strips. Until 1939 only the sheet 2B Praha of this newly compiled map, which had to replace 1:750,000 synoptical map, was published. The sheets 3B Budějovice and 3C Bratislava were in stage of compilation.

1:750,000 synoptical map: This map is revised edition of the 1:750,000 synoptical map of Central Europe constructed in Bonne projection and published by K. und k. Military Geographic Institute. The sheets are uniform guadrangles with dimensions 34.5 x 50 cm. The Č.S. Military Geographic Institute published 1920-24 a preliminary edition of this map consisting of 9 sheets (projected 13 sheets). The sheets were reproduced without relief in three colours i.e. sheet lines, cultural features, nomenclature and marginal information in black; hydrography with names in blue and international boundaries in red. In 1934, the second edition consisting of the same

9 sheets was published. This carefully revised edition includes relief expressed by hachures. The map is reproduced in five colours, i.e. graticule, cultural features without roads, printed nomenclature and marginal information in black; roads in red; hydrography with names in blue; relief in brown and international boundaries emphasized with green strips. This edition in respect to the 1:750,000 sheets published by K. und k. Military Geographic Institute shows considerable improvement.

(7) 1:1,000,000 International map: The Č.S. Military Geographic Institude had completed the sheet M-33 Praha of the International map.

IIb. The Survey executed by Protectorate's Survey Office (Landesvermessungsamt Böhmen und Mähren).

Germans in 1939, at the time of occupation of Czechoslovakia and establishment of the Protectorate, found that only 5% of the Protectorate's territory (total 49.000 km^2) was covered by the new topographical survey at 1:10,000 and 1:20,000 scale. Because the reambulated plane table sections at 1:25,000 scale (10% of territory) and the revised 1:75,000 map did not meet the military requirements the newly created Protectorate's Survey Office begun with a new topographical survey at 1:25,000 scale. At the outset of this survey it was planned that the entire territory of the Protectorate would be surveyed within 10 - 12 years.[90] (See Inclosure 12).

1. Geodetic foundation:

a. Ellipsoid of Bessel.

b. Projection: The $6'_\phi \times 10'_\lambda$ sheets at 1:25,000 scale are constructed in the Prussian system of polyhedric projection with $1^o_\phi \times 1^o_\lambda$ sheet (Gradkartenblatt) subdivided into 60 plane table sheets. Starting meridian Greenwich. In the Prussian mapping the meridian of Ferro with an arbitrary value 17° 40' West of Greenwich was used as starting meridian; therefore the sheet lines of 1:25,000 sheets cut in 10' of longitude would coincide when either Ferro or Greenwich is used as starting meridian. The geographic coordinates of sheet corners expressed in whole minutes refer to Potsdam datum. Grid: 3° GK 1 km (4 cm) grid.

d. Triangulation: Czechoslovakian Uniform Cadastral Triangulation incorporated into German final "Reichsdreiecksnetz" oriented on Potsdam datum with:

$$\phi = 52^o\ 22'\ 53''.9540$$

$\lambda = 13^\circ\ 04'\ 01''.1527$ East of Greenwich
$\alpha = 154^\circ\ 47'\ 32''.19$ to Golmberg. [153]

For the purpose of incorporation the "Reichsdreiecksnetz" was extended over the territory of the Protectorateand 36 first order stations of Czechoslovakian basic Cadastral trigonometric net were reobserved and two new base lines at Poděbradý and Kroměřiž were measured. The mean square error of direction in the adjusted net is ± 0''.23. In order to furnish a sufficient number of trig points needed in topographical survey in 1940-43, the net was densified with an additional 10,965 II-V order trig points. The incorporation into final "Reichsdreiecksnetz" together with the transformation of coordinates of all trig points into D.G.K. system had to be completed by 1 April, 1944. (On the territory of the Protectorate there existed 5083 trig points established by surveying authorities of the first Č.S. Republic, of them 101 1st order, 194 2nd order, 465 3rd order, 964 4th order and 3359 5th order).

d. Elevations: In order to bring the vertical control of Protectorate into sympathy with the vertical control of the Reich, Germans in 1939-43, measured:

1848 km I order precise leveling with accuracy	± 0.42 mm/km,	
1873 km II order precise leveling with accuracy	± 0.41 mm/km,	
1465 km Technical leveling with accuracy	± 0.48 mm/km.	[90]

As vertical datum German N.N. was used. The reduction of Czechoslovakian vertical control which refers to Molo Sartorio, Trieste (Molo Sartorio 0.378 m below N.N.) in 1944 was in work but not yet completed. In the topographical survey at 1:25,000 scale the elevations above N.N. were used.

2. Topographical survey:

a. The topographical survey in 1940-45 was executed according to instructions and standards prescribed in 1939 for the German 1:25,000 topographical map (1:25,000 Musterblatt 1939). It was carried out mostly by plane table method. Only 2370 km^2 were photogrammetrically compiled and then by plane table method revised in the field.

The average norm achieved by 1 topographer in 6 months was 85 km^2. Up to the end of 1943 there was surveyed:

topographical survey at 1:25,000 scale	13.300 km^2,	
topographical survey at 1:10,000 scale	650 "	
Deutsche Grundkarte at 1:5000 scale	272 "	
Boundary survey along Slovakian boundary	76 "	
T o t a l	14.298 km^2,	[90]

i.e. 29.1% of the Protectorate's territory or 10.2% of the Č.S.R., (See Inclosure 12).

b. At the same time (1940-43) old Austro-Hungarian plane table sheets of the III Topographical survey were reambulated. The reambulation carried out up to the end of 1943 covered 20.300 km^2 or 41.4% of the Protectorate's territory (14.5% of the territory of Č.S.R.). The average norm achieved by 1 topographer in 6 months was 340 km^2. It should be noted that this reambulation was carried out solely for the purpose of improving and bringing up to date the obsolete 1:75.000 map.

c. According to the "Planheft Grossdeutsches Reich" pg. 160 it was planned to cover by 1944-45 the rest of Protectorate's territory (12.000 km^2) by the new topographical survey at 1:25,000 scale and reambulation of old Austro-Hungarian 1:25,000 plane table sections.

3. Maps:

The plane table sheets of 6'$_\phi$ x 10'$_\lambda$ were reproduced as sheets of the German 1:25,000 topographical map. The reproduction was made photolithographically directly from the topographical manuscripts without the drawing of colour separations. The cultural features, relief with 10 m contours (5, 2.5, m auxiliary contours), drainage and woodland as well as the 1 km D.H.G. grid are reproduced in gray colour directly from manuscripts. The nomenclature and elevations with marginal information in black colour and the gray-brown shading of relief were supperimposed. Consequently by reason of this accelerated method of reproduction in monotonous gray colour the map fails to meet the requirements of contemporary mapping in respect to legibility and to the aesthetic considerations. Some symbols of trig points remained on manuscripts drawn in pencil and therefore disappeared in reproduction; meanwhile corresponding names and elevations are shown in black print.

The map was compiled from new topographical surveys executed at 1:25,000, 1:10,000 and 1:5000 scale by Protectorate's Survey Office (14.298 km^2) and from reduced 1:20,000 plane table sheets surveyed by the Czechoslovakian Military Geographic Institute (2450 km^2). Reduced and recasted Czechoslovakian sheets were also reproduced directly; hence the features are symbolized according the Czechoslovakian standards. The native Czech toponymy is completely germanized (translated or transliterated), which is also a great deficiency of the map.

In the possesion of AMS were 117 sheets of this 1:25,000 map which were reproduced as AMS M 873 (GSGS 4741) series. Some sheets along the Protectorate's boundaries were completed by using parts of the reambulated 1:25,000 sheets, or parts of enlarged 1:50,000, 1:75,000 sheets of Czechoslovakian or Polish maps.

With the exception of 117 sheets of 1:25,000 German topographical map compiled from the surveys prior to 1944, and reprinted by AMS, there has been found in the AMS files no additional topographical material of Austro-Hungarian 1:25,000 sections reambulated by Protectorate's Survey Office or plane table sheets surveyed in 1943/44.

The Protectorate's Survey Office published 1:75,000, 1:200,000, 1:500,000 and 1:750,000 maps, all of which are reproductions of Czechoslovakian maps, based on the old Austro-Hungarian III Topographical survey, partially corrected and provided with provisional boundary lines and Germanized toponymy.

IIc. The survey and mapping activities in the Second Czechoslovakian Republic.

After World War II the agencies responsible for geodetic, topographic and cartographic activities in the second Czechoslovakian Republic up to the end of 1953 were in a stage of reorganization, finally in 1953-54, they were organized following entirely the pattern established in USSR. Similar to the Soviet GUGK in ČSR the Central Administration of Geodesy and Cartography (Ustřední Správa Geodesie a Kartografie - USGK) was created. Because of the autonomous status of Slovakia the Central Administration of Geodesy and Cartography has in Bratislava an affiliated agency-the Administration of Geodesy and Cartography for Slovakia (Správa Geodesie a Kartografie - SGK na Slovensku). The USGK is subordinated to the Minister of the Communal Management (Ministr Mistniho Hospodářstvi) and the SGK for Slovakia to the Delegate of the Communal Management (Pověřenec Mistniho Hospodarstvi) for Slovakia.

The USGK is the supreme civilian agency responsible for research, planning and execution of the works in the field of geodetic astronomy, gravimetry, triangulation with base measurement, leveling, topographical survey, photogrammetry, cartography and map reproduction. In order to carry out these numerous activities it has the following subordinate agencies:

- Institute for Geodetic, Topographic and Cartographic Research in Prague (Výzkumny ústav geodetický, topografický a kartografický v Praze);

- Geodetic and Topographic Institute in Prague (Geodetický a topografický ústav v Praze);

- Cartographic and Reproduction Institute in Prague (Kartografický a reprodukcni ústav v Praze);

- Geodetic, Topographic and Reproduction Institute in Bratislava (Geodetický, topografický a kartografický ústav v Bratislavě); and

- District Geodetic and Cartographic Institutes (Oblastný ústavy geodesie a kartografie) at Prague, Plzen, Liberec, Hradec Králove, Česke Budějovice, Brno, Opava, Bratislava, Žilina and Košice.

The USGK closely collaborates with the independent Military Topographic Service (Vojenska topograficka služba), the agency responsible for the military survey and mapping. The activities of the Military Topographic Service as well as topographic maps are secret.

1. Geodetic foundation:

   a. Ellipsoid of Krasovskiy.

   b. Projection: Gauss-Krueger (Transverse Mercator) projection with 6° zones, central meridians 15° and 21°, scale factor = 1, since 1953 used in the mapping at 1:10,000, 1:25,000, 1:50,000, 1:100,000, 1:200,000 and 1:500,000 scales; with 3° zones, central meridians 12°, 15°, 18°, 21° and 24° East of Greenwich, scale factor = 1, used in the mapping at 1:5000 scale and larger.

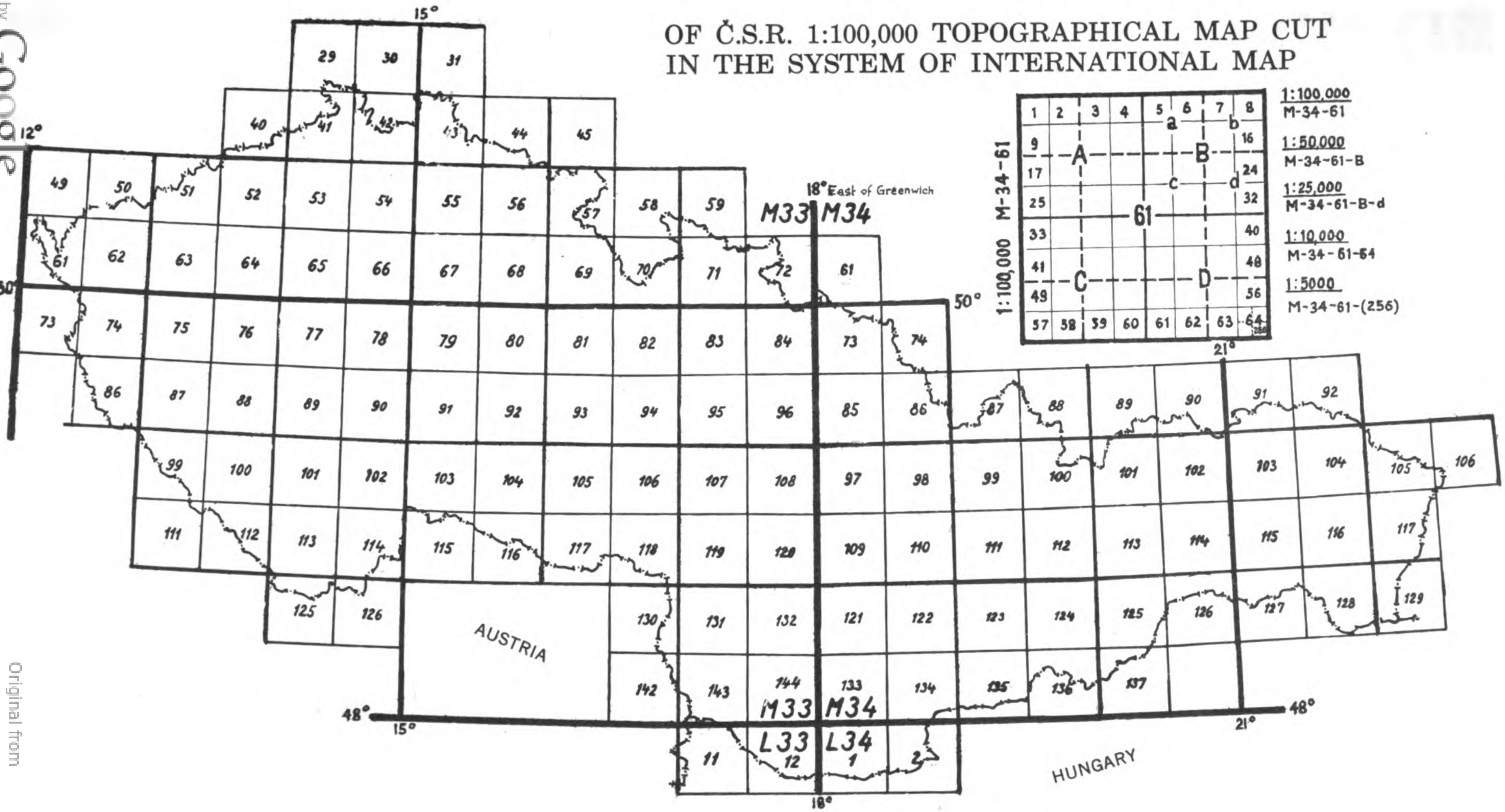
   The topographical manuscripts at 1:5000, 1:10,000 and 17 sheets of the 1:50,000 special map compiled in 1945-53 by civilian agencies have sheet lines and grid constructed in Křovák's conformal oblique conical projection with starting meridian Ferro.[42] (Relation to Greenwich used for the 1:5000 and 1:10,000 sheets = 17° 39'57"35; for 1:50,000 sheets = 17°40'). The topographic manuscripts at 1:25,000 scale surveyed in 1946-53, by the Military Topographic Service are constructed in Gauss-Krueger projection with 6° zones (DHG) as a continuation of the Protectorate's topographical survey at 1:25,000 scale.

   Along with the adoption of Gauss-Krueger projection there were also adopted the USSR sheet division and code in the system of International map. In this system the 1:1,000,000 sheet with dimension of 4° in latitude and 6° in longitude by 12 zones and 12 columns is divided into 144 sheets at 1:100,000 scale with dimensions 20' in latitude and 30' in longitude. The subdivision of the 1:100,000 sheet to 1:50,000 and larger scale sheets is quadripartite. [142] (See Inclosure 15).

Inclosure 15

INDEX SHEET

OF Č.S.R. 1:100,000 TOPOGRAPHICAL MAP CUT IN THE SYSTEM OF INTERNATIONAL MAP



The recasting of the sheets of all topographic maps of Křovák's and Potsdam systems to the sheets cut in the system of the international map is in process.

c. Triangulation: The basic trigonometric net (Zakladni trigonometricka sit - ZTS). (See Inclosure 16). The basic trigonometric net includes the first order net of the Protectorate surveyed in 1940-44, as a part of the German "Reichsdreiecknetz" and the first order net established in 1949-1955 in Slovakia. The net consists of 6 base lines with varying lengths from 4 to 12 km, base nets and 227 triangles which include 144 first order stations. The base lines are as follows:

Poděbrady (1940) with a net of 4 stations
Kroměříž (1941) with a net of 4 stations
Cheb (1947) with a net of 4 stations
České Budějovice (1948) with a net of 4 stations
Jesenske (1949) with a net of 3 stations
Michalovce (1950) with a net of 3 stations.

The measurements were carried out by Jäderin base apparatus with a relative error of 1/2,000,000 to 1/6,000,000. For the purpose of comparisons at Prague, a base line with a length of 960 m was measured.

In the observation of base extension nets small reflectors were observed with Wild T3 theodolites in the evening and during the night. The adjustment of the base nets was carried out by the method of conditional observations. The relative errors of the exit sides are about 1/1,000,000.

The observations of the basic trigonometric net were not carried out uniformly. The western part (Protectorate) was observed by Schreiber's method and the thedolites Askania, Chasselon, Hildebrand, Fennel and Wild T3 were used. Heliotropes were observed during the day and electric reflectors during the night. The eastern part was observed by method of direct observations of all angles closing the horizon of the station using Wild T3 theodolites. The observations on each station were carried out by three observers using three different Wild T3 theodolites. Each angle was observed in 48 sets, each set composed of two observations with telescope left and two observations with telescope right (16 sets by each observer and theodolite). The observations were carried out during the night and electric reflectors were observed. The accuracy of observations would be expressed by the mean error of closure of triangle ± 0.66" and very exceptional maximal error of closure ± 2." The mean square error of one observed direction computed by formula of Ferrero is:

$$m_d = \pm \sqrt{\frac{[f^2]}{6\,n}} = \pm\, 0.27'' \qquad [34]$$

The average length of the side in the net is about 35 km.

The adjustment of the net was carried out by method of Pranis-Praniévitch using the ellipsoid of Krasovskiy as the reference surface. In the adjustment of the net there were included 6 base lines projected from the surface of geoid to the surface of ellipsoid and numerous Laplace azimuths. As the national datum serves station Pecný (30 km southeast of Prague) determined astronomically, which is identical with the first order station Pecný marked with a monument in 1936. (Identical with K. und k. MT first order station No. 22 Pecný, elevation 546 m). Above the 1936 monument there was recently erected a geodetic observatory. [144]

The results of this adjustment will serve in the solution of certain scientific problems particularly in the study of the geoid in the area of Czechoslovakia as well as to improve the position of the uniform technical triangulation (up to 1952 called uniform cadastral triangulation). The basic trigonometric net is tied with the first order nets of USSR, Poland, East Germany and Hungary. The uniform technical triangulation consists of 1st, 3rd, 4th and 5th order nets. The average density of this triangulation is 1 trig point per 6 km^2. (The sides of the 5th order net 2-3 km.) The uniform technical triangulation is included into system of the USSR triangulation Pulkovo 1942. The coordinates used in the mapping of ČSR are 6^o and 3^o GK's in terms of Pulkovo 1942.

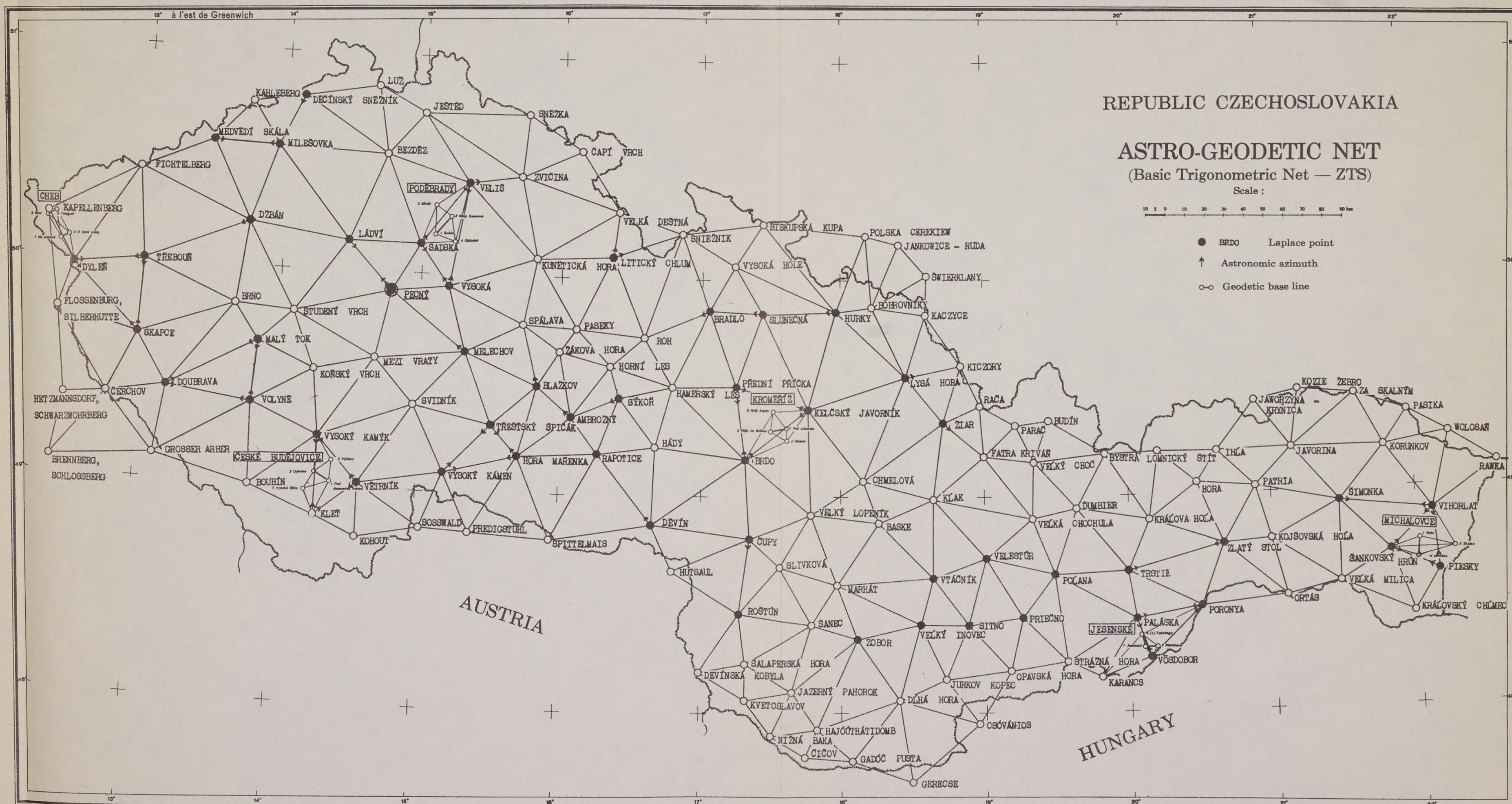
d. Elevations: In the incorporation of the precise leveling of first ČSR into the part V of the German vertical net (Reichshöhennetz) referring to N.N (Mean sea level of the North Sea determined in the Harbour of Amsterdam), at the basic benchmark Lišov the following relation between two starting levels was obtained

$$H_{A.S._{Lišov}} = H_{NN} + 248.6 \text{ mm}$$ [89]

The adjustment was carried out in 1942. In 1944, the precise leveling net of ČS Military Geographic Institute covering Slovakia was attached to the precise leveling net of Protectorate referring to N.N.

After World War II the elevations of the Protectorte's precise leveling and attached precise leveling of Slovakia (carried out by Č.S. Military Geographic Institute 1922-26) referring to N.N. were reduced by 248.6 mm. These elevations refer to the starting level of the basic benchmark Lišov as

Inclosure 16



determined in the precise leveling of the Austro-Hungarian Monarchy called Adriatic system of elevations, Lišov. (Výškový sýstem Jadranský Lišov).

Since the precise leveling nets of the Ministry of Public Works and of Č.S. Military Geographic Institute includes large internal differences (+ 40 to - 135 mm and - 140 to - 180 mm respectively) it was already in 1938 decided to establish a uniform leveling net. The occupation of ČSR by Germans did not postpone the beginning of the work because the precise leveling net of the Protectorate established in 1939-1942, is a part of the present Č.S. Uniform leveling net (Č.S Jednotna nivelačna sit - ČSJNS).

The basic (first order) leveling net of high precision consists of 27 loops with 98 duplicate level lines having a total length 5713 km and covers the entire territory of the second ČSR. (See Inclosure 17). The observations which started by Protectorate's Survey Office in 1939 were interrupted in 1941. After World War II (in 1946-1948), the basic leveling net in the boundary regions (former Sudetenland) was supplemented with new level lines. In 1949-1952, the basic leveling net in Slovakia was established.

The observations were carried out with the Zeiss III, Zeiss A and Wild III precise leveling instruments having plane-parallel glass plate (optical micrometer) and invar rods. The maximal length of the sight permitted in the observing from the center was 50 m. The maximal differences permitted in duplicate level lines are:

2mm $\sqrt{R}$ km between two consecutive benchmark, and
4mm $\sqrt{L}$ km in the long level lines.

The probable errors computed from the closures of the loops and from the adjustment of the net are:

$$u_r = \pm 0.58 \text{ mm/km}$$

$$u_{r_v} = \pm 0.59 \text{ mm/km.}$$ [34]

Using these values in the computing of the accidental, systematical and total probable errors, considering the limit of the distance Z = 50 km, the following values which express the accuracy of the basic leveling net were obtained:

probable accidental error $\eta = \pm 0.28$ mm/km

probable systematical error $\zeta = \pm 0.53$ mm/km

probable total error $\tau = \pm\sqrt{\eta^2 + \zeta^2} = \pm 0.59$ mm/km. [34]

The systematical mean square error of difference of elevation computed from the error of calibration of rods, inaccuracy caused by refraction and others is ± 0.004 mm per 1 meter of Δ h.

The adjustment of the basic (first order) leveling net was carried out by method of conditional observations and partly by method of indirect observations. The elevations were corrected by application of orthometric corrections.

The basic leveling net is attached to the starting benchmark No. 2919 Lišov near Budějovice H = 565.1483 m above the mean sea level of Adriatic Sea determined in 1875 at Molo Sartorio in the Harbour of Trieste. In order to protect the stability of the basic leveling net in geologically stable areas 21 basic benchmarks were erected.

The basic leveling net is connected with the precise leveling nets of USSR, Poland, Germany and Hungary. The mean differences of these connections are as follows:

with USSR	$H(\check{C}SJNS)_{Li\check{s}ov}$ =	$H_{Kronshtadt}$	+ 460 mm
with Poland	$H(\check{C}SJNS)_{Li\check{s}ov}$ =	H_{NN}	+ 347 mm ± 20 mm
with Germany	$H(\check{C}SJNS)_{Li\check{s}ov}$ =	$H(RHN)_{NN}$	+ 250 mm
with Hungary	$H(\check{C}SJNS)_{Li\check{s}ov}$ =	H_{Nadap}	− 252 mm ± 16 mm [89]

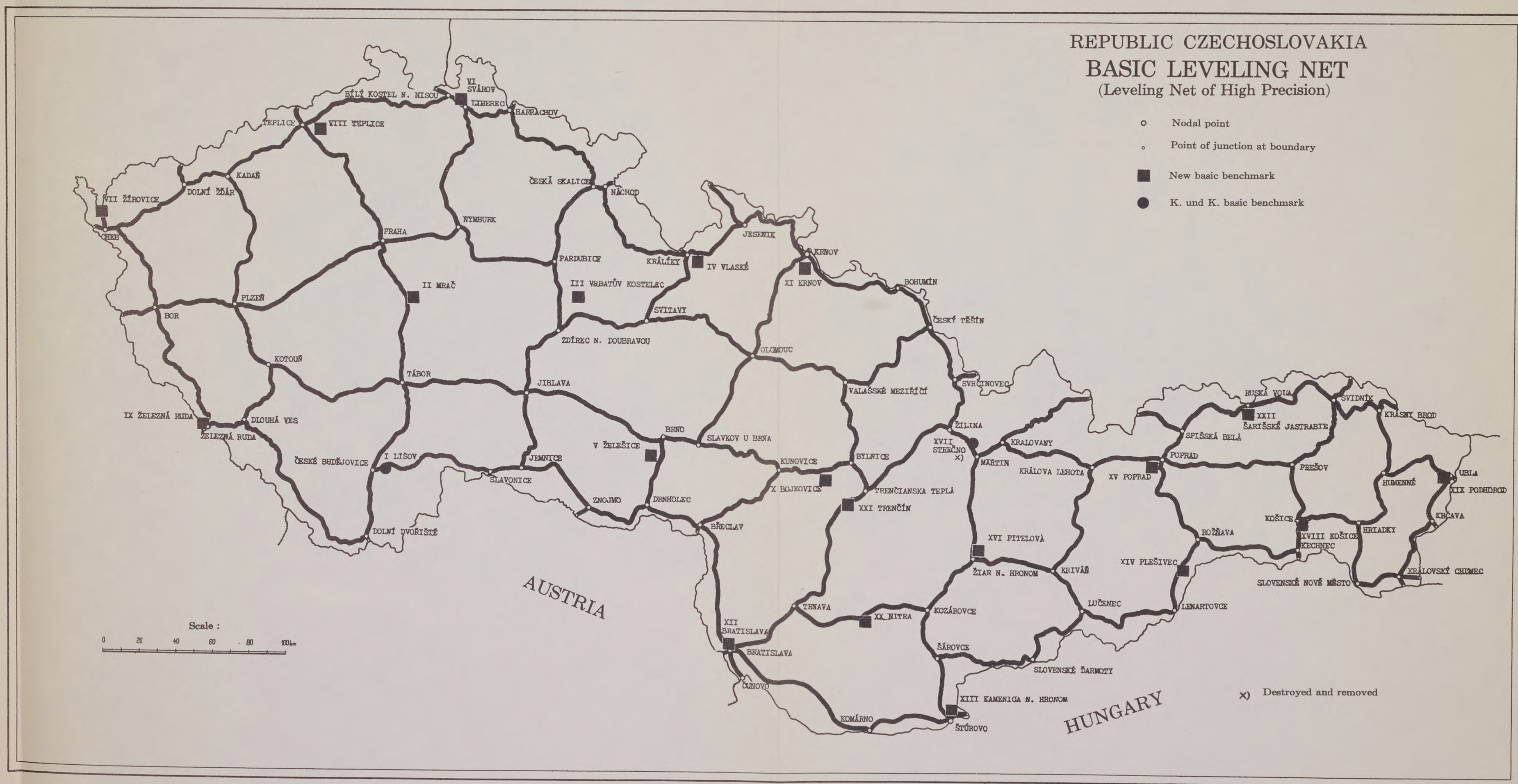
To the basic leveling net of high precision there were attached the 2nd order precise leveling net completed in 1954 and the 3rd order leveling net (technical) which is in work and should be completed in 1960. These leveling nets compose the Č.S. Uniform leveling net (Č.S. Jednotna nivelačna sit - ČSJNS) which is incorporated into the international system of eastern leveling nets referring to the mean sea level of the Baltic Sea established in 1840 in the Harbour of Kronshtadt. Only elevations referring to the mean sea level of the Baltic Sea have been used in Č.S. mapping since 1953.

Because in 1953, the basic leveling net was not yet adjusted the elevations referring to the mean sea level of Adriatic Sea for the immediate use in the survey were obtained in two ways:

- by reduction of the elevations of the leveling net of Ministry of Public Works and to it attached leveling net of Č.S. Military Geographic Institute referring to the mean Sea level of Adriatic Sea (Lišov) reduced by 680 mm; and

- by reduction of the preliminary elevations of the ČSJNS adjusted in two parts (Net of Bohemia and Moravia and to it attached net of Slovakia) referring to the mean sea level of Adriatic Sea (Lišov) reduced by 460 mm. [41]

Inclosure 17



The elevations of the identical points of these two, by various reductions of the elevations of two different nets created two baltic systems, marked B68 and B46, slightly differ between the systems, and show differences in respect to the final elevations of the Baltic system which result from the uniform adjustment of the ČSJNS incorporated into the international system of the eastern leveling nets.

The elevations of trig points determined by means of trigonometrical leveling are in sympathy with the elevations of ČSJNS.

2. Topographical Survey.

Prior to World War II the topographical survey was carried out exclusively by Č.S. Military Geographic Institute; meanwhile in the Second Republic it is carried out by civilian agencies as well as by the Military Topographical Service. The civilian agencies National Surveying and Cartographic Institute in Prague (Státni zeměměřický a kartografický ústav v Praze) with affiliated Slovakian Surveying and Cartographic Institute (Slovenský zeměměřický a kartografický ústav) in Bratislava in 1946 started with training of civilian topographers, primarily used in the topographical surveys at 1:5000 and 1:10,000 scale.

a. The survey at 1:5000 scale started in 1948: The manuscripts of this topographical survey have to serve as basic material for the new national 1:5000 map needed in the planning of national economy. (1:5000 statni mapa hospodářstvený). The method generally applied in the survey was plane table tachymetry. The plane table sheets are rectangulars 40 x 50 cm (2 x 2.5 km) with 4 cm (200 m) grid constructed in the system of Křovák's conformal oblique conical projection. The sheets were provided with plotted trig points and pantographically reduced cadastral planimetry of the new Czechoslovakian cadastral survey. Each sheet is composed of 16 cadastral sheets at 1:1000 scale (rectangular 50 x 65.5 cm with surface 0.3125 km^2) or 4 cadastral sheets at 1:2000 scale constructed in the same Křovák's projection. In the areas without new cadastral survey the topographical survey at 1:5000 scale was carried out by method of numerical tachymetry. The relief is expressed by contour lines with the intervals 1,2 and 5 m according to the steepness of relief. The aerial photogrammetry, practically speaking, in the first post World War II years had no application in the 1:5000 topographical survey. (German occupiers in 1945 left of photogrammetric equipment only one Zeiss C5 stereoplanigraph and one old stereoautograph, applicable merely in terrestrial restitution, both used, by the Military Topographic Service in the compilation of 1:25,000 map.) At the outset of the survey it was projected that the 1:5000 topographical survey with about 26,000 plane table sheets covering the territory of the second ČSR will be completed within 60 years. The 1:5000 topo-survey progressed very slowly; therefore proposals were made to the effect that the manuscripts surveyed at 1:5000 scale should be reduced to 1:10,000 scale and a 1:10,000 topographical map compiled as well as the topographical survey of the entire country should proceed at 1:10,000 scale. In this case the period of time needed to cover the entire territory of ČSR with the 1:5000 map to be used in the planning of construction of industry, communications in colonization and forestry would be reduced from 60 to 25 years. In 1953, the year of complete reorganization and centralization of the entire Czechoslovakian geodetic service the 1:5000 topographical survey did not yet cover the surface covered by the new cadastral survey (7% of the ČSR. territory).

b. The topographical survey at 1:10,000 (1:5000) scale: The newly created Central Administration of Geodesy and Cartography in 1953 in order to make Czechoslovakian maps uniform with the maps of USSR adopted ellipsoid of Krasovskiy, datum Pulkovo 1942, vertical datum mean sea level of Baltic Sea as defined by observations of the automatic tidal gauge in the Harbour of Kronshtadt (1840), Gauss-Krueger projection with the USSR sheet division and code in the system of International map, and USSR topographic symbols published in 1951. Along with this adoption it was decided to continue the topographical survey at 1:5000 scale only in the industrial and densely settled areas; all other territory has to be surveyed at 1:10,000 scale and more extensive application of photogrammetry must be made to increase the progress of the survey.

The plane table sheets are trapezoids cut on graticule constructed in Gauss-Krueger projection with dimensions and grid as follows:

- 1:5000 $1'15''_{\phi} \times 1'52.5''_{\lambda}$ (about 46 x 47 cm); 10 cm (0.5km) 3° G.K. grid; with the surface 5.4 km; 1/256 part of the 1:100,000 sheets,

- 1:10,000 $2'30''_{\phi} \times 3'.45_{\lambda}$ (about 46 x 47 cm); 5 cm (0.5km) 6° G.K. grid; with the surface 21.7 km^2; 1/64 part of the 1:100,000 sheet. (See Inclosure 15). [174]

The topographical survey is executed in the same manner as prior to 1953, with the exception of greater application of aerial photogrammetry which in 1955 already covered more than 50% of the total surface surveyed in this year. The topographical survey at 1:10,000 (1:5000) scale in 1960 should cover more than 1/3 of the territory of ČSR, i.e., about 45,000 km^2.

The photogrammetric equipment of the civilian surveying agencies and Military Topographic Service consists of:

Zeiss RMK 18 x 18 cm, f = 21 cm camera,
Wild RC-5a 18 x 18 cm, f = 21 cm camera,
Wild RC-7 14 x 14 cm, f = 17 cm plate-camera,
Zeiss C-5 stereoplanigraphs
Zeiss C-6 stereoplanigraphs
Wild A-5 autographs
Wild A-7 and A-8 autographs
Zeiss aerialprojector-multiplex
Topo-stereometers STD-2
Zeiss SEG I automatic rectifier
Zeiss SEG IV automatic rectifiers
Wild E-2 automatic rectifier. [80]

The aerial photographs for the 1:10,000 (1:5000) maps are carried out at the scale 1:13,000 (1:9000) from an altitude 2700 (1900)m. Vertical photographs with overlappings: Stereo-pairs 60% and strips 30% are used.

The methods applied in the photogrammetric survey are:

(1) Universal method (stereocompilation): Compilation is carried out by stereoplanigraphs and autographs; 2nd order instruments or multiplexes are not used. The orientation of stereo-pairs ordinarily bases upon in the field panelled triangulation and traverse stations. Aerial triangulation is applied only in areas with insufficient density of triangulation. The photogrammetrically compiled manuscripts are checked and supplemented in the field by topographers in manner of plane table survey.

(2) Combined method (one plate photogrammetry): In the flat land (14% of territory) where in the rectifying horizontal error due the relief is smaller than 0.4 mm the combined method is applied. The rectified photographs are composed into photo-maps. Accuracy of rectifying vary from ± 0.3 mm to ± 0.5 mm. From photo-maps with plotted sheet lines, grid and trig points gray lines are reproduced and mounted upon plane tables and then in the field surveyed by topographers. This survey carried out by plane table method consists of checking the photographed planimetry and of measurements of elevations (in the plain mostly used spirit leveling) used in the expression of the relief. Since the horizontal accuracy of the planimetry obtained in the aerial survey by combined method is considerablly lower than that obtained by universal method (stereo-compilation) and because a well organized aerial survey by universal method is less expensive the application of combined method is reduced more and more.

(3) Differential method applied in USSR was tested and found insufficiently accurate and less economical than universal and combined methods, hence it is not applied in the aerial survey of ČSR. [80]

c. <u>The topographical survey at 1:25,000 scale</u>: Prior to 1953, this survey was carried out by components of the Military Topographic Service; since 1953, the Central Administration of Geodesy and Cartography with its subordinate agencies also participates in the 1:25,000 topographical survey. The survey was carried out by the method of plane table tachymetry and by aerial photogrammetry. Of the topographical equipments two types, (i.e. Frič and Stodolkevich) were used.

In the period of 1945-1950, the topo-survey was continued in the manner similar to that applied in the Protectorate, evidently by use of Czechoslovakian symbols and toponymy. The sheet lines with dimensions $5'_{\phi} \times 10'_{\lambda}$ with the 1 km (4 cm) grid constructed in Gauss-Krueger projection with 3° zones were retained. In 1951 the Military Topographic Administration introduced the sheet lines used in USSR, i.e., cut in the system of International map. Consequently the 1:25,000 plane table sheets are trapezoids with dimensions $5'_{\phi} \times 7'30''_{\lambda}$ constructed in Gauss-Krueger projection with 6° zones. The plane table sheet with 1 km (4 cm) plotted grid and surface 84 km^2 (at center of ČSR $\phi = 49^{\circ}\ 30'$ covers 83.9 km^2) is 1/16 part of the 1:100,000 sheet.

In the application of the aerial photogrammetry the same principles as in the 1:10,000 (1:5000) topographical survey were followed. The photographs were made by Zeiss and Wild 18 x 18 cm, f = 21 cm cameras at scale 1:18,000 to 1:26,000 from an altitude 3800 m to 5500 m. The most adequate photographs for the compilation at 1:25,000 were photographs at 1:23,000 with flight altitude 4800 m. In the stereo-compilation carried out at 1:25,000 scale exclusively first order photogrammetric instruments, i.e. stereoplanigraphs and autographs were used. In the orientation of stereo-pairs panelled trig points were used. Aerial triangulation carried out on Wild A-5 autograph was utilized only in the large mountainous regions covered by forests. The stereocompiled manuscripts are checked and supplemented in the field by topographers using the method of plane table tachymetry. The topographical survey at 1:25,000 scale in the last years was carried out by extensive application of photogrammetry in a rapid tempo and was in 1957 completed. [80]

The accuracy of the 1:25,000 manuscripts was tested and the results of the tests made on two arbitrarily selected sheets show the following accuracy of the detail points:

positional error $E_2 = \pm\ 0.53$ mm (at 90% level = ± 0.88 mm)
vertical error $Eh_2 = \pm\ 1.08$ m.

The vertical accuracy is excellent, but the horizontal accuracy is lower than that achieved in the topo-surveys carried out between the two World Wars (± 0.46 mm).

After the completion of 1:25,000 topo-survey the topographers and photogrammetrists of the Military Geographic Service and civilian agencies are together engaged in the 1:10,000 (1:5000) topographical survey.

3. Maps:

Large and medium scale topographic maps showing the territory of ČSR are classified. The release of every copy of 1:5000 - to 1:200,000 sheets must be permitted by the administration of Military Topographic Service. The maps published after 1953 are similar to the corresponding USSR topographic maps. There are still in use the maps published by Č.S. Military Geographic Institute of the first ČSR. After World War II there were published the following maps.

a. 1:5000 National map (statni mapa hospodářstvený): The 40 x 50 cm rectangular sheets are reproductions of the manuscripts of the 1:5000 topographical survey. The sheets are reproduced in colours. Coverage about 7% of the territory of ČSR. The sheets constructed in the Křovák's conformal oblique conical projection of Bessel ellipsoid are after 1953 in process of recasting to Gauss-Krueger projection with 3^{o} zones referring to Krasovskiy ellipsoid. The trapezoidal sheets of the new edition, having dimensions $1'15"_{\phi}$ x $1'52.2"_{\lambda}$ are reproductions of the new post 1953 manuscripts or recompiled and recasted sheets of the 1948-53 manuscripts. The map represents a modern basic topographic map which meet the requirements of the engineers and technicians in the planning of communications, industrial planning, colonization and forestry. The sheets of the 1:5000 map are also excellent cartographic material for the compilation of 1:10,000 and 1:25,000 topographical maps.

b. 1:5000 National map-compiled (statni mapa-odvodzený): The sheets are rectangulars 40 x 50 cm (2 x 2.5 km) with 4 cm (200 m) grid constructed in the Křovák's conformal oblique conical projection. The planimetry is compiled from 1:1000, 1:2000 and 1:2880 cadastral maps. The elevations and contours are compiled from topographic maps at 1:10,000, 1:20,000 and 1:25,000 scale. At the time of compilation the new topographic maps covered merely 20% of the territory of ČSR and 80% manuscripts of the III topographical survey of the Austro-Hungarian Empire (1869-1887). The compilation started in 1950 and was completed in 1955. Only 200 copies of each sheet were published. About 26,000 sheets cover the territory of ČSR.

It is evident from the manner of compilation that this map was compiled in order to cover various temporary needs of civil engineers for a basic map. Since even the relief enlarged from new 1:10,000, 1:20,000 and 1:25,000 maps would not meet technical requirements prescribed for a 1:5000 map the relief taken from the old Austro-Hungarian manuscripts could serve merely the purpose of general orientation. [76]

c. Topographical map at 1:10,000 scale: The sheets are trapezoids with dimensions $2' 30"_{\phi}$ x $3'.45"_{\lambda}$ with 5 cm (0.5 km) grid constructed in Gauss-Krueger projection with 6^{o} zones. The sheets are reproductions of the manuscripts of the new 1:10,000 topographical survey or are compiled from the reduced manuscripts of 1:5000 topographical survey. The map is reproduced in colours and will in 1960 cover about one third of the territory of ČSR. This modern map meet the requirements of civil engineers in all areas except those with large settlements and industry which therefore are surveyed at 1:5000 scale and for which the sheets of 1:5000 topographical map are published.

d. Topographical map at 1:25,000 scale: At the present time this map is the basic topographical map which covers the entire territory of ČSR. The map is compiled from the 1:10,000 and 1:20,000 topographical maps of the first ČSR and from the 1:25,000 topographical map based upon the topographical survey carried out by Protectorate's Survey Office which together cover 20% of the territory of present ČSR. The other 80% of territory are covered by topographical survey at 1:25,000 scale carried out after World War II by the Military Topographic Service in collaboration with civilian agencies. In the areas of this new survey the sheets of the 1:25,000 topographical map consist of the redrafted and reproduced 1:25,000 topographical manuscripts. The sheets are trapezoids with dimensions $5'_{\phi} \times 7'\ 30''_{\lambda}$ with 4 cm (1 km) grid constructed in Gauss-Krueger projection with 6^{o} zones. The map is reproduced in colours, the symbols are similar to those used in the USSR maps; the relief is expressed by contours with 10 m contour interval (5 m in plain and hilly land). The 1:25,000 topographical map is the Czechoslovakian tactical map of the largest scale. It represents the basic cartographic material for the compilation of the 1:50,000 topographical map and smaller scale maps.

Nothing has been published concerning the accuracy of this classified map and none of the sheets is available. Considering the manner of survey it should meet the requirements of contemporary 1:25,000 maps.

The topographical survey for this map, carried out after World War II and covering about 105,000 km^2 was by extensive application of photogrammetry completed in 12 years. In recent years it represented 72% of all Czechoslovakian survey-activities. In the last three years the areas surveyed photogrammetrically were larger than those surveyed by the classical method of plane table tachymetry.

e. Topographical map at 1:50,000 scale: In the period 1946-1950, the compilation of this map was continued in the manner applied prior to World War II. From the cartographic material of the Protectorate's 1:25,000 topographical survey there were compiled by civilian agencies 17 sheets constructed in the Křovák's conformal oblique conical projection. (See page 112). These sheets and the prewar 1:50,000 sheets are in process of recasting and reproduction in order to bring them sympathy with the adopted USSR standards.

The new sheets are trapezoids with dimensions $10'_{\phi} \times 15'_{\lambda}$ with the 4 cm (2 km) grid constructed in the Gauss-Krueger projection with 6° zones. The sheets are similar to the sheets of the USSR 1:50,000 topographical map. The progress of compilation and present coverage of 1:50,000 sheets is unknown.

f. Topographical map at 1:100,000 scale: The compilation of this tactical-operational map had already been planned by the Č.S. Military Geographic Institute. The compilation started after the adoption of USSR mapping standards in 1953. The sheets are trapezoids with dimensions $20'_{\phi} \times 30'_{\lambda}$ with 5 cm (5 km) grid constructed in Gauss-Krueger projection with 6° zones. One sheet represents 1/144 part of the 1:1,000,000 sheet of International map and at center of Czechoslovakia ($\phi = 49^{\circ}30'$) covers 1342 km^2. The territory of the ČSR is covered by 131 sheets. (See Inclosure 15). The basic cartographic material used in the compilation of 1:100,000 sheets are the sheets of 1:50,000 and 1:25,000 maps. The progress in compilation and present coverage are not known. The compilation is carried out by the Military Topographic Service in collaboration with civilian agencies and should in 1960 cover 50% of the territory of ČSR.

g. Topographical map at 1:200,000 scale: After 1953, this operational map is compiled from the cartographic material based upon the new 1:25,000 (1:10,000 and 1:20,000) topographical survey. The sheets are trapezoids with dimensions $40'_{\phi} \times 1^{\circ}_{\lambda}$ with 5 cm (10 km) grid constructed in the Gauss-Krueger projection. One sheet composed of 4 sheets of 1:100,000 scale map represents 1/36 part of the 1:1,000,000 sheet of the International map. The sheets are coded with Roman numbers I-XXXVI, for instance M-33-XXXVI. The compilation of sheets is in process; progress and present coverage are unknown. 41 sheets will cover the territory of ČSR.

h. Synoptical map at 1:500,000 scale: This map with sheets having dimensions $2^{\circ}_{\phi} \times 3^{\circ}_{\lambda}$ is in process of compilation. 9 sheets will cover the entire territory of ČSR.

i. International map at 1:1,000,000 scale: Four sheets, i.e. M33, M34, L33 and L34 cover the entire territory of the ČSR. The map is in process of compilation but progress is unknown.

j. The Central Administration of Geodesy and Cartography published the 1:400,000 administrative map and the 1:500,000 road map as well as numerous school maps, atlases, and some tourist maps.

HUNGARY

III. HUNGARY

After World War I the Hungarian half of the Austro-Hungarian Empire known as "provinces of St. Stephen's crown" including present Hungary, Burgenland, Prekmurje Medjimurje, Croatia and Slavonia, Vojvodina, Transylvania, Carpatho-Ukraine and Slovakia by treaty of Trianon was reduced to the area compactly settled by Hungarians of which the Kingdom of Hungary with a surface of 93.073 km^2 was created. After World War II Hungary became a people's republic and with corrected boundary at Bratislava bridgehead has a surface of 93.030km^2. Since in the organization of survey in the present People's Republic of Hungary various changes occurred and recent survey activities can not be regarded merely as a continuation of those carried out prior to 1945 in discussing the Hungarian mapping two periods should be differentiated, i.e. the period of the Hungary between the two World Wars (1918-1945) and the period after 1945 - the P.R Hungary.

IIIa. The survey activities in the Hungary between the two World Wars (1919-1945).

"The basic material of the maps inherited from the Military Geographic Institute of Vienna should be considered as completely obsolete. The 1:25,000 plane table sheets were not revised and also their degree of accuracy does not meet the much higher requirements of contemporary mapping---, "wrote general Aurel Medwey (Kruttschnitt) director of Hungarian Cartographic Institute (Magyar Kir. Allami Terképészet) in his article "Topographical mapping published in the Mitteilungen des Reichsamts für des Landesaufnahme 1932/33, No. 2, pp. 99-114 (File No. B-664.2001 Vol. 8). Consequently in Hungary a new topographical survey, completely independent of the III Topographical survey of Austro-Hungarian Empire was started in 1927.

In order to satisfy the need for a better map, for use during the time needed for completion of the new survey, the old Austro-Hungarian 1:25,000 plane table sections of III topographical survey were reambulated and sheets of 1:75,000 special map revised.

1. Geodetic foundation:

Hungarian topographical surveys at 1:25,000 and 1:50,000 scale have a new geodetic foundation which differs from those on which the Austro-Hungarian mapping was based.

a. Ellipsoid of Bessel:

b. Projection: The stereographic projection was used in the new Hungarian mapping carried out between the two World Wars.

(1) The entire territory of post-World War I Hungary (93.073 km^2) is covered by the "Budapest system" of stereographic projection with origin in base point of East tower of former astronomical observatory of Budapest on Gellérthegy,

with: $\phi = 47°29'09''.6380$

$\lambda = 36°42'53''.5733$ East of Ferro (Ferro = $17°39'46''.02$ West of Greenwich), derived from the astronomic observations in 1907, and

$\alpha = 191°28'52''.19$ to Nagyszal retained from 1874 datum values derived geodeticaly from Vienna University. [118]

The projection of meridian of origin - Budapest's meridian - on the stereographic plane represents the x axis and the perpendicular to it the y axis. In order to obtain all positive values of coordinates the origin is numerically shifted 500 kilometers South and West (false origin).

(2) In the topographical survey at 1:40,000 scale executed in 1941-43 in the Northern part of Transylvania, occupied by Hungarian Army, east of the 40°30' meridian and south of the 47°30' parallel the "Marosvásárhely system" of stereographic projection was used. Origin is first order station of cadastral triangulation Kesztej with:

$\phi = 46°33'09''.12 \pm 0''.31$ astronomically determined by K. und k. MGI in 1891 (computed in 1909);

$\lambda = 42°03'20''.955$ East of Ferro, ($17°39'46''.02$ West of Greenwich) geodetically derived from Gellérthegy-1907 datum;

$\alpha = 146°57'41''.052$ to Tiglamor. [37]

False origin 600 km South and West.

c. <u>Triangulation</u>:

(1) The triangulation of the Hungarian Cadastral Survey (Magyar Kir. Allami Földmérés) consisting of I - IV order nets with a density of 1 trig point per 2 km^2 served as the base for the topographical survey.

In the regions with a lower density or where markers could'nt be found cadastral triangulation was densified by the Cartographic Institute. The minimal density required in topographical survey at 1:25,000 scale was 20 trig points to one plane table sheet (65 km^2).

Since the outset in 1860, cadastral triangulation has been based on base lines at:

Wiener Neustadt	(1857)	9484.065 m
Arad, St. Anna	(1840)	8767.578 m

Partin (Galicia) (1849) 5972.501 m
Radovec (Radautz, Bucovina 1818) 9860.953 m

and upon the first order chains of the K. und k. II Military triangulation connecting the above-mentioned base lines. These chains divided into two groups:

1st Group: Chain Wiener Neustadt - Budapest-Arad, St. Anna and chain Budapest-Partin, 71 stations, 100 triangles with the error of angle by formula of Ferrero ± 0.93",

2nd Group: Chain Partin-Radovec and chain Radovec-Arad, St. Anna; 75 stations 106 triangles, the error of angle by formula of Ferrero ± 0.86"

were in 1860-69 rigorously adjusted by the method of least squares. The territory of Hungary located among these chains was covered by the Cadastral first order net built as a fill net upon the main net consisting of the mentioned chains. In 1874, the base line at Radovec was resurveyed and an error of 1.986 meters was established. The additional base lines were measured in 1885, at Budapest and in 1897, at Szatmarnémety. The main chain between the resurveyed base line of Radovec and base line of Szatmarnémety was newly adjusted, but the larger part of the triangulation remains influenced by the erroneously measured base line of Radovec. The lower order nets including the IV order net were gradually developed from this combined first order net. (See Inclosure 18)

The adjustment and computations were carried out in the conformal stereographic plane, the reduction being made by use of Marek-Hoffmann's tables, according to the Gauss principle, first from Bessel ellipsoid to Gaussian sphere with:

$$r = 6{,}378\ 512 \text{ m and}$$

ellipsoidal parallel = $46^\circ 32' 43.''4104$ and corresponding

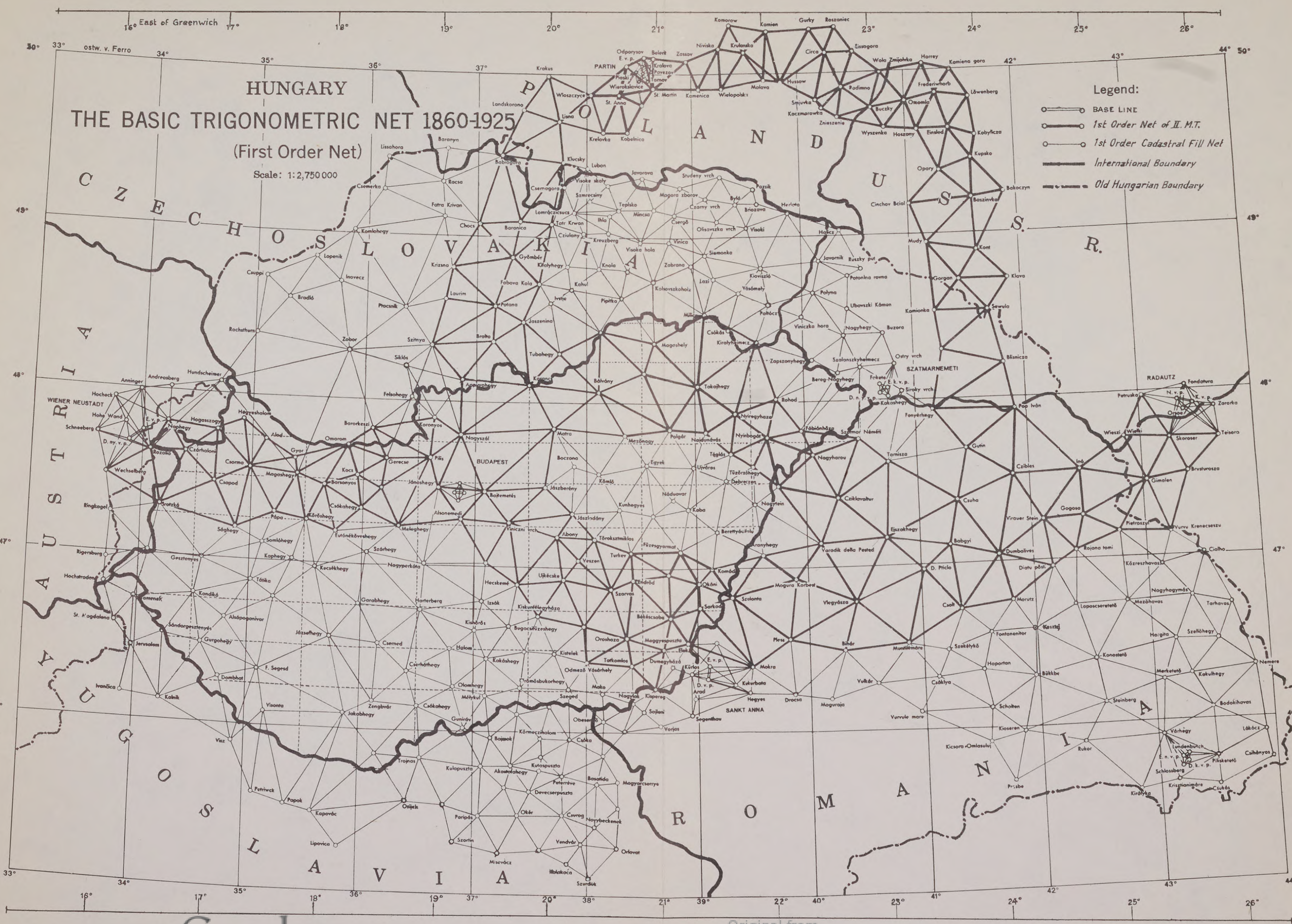
spherical parallel = $46^\circ 30' 00.''00$

and then to stereographic plane touching the Gaussian sphere at the point of origin-(base point of the eastern tower of Budapest's former astronomic observatory at Gellérthegy) for which the coordinates

$$\phi = 47^\circ 29' 14.''93$$

$$\lambda = 36^\circ 42' 51.''69 \text{ East of Ferro}$$

Inclosure 18



$\alpha = 100^\circ 47' 14''.34$ to Széchényihegy (in sympathy with

α to Nagyszal $= 191^\circ 28' 52''.19$) were geodetically derived from Vienna University, Observatory. This is the 1874 datum of the Budapest system. (In derivation carried out in 1861-63 Walbeck ellipsoid was used.) [66]

In 1907, Dr. A. Fasching derived the position of the eastern tower of the former observatory at Gellérthegy from the coordinates of Laplace station Széchényihegy (located 4610 m northwest of Gellérthegy), determined by K. und k. MGI in 1877, and obtained the following coordinates:

$\phi = 47^\circ 29' 09''.6380$

$\lambda = 36^\circ 42' 53''.5733$ East of Ferro

$\alpha = 100^\circ 47' 07''.90$ to Széchényihegy. [66]

This position, considered 1907 datum point, represents in respect to the position of the 1874 datum a shift to the southeast of

$\Delta\phi = -5''.2920$

$\Delta\lambda = +1''.8833$

and a rotation of

$\Delta\alpha = -6.44.$

Due to large linear and surface distortions which the stereographic projection showed along the periphery of prewar Hungary (about 1/1000) the Cadastral Survey in order to keep the linear distortion within limits of 1/10,000 in 1908 introduced a system of 3 cylindric projections with oblique axes; hence, the territory of prewar Hungary was covered by 3 horizontal zones of cylindric projections. In all zones the meridian of Budapest:

$\lambda = 36^\circ 42' 53''.5733$ East of Ferro

serves as x axis. The oblique cylinders touch the Gaussian sphere along the great circles perpendicular to the meridian at the points of origins located on the meridian of Budapest at latitudes:

$\phi = 48^\circ 42' 56''.3180$ North cylinder,

$\phi = 47^\circ 08' 46''.7267$ Central cylinder

$\phi = 45^\circ 34' 36''.5869$ South cylinder.

For the orientation the azimuth Gellérthegy-Széchényihegy of 1907 is used:

$\alpha = 100^\circ 47' 07''.90;$ [118]

hence the common x axis of the 3 cylindric projections forms with the x axis of stereographic projection the angle of - 6"44. The computation of cadastral triangulation since 1908 was carried out in the cylindric system. The stereographic projection is used only for the adjustment of I and II order nets in the regions within a distance of 127 km from the origin where distortion is within limits of 1/10,000. A rapid conversion of cylindric coordinates into coordinates of the new stereographic system, exclusively used in the mapping, is facilitated by nomograms.

In the Hungarian mapping the old Austro-Hungarian sheet division and subdivision of graticule system with starting meridian Ferro was retained. But the plane table sections at 1:25,000 scale of the new topographical survey and the reambulated plane table sections (recasted and provided with new cadastral planimetry) as well as the new 1:25,000 topographical map compiled from the newly surveyed and reambulated plane table sections are constructed in stereographic projection (Budapest system). Considering the different manner of construction of polyhedric and stereographic projection the new stereographic sheets are not congruent with the corresponding polyhedric sheets. Beside this constructional difference the stereographic sheets due to the southeast shift of origin for:

$$\Delta\phi = -5''.2920 = \Delta N = -163.4 \text{ m} = 6.5\text{mm}/1{:}25{,}000$$

$$\Delta\lambda = +1''.8833 = \Delta E = +39.4 \text{ m} = 1.6\text{mm}/1{:}25{,}000$$

have in respect to the old polyhedric sheets a considerable shift of sheet corners toward the north-west. In order to facilitate the use of both types the old sheet corners are plotted on the sheets of the new 1:25,000 map.

Stereographic sheet corners were computed within an accuracy ± 1 m. Meanwhile the old Austro-Hungarian plane table sections in the area of Central Hungary belong to Vienna University system and to Arad, St. Anna system, or their positions represent a compromise between the two systems with the sheet corners having a displacement up to ± 75 meters. Furthermore the old revised sheets of II topographical survey used in this area were shifted erraticaly. (See chapter III-1-c(3,a,b,c)Pp 17-26.) Consequently the relation: Stereographic sheet corners - sheet corners of old 1:25,000 plane table section was not obtained from computations, but rather determined graphically by scaling from identical points.

In the topographical survey at 1:40,000 scale executed for the purpose of compilation of 1:50,000 map the stereographic sheets were used. The sheets west of 40°30' meridian belong to Budapest system and east of 40°30' meridian and south of 47°30' parallel belong to the Marosvásárhely system.

But the geographic positions of sheet corners are not in sympathy with the geographic position of the origin of stereographic projection; hence the inconsistent sheet lines of these new stereographic sheets result from a compromise with the sheet lines of the polyhedric sheets of St. Anna System, actually have the latitude derived from Vienna, University and the longitude from St. Anna datums.

This statement is confirmed by the results obtained from the comparisons of the scaled position of 1st order station Kesztej (origin of Marosvásárhely system) with its geographic coordinates referring to Gellérthegy (Hungarian Cadastral Net), Hermannskogel (III K. und k. M.T. - Ergebnisse der Triangulierungen), St. Anna and Vienna University datums (II K. und k. M.T. - Positions Rechnungen). The position of Kesztej is scaled from 1:50,000 sheet 5373 W-Marosvásárhely. The results of comparisons are as follows:

	ϕ			λ		
Datum	computed	scaled	$\Delta\phi$	computed	scaled	$\Delta\lambda$
Gellérthegy (longitude)	46°33'09".12	12".70	+ 3".58	42°03'20".95	24".75	+ 3".80
Hermannskogel	10.71	12.70	+ 1.99	23.89	24.75	+ 0.68
St. Anna	15.01	12.70	- 2.31	25.69	24.75	- 0.94
Vienna Univ.	11.76	12.70	+ 0.94	18.51	24.75	+ 6.24

The manuscripts of the Hungarian topographical survey as well as the Hungarian maps 1:25,000, 1:50,000 1:75,000 and 1:200,000 are provided with 4 cm grid representing an interval of 1,2,3, and 8 km respectively. The 1 km ticks are plotted along the neat lines. The construction of the grid is always based upon the position of trig points because the positions of the sheet corners of 1:25,000 old plane table sections, 1:50,000, 1:75,000 and 1:200,000 maps are not reliable. In the Hungarian mapping the construction of sheets, plotting of points and compilation were always based upon the stereographic grid.

(2) Observations were started in 1925 by Cadastral Survey of post war Hungary for a new first order net which would have an average length of the sides about 35 kilometers. One purpose of this net was the elimination from the Hungarian triangulation of the remaining errors caused by erroneous measurement of the Radovec

base line. By 1945, the observations carried out by use of modern instruments and by application of contemporary surveying methods had been only 80% completed; hence this new net was not utilized in the geodetic foundation of the topographical survey carried out prior to World War II.

(3) The cadastral triangulation in Transylvania (1885-1917) used in the topographical survey at 1:40,000 scale is based on first order chains of K. und k. III Military Triangulation (1870-83) connecting the resurveyed base line of Radovec with base line of Brasov and base line of Brasov with base of Arad, St. Anna. The chains were regionally adjusted in two groups. The computations were carried out in stereographic projection (Marosvásárhely system) established in 1890, with the origin cadastral first order station Keszte with coordinates given in this chapter subpara b. (2).

d. Elevations:

Because the Austro-Hungarian precise leveling (1873-98) with a mean error of ± 5.1mm/km, some line also ± 12mm/km, would not meet the requirements of modern precise leveling, the Hungarian Cadastral Survey in 1921 started a new precise leveling. For the starting point the basic benchmark No. 11257 Nadap, determined in 1888 by K. und k. Austro-Hungarian precise leveling with the elevation 173.8385 m above the mean level of Adriatic Sea, established in vertical datum Molo Sartorio, Trieste (1875) was adopted. Benchmark Nadap ($\phi = 47^{\circ}15'$, $\lambda = 36^{\circ}17'$) is located about 51 km southeast of Budapest.

The Cadastral Survey up to 1939 had accomplished 5939 km of 1st order (high precision) duplicate level lines with 4950 benchmarks which comprise 39 loops and 1962 km 2nd order (precise) duplicate level lines (78 loops) with 1613 benchmarks; together 7901 km duplicate level lines with 6563 benchmarks.

The observations were carried out by Oltay-Süss precise leveling instrument with telescope having magnification 40 and sensitivity of the spirit level 4"-5". The 3.15 m long level rods made of paraffinized wood with 5 cm intervals every day were compared four times with the normal meter and were tested yearly in the Hungarian Bureau of Standards. The maximal length of the sight permitted in the observing from the center was 50 m. The sections were the same day observed in both directions. The maximal difference permitted between the results of forward and backward observations is as follows:

1st order $d = \pm 1.2 \text{ mm } \sqrt{L} \text{ km}$

2nd order $d = \pm 2.4 \text{ mm } \sqrt{L} \text{ km}$

The leveling of high precision (1st order) in 1939 was completed but it was not adjusted. The adjustment carried out after World War II was completed in 1949. The following values express the accuracy of the 1st and 2nd order precise leveling:

1st order: Probable total error = ± 0.30 mm/km
2nd order: Probable total error = ± 0.66 mm/km [9]

The leveling of high precision (1st order) in 1925 was tied at Pammhagen with the leveling net of Austria and in 1932 at Horvátjárfálu (Jarovec), Komárom , Esztergom and Szob with the leveling net of Czechoslovakia.

The mean differences of the Hungarian preliminary elevations in respect to Austrian and Czechoslovakian would be expressed as follows:

$$H_H - H_A = + 0.07109 \text{ m}$$
$$H_H - H_{\check{C}S} = + 0.08642 \text{ m.} \quad [151]$$

(1) Because the cadastral trig stations used in topographical survey had elevations based upon old Austro-Hungarian precise leveling the Cartographic Institute determined new elevations in sympathy with the new precise leveling. This was done by means of trigonometric leveling or by extension of III and IV order spirit level lines (technical leveling) to the trig points, the usual practice in flatland. Consequently the elevations used in the new 1:25,000 topographical survey are based on the new Hungarian precise leveling.

(2) The old 1:25,000 plane table sections of the III Topographical survey and the old sheets of 1:75,000 map compiled from the old plane table sections have elevations based:

(a) On elevations of old cadastral trig points derived by means of trigonometrical leveling from the mean sea level of Adriatic Sea (the relation of this mean sea level to the mean sea level determined in 1875 by vertical datum Trieste, Molo Sartorio is unknown), which differ from the elevation of precise leveling from - 3 to + 3 meters.

(b) On elevations of Austro-Hungarian precise leveling (1873-98); the differences with the new Hungarian precise leveling amount up to - 10 cm and are cartographically negligable. (Only plane table sections of a small region in Central Hungary and reambulated plane table sections of Transylvania.)

(3) The new topographical survey at 1:40,000 scale has in Transylvania the elevations based on Austro-Hungarian precise leveling.

2. Topographical Survey:

The topographical activities in Hungary in the period between the two World Wars fluctuated between two antipodal aspects, i.e:

- desire for a systematical topographical survey based on the new geodetic foundation of which a contemporary topographical map would be produced, and

- requirement for an adequate map, which would as soon as possible cover the territory of reduced Hungary, forced by unhealthy political relations among the successor states. In order to satisfy the desire for a modern map in 1922-38 a completely new topographical survey at 1:25,000 scale was inaugurated. This survey has no connection with the old Austro-Hungarian topographical survey and its geodetic foundation.

  The military requirements for an accelerated production of adequate maps were met by utilization of improved Austro-Hungarian 1:25,000 plane table sections and 1:75,000 special map. This urgent need was only partially satisfied by:

- the reambulation of 1:25,000 plane table sections carried out in 1920-26 and in 1939-40;

- the revision of 1:75,000 special map carried out in 1924-34 at 1:60,000 scale;

- the revision of 1:75,000 special map executed in the field at 1:40,000 scale in 1941-43, and

- the rapid topographical survey at 1:40,000 scale executed in 1941-43 in Transylvania.

In 1945 at the end of World War II 51 incomplete sheets of the old 1:75,000 special map covering 30% of the territory remained unrevised.

a. Topographical Survey at 1:25,000 scale

In the topographical survey at 1:25,000 scale the stereographic plane table sheets with graticule sheet lines of $3'45''_{\phi} \times 7'30''_{\lambda}$ were used. In respect to different types of terrain the topographical survey was carried out by various methods.

(1) The method of plane table tachymetry, was applied ordinarily in the mountainous and hilly land not covered by large forests. It was based on cadastral triangulation with a density of 1 trig point to 2 km^2. As the foundation of detail survey on the plane

table sheets the 1 kilometer (4 cm) grid was constructed and in sympathy with grid the trig points and sheet corners plotted, then the cadastral planimetry (old cadaster at 1:2880, new cadaster at 1:2000 scale) was pantographically reduced. This foundation was, in the case where a normal developement of the detail survey by polar method would require a greater density of fixed points, densified with graphical points by plane table triangulation. The positions and elevations of the detail points were determined tachymetrically (stadia method).

There were determined per 1 km^2:

80 - 160 detail points and
5 - 70 elevations. [118]

The relief expressed by contours with interval of 10m (auxiliary countours 5 and 2.5m) was drawn immediately in the field. Lower elevations, terraces and waves within the limits of contour interval are expressed by hachures.

In the regions where the water cooperatives carried out a survey for purposes of regulation of river channels, the leveling records of this survey were utilized. Some areas without (or with obsolete) cadastral survey were surveyed solely by plane table tachymetry based on triangulation densified by normally developed plane table triangulation. Consequently due to this variance of surveying records utilized and due to different types of terrain the average norm achieved by 1 topographer varied:

from $\frac{1}{2}$ to 2 km^2 per day or
1 - 4 plane table sheets (65-260km^2)
per 6 months.

Total coverage up to and including 1938 was 13.450 km^2 i.e. 65.5% of the area covered by the new survey or 14.4% of the territory of Hungary.

(2) Aerial stereophotogrammetry has been used since 1927 in the survey of mountainous and hilly regions covered by extensive forests. The stereophotogrammetrical survey had the following course:

(a) The existent trig points and benchmarks were panelled in the field.

(b) The convergent aerial photography was made by Zeiss C-3 18x18 cm, f = 21 cm camera.

Altitude 2100-2500 m
Angle of convergency 32°
Overlappings: stereo-pairs 95%, strips 20%.

(c) Additional tie points were selected on photographs and their positions and elevations determined in the field tachymetrically by polar method up to a distance of 300 m from the existent trig points, by numerical traverses or graphically by plane table triangulation.

(d) The tie points together with stereographic 1 km grid were plotted at 1:10,000 scale and the compilation carried out at outset by Hugershoff aerialcartograph, and later by Zeiss C-5 stereoplanigraph and Wild A-4 autograph.

(e) The stereocompilation at 1:10,000 scale was checked and supplemented in the field by plane table method and then reduced to the 1:25,000 scale.

The total coverage of stereophotogrammetric compilation including 1938 was 1410 km^2, i.e., 6.9% of area covered by the new topographical survey or 1.5% of the territory of Hungary.

(3) The one plate photogrammetry was used in the flat land which represents 60% of Hungarian territory. The utilization of one plate photogrammetry in the Hungarian mapping started in 1922 at the beginning of the new topographical survey at 1:25,000 scale. During the first years of the survey the photography was made from an altitude of 3500-3700 m by Zeiss camera 13x18 cm f = 21 cm using the Perutz plates. Vertical photographs with an overlapping of 60% were by method of graphical construction based on identical points of cadastral planimetry utilized in the supplementing of planimetry of the new cadastral survey. In this way supplemented plane table sheets were completed in the field by topographers, including the measurement of elevations and expression of the relief by contours. Since 1927, the Zeiss RMK 18x18 cm, f = 21 cm camera with film was used in photography at altitude of 2100-2500 meters. The photographs were rectified at 1:10,000 scale by Wild-Odencrants automatical rectifier and by Aschenbrenner's semiautomatical rectifier. As tie points needed in rectification the prior photography panelled trig points, on the photographs selected and later in the field determined tie points, and the points scaled from cadastral map were used. From the rectified photographs a photo map at 1:10,000 scale, based on tie points plotted together with stereographic 1 km grid, was constructed. The average error in rectifying at 1:10,000 scale was ± 3.8 m; the maximal error ± 5.7 m.[126] This map was photographically reduced to 1:25,000 scale, blue lines made and in the same manner as before was completed in the field by topographers. By the utilization of one plate photogrammetry the rate of progress in surveying of flat lane was doubled.

Total coverage of topographical survey by utilization of one plate photogrammetry was 5680 km^2; i.e. 27% of area covered by the new topographical survey or 6.1% of the territory of Hungary.

b. Topographical Survey at 1:40,000 scale

In 1941-43, in order to extend the Hungarian 1:50,000 map over the part of Transylvania occupied by the Hungarian Army a rapid topographical survey was carried out. In this survey the stereographic plane table sheets with graticule sheet lines of $7'30''_{\phi} \times 7'30''_{\lambda}$ covering a surface of about 133 km^2 were used. The survey was based on cadastral triangulation established prior to 1917 by the Hungarian Cadaster (5-20 trig points to 1 plane table sheet, i.e., 1 trig point per 30-8 km^2). The cadastral planimetry in this survey was not utilized. The entire area of 25,000 km^2 was covered by aerial photography. The existent trig points were panelled before the photography was flown. The compilation of 3/4 of the area was accomplished by multiplex at 1:10,000 scale. the rest of the area surveyed was compiled either by stereoplanigraph or in the plain along the Hungarian boundary the photo maps were made by rectifying (one plate photogrammetry). The compilations as well as the photo maps were reduced to 1:40,000 scale and were checked and supplemented in the field by topographers using the plane table method. The relief was expressed by contours with interval of 20 meters, auxiliary contours on 10 and 5 meters.

One topographer in a summer period of 6 months normally completed 2 plane table sheets (266 km^2).

Due to the variations in methods and instruments applied in the photogrammetric compilation this topographical survey is lacking in uniform accuracy over the area surveyed. Evidently the regions compiled by stereoplanigraph are expressed by much higher degree of accuracy than those compiled by multiplex and the survey carried out by a field revision of photo maps is of even lower accuracy than a multiplex compilation.

3. Maps

a. New Hungarian Maps: (See Inclosure 12):

(1) The 1:25,000 topographical map: The 414 stereographic sheets with $7'30''_{\phi} \times 15'_{\lambda}$ graticule sheet lines would cover the territory of Hungary. These sheets are constructed in stereographic projection (Budapest system) and provided with stereographic 1 km grid as already discussed in the chapter 1 (geodetic foundation). On the sheets the positions (sheet corners) of old corresponding 1:25,000 plane table sections

are plotted. The geographic coordinates of sheet corners are given with the longitude East of Ferro, but the upper and lower neat lines (parallels) are provided with minute ticks referring to Ferro and to Greenwich.

The relief is expressed by contour lines with interval of 10 meters and by 5 and 2.5 m auxiliary contours. The reproduction was made photolithographically. The sheets were printed in 2,3 or 4 colours: Cultural features, nomenclature and elevations and cliffs (sheets printed in 2 clours, also woodlines and drainage, sheets in 3 colours also drainage) in black colours, relief brown, woodlines green and drainage blue. In 1944 the total coverage of the new 1:25,000 topographical map was 220 sheets (and 9 sheets of Czechoslovakian territory at that time occupied by Hungarian army) i.e. 56,000 km^2 or 60% of the territory of Hungary.

In respect to the topographical material used in compilation, different standard-symbols of 1923, 1930, and 1931, reproduction in 2, 3 and 4 colors, and size of the sheets the map is not uniform.

(a) The sheets compiled from the new topographical survey: These sheets appeared in 3 editions with different sizes, i.e., composed of 4, 2 and 1 plane table sheet. They represent the topographical manuscripts redrafted for the reproduction without any generalization. In 1940, total coverage of the new 1:25,000 scale topographical survey was 80 sheets i.e. 20,540 km^2 or 22% of entire territory of Hungary.

(b) The sheets compiled from reambulated old Austro-Hungarian plane table sections of the III topographical survey: Actually these sheets were constructed in stereographic projection (Budapest system) and provided with the reduced cadastral planimetry; but the relief expressed by 20 m contours was taken from Austro-Hungarian plane table sections and supplemented by interpolated 10 m contour lines. These plane table sections were reambulated in the field. The reproduction was done in the same manner as the newly surveyed sheets. Only the four plane table sheet size ($7'30_{\phi}$ x $15'_{\lambda}$) was published.

Evidently, the sheets of the new 1:25,000 topographical map are not of the same accuracy, particularly not in respect to the expression of the relief. In addition to the highly accurate sheets compiled on stereoplanigraph, there are a large number of sheets surveyed by plane table method with 5-70 spot elevations measured per 1 km^2. This number of measured elevations sometimes would be insufficient for an accurate expression of the relief by contour lines. The upper limit of 70 points should be considered as a sufficient basis for an experienced topographer to express by contours 1 km^2 mountainous or hilly terrain normally shaped by fluvial erosion without many details; on the other hand in the areas of sand dunes and particularly in the karstic areas 70 spot elevations would be insufficient for an exact contouring. Because in Hungary there are no extensive regions with detailed relief, the sheets compiled from the new plane table survey would meet the contemporary mapping requirements which in no case could be satisfied by reambulated sheets. Considering the position and completeness of the planimetry both types, a and b, would completely satisfy the requirements of contemporary mapping.

(2) The 1:50,000 topographical map:

(a) In the compilation of the 1:50,000 topographical map from the 1941-43 topographical survey the stereographic sheets with the dimensions $15'_\phi \times 15'_\lambda$ ($\frac{1}{2}$ of 1:75,000 sheet) were used. There are 56 sheets covering the central region of the Northern Transylvania and 1 sheet of Carpatho-Ukraine. Except for parts of the 6 sheets along the Romanian boundary these sheets do not cover the territory of present Hungary. The sheets covering Hungarian territory along the Romanian boundary were compiled from the old polyhedric 1:25,000 plane table sections which were for this purpose photo revised. These sheets were reproduced in the same manner as the sheets compiled from the manuscripts of the new 1:40,000 topographical survey. The sheets along the German demarcation line between Hungary and Romania are combined i.e. composed of the new survey covering the Hungarian part and of enlarged 1:75,000 special map used to cover the Romanian part of the sheets. The sheets west of 40°30' meridian belong to Budapest system and the sheets east of 40°30' meridian and south of 47°30' parallel belong to Marosvasarhely system. These sheets are provided with 2 km stereographic grid (1 km ticks along the neat lines) which in the newly surveyed part agree with horizontal control within ± 10 m; but disagree up to 150 m in the part covered by enlarged 1:75,000 map. The geographic coordinates of sheet corners are given with the longitude east of Ferro, but the upper and lower neat lines (parallels) are provided with minute ticks referring to Ferro and to Greenwich.

The compilation was made at 1:40,000 scale; actually at this scale the blue lines of 4 plane table sheets were composed and fitted into sheet lines of 1:50,000 sheet and the colour separations were drawn. The relief is expressed by the combination of contours with 20 m interval (auxiliary contours 10 m and 5 m) and shading. The reproduction in 5 colours, cultural features and nomenclature black, relief brown with brown-gray shading, drainage blue and woodland green, was made photo-litographically. The compilation of this map with the size of symbols and lettering as well as representation of the relief (20 m contours emphasized by shading) was designed to be used by motorized units. The larger size of symbols and lettering together with shading of relief make the map very legible, really a "saddle map".

(b) Due to the military requirements for a tactical map at 1:50,000 scale in 1941, the compilation of the 1:75,000 sheets was dropped and the existent sheets of the new 1:75,000 map were in 1943 revised and without any change in the position and 1 km grid enlarged to 1:50,000 scale. Since the new 1:50,000 sheets ($15'_{\phi} \times 15'_{\lambda}$) cover half of the 1:75,000 sheets they retain the old numbers in the map index with an addition of NY (West) and K (East.) The sheets were supplemented with corresponding additional marginal information.

(3) <u>The new 1:75,000 map</u>: This map, which is intended to gradually replace the old special map, was compiled from the new 1:25,000 topographical map. In order to facilitate the use of the new sheets together with old sheets, the subdivision, sheet lines, and surface of the old polyhedric sheets were retained in the construction of the new sheets, but the interior contents - all features - were plotted in stereographic projection. Actually the reduced 1:25,000 stereographic sheets were fitted into 1:75,000 sheet by exact matching of stereographic grid. The $15'_{\phi} \times 30'_{\lambda}$ sheet is composed of the recasted 1:25,000 sheets and covers the surface of 1:25,000 sheets limited by old polyhedric sheet corners which are on the 1:25,000 sheets plotted beside the stereographic sheet corners. The composing was made at 1:60,000 scale with the transparent reduced blue lines of the 1:25,000 map fitted into $15'_{\phi} \times 30'_{\lambda}$ sheet at 1:60,000 scale constructed by matching of stereographic grid. The sheets are provided with 3 km stereographic grid and 1 km ticks plotted along the neat lines. The grid is in agreement with the horizontal control. The maximal error in plotting is $\pm$ 0.2 mm = $\pm$ 15 m.

Matching between the old and new 1:75,000 sheets. In spite of the identical sheet lines used in the cut of the new and old sheets the detail along the neat lines of two different sheets covering the same area do not coincide exactly. By a recapitulation of previous discussions about the various geodetic foundations on which the polyhedric sheets are based, the manner of the incorporation of the cadastral records (control and planimetry) into polyhedric graticule sheets where these records at time of the III Topographical survey existed, the use of old Cassini's sheets of II Topographical survey recasted and fitted into graticule system by means of erratic shifts, as well as the limited number of surveyed points used in the drawing of features in III Topographical survey, it would be easy to comprehend the displacement of the features which arise if the sheets of the old special map are matched or compared with the sheets of the new 1:75,000 map. Considering that the new 1:75,000 sheets are based on adjusted cadastral triangulation, constructed in the stereographic projection where the features plotted in sympathy with the uniform stereographic grid obtained their exact positions and true mutual relation, there can be neither a congruency between the features of the old and new sheets covering the same area nor exact ties between the adjacent sheets. If from the amount of the disparities between the positions of the features on old and new sheets systematical projectional difference could be eliminated, the remainders would exactly express the displacements by which the positions of the features were distorted in the compilation of the old sheets.

On base of the blue lines copied at 1:60,000 scale two colour separations were drawn. In the drawing of colour separations unimportant cultural features were omitted and the relief expressed by 10 m contours was slightly generalized. The colour separations were helioengraved into copper plates and by offset printing reproduced in 5 colours i.e: cultural features, lettering and cliffs in black colour, contoured relief in brown with shading in gray-brown colour, drainage (water features) in blue and woodland in green colour. Until 1944, were published 48 sheets of the new 1:75,000 map. Some sheets were published only in 4 colours with black water features.

(4) The sheets of the 1:25,000, 1:50,000 and 1:75,000 new Hungarian maps were compiled with sufficient accuracy that the stereographic grid constructed on these sheets should be considered as a fire control grid. Since in the Hungarian mapping the construction and compilation of sheets is based upon the stereographic grid and the sheet corners, except for the new 1:25,000 map, are inconsistent all these sheets can be exactly positioned by means of the grid intersections nearest to the sheet corners.

The new sheets of the 1:25,000 and 1:50,000 maps compiled from the manuscripts of the new topographical surveys at 1:25,000 and 1:40,000 scale and of 1:25,000 reambulation (not the 1:50,000 sheets enlarged from 1:75,000 map) include a very important innovation for the artillery i.e: in addition to giving in parenthesis ground elevations of the high objects (orientation points) as churches, smokestackes etc., determined trigonometrically there are also indicated the heights of the objects (signals) referring to the top of the object or to the certain elevated clearly visible feature on the object (lower, upper edge of belfry window, cross, knob on belfry).

(5) Tourist map 1:50,000 scale: In the compilation of the tourist map the sheets of 1:25,000 topographical map were used. The planimetry was considerably generalized but completed with various tourist records. The map was reproduced in 8 or more colours. The relief is expressed by a combination of 10 meter contours and shading. The map covers only the regions important to tourism and sport.

b. The Hungarian maps based on the III Topographical Survey of the Austro-Hungarian Empire.

All these maps evidently are burdened with the previously explained deficiencies of the Third topographical survey.

(1) Copies of 1:25,000 plane table sections: The 185 sheets (40% of the territory of Hungary) in 1944 were not yet covered by the new 1:25,000 map; therefore for this area the manuscripts of the Third topographical survey were photolithographically reproduced, provided with superimposed 1 km stereographic grid and copies printed in black colour. The manuscripts were not revised and not supplemented with any additional features prior to the reproduction. The stereographic grid was graphically superimposed in sympathy with some identical trig points used in the cadastral survey and in topographical mapping. But the scaling of other control shows a mean disparity of ± 60 m (maximal above 170 m); hence the grid could be considered merely a reference grid.

(2) The 1:50,000 sheets enlarged from the sheets of 1:75,000 special map: For the areas not covered with the new 1:50,000 topographical map compiled from the new topographical survey at 1:25,000 and 1:40,000 scale since 1951 there were produced the 1:50,000 sheet by cutting into west and east half of enlarged 1:75,000 sheets of the old special map. For this purpose primarily the revised 1:75,000 sheets were used. The unrevised sheets were revised in the field prior to the recasting (Northern Transylvania in 1943). The black hachured sheets are printed in two colours, i.e. cultural features, relief, water features black, and woodland green. The sheets with inconsistent sheet lines, without any change in position, were in the same manner as the old 1:25,000 plane table sections provided by 2 km stereographic grid of Budapest or Marosvásárhely system. The graphically superimposed grid of both systems compared with the control show the disparities up to 200 meters and represents merely a reference grid. In order to effect a detail match with the adjoining stereographic sheets crosses marking the positions of sheet corners of the stereographic

sheets (new 1:50,000 map) were plotted on the polyhedric sheets.

(3) The old 1:75, 000 special map: In 1941, at the time that the compilation of 1:75,000 map was discontinued the total coverage of 122 sheets of the territory of Hungary with the neighboring frontier-regions was covered as follows:

48 new stereographic sheets (5 in Czechoslovakia and 8 in Austria),
23 revised sheets,
51 unrevised sheets of which only 28 covering the territory of Hungary.

In the areas not covered by the new stereographic sheets the sheets of Austro-Hungarian special map are available to satisfy the urgent military and civilian needs.

(a) Revised sheets: These sheets were revised in the field by a method similar to the method explained in chapter C-IV pp. 56-57. Prior to the field work the sheets were supplemented by the method of graphical construction with additional features from aerial photography. Along with the field revision the considerable germanized nomeclature was replaced by native names. The sheets were ordinarily published only in black colour with unchanged expression of the relief. Some sheets have in red colour superimposed international and district boundary lines and some in the plain have brown contours and hachures. The revised sheets have along the upper and lower neat lines in addition to Ferro ticks 5' ticks referring to the meridian of Greenwich. These sheets with inconsistent sheet lines were reproduced without any change in position. The graphically superimposed 3 km grid, or only 1 km ticks, in respect to the reasons already discussed in connection with the matching between the new and old sheets (Chapter: "The new 1:75,000 map") represents merely a reference grid.

(b) Unrevised sheets: The unrevised sheets of the Austro-Hungarian special map were reproduced without any changes in position and detail. There are two editions i.e. one without grid and the other with graphically superimposed stereographic grid of Budapest or Marosvásárhely system. The sheets covering the overlapping zone of two systems are printed on both sides of paper and one side is provided with the grid of Budapest system the other one with the grid of Marosvásárhely system. According to the previous discussions it is evident that these grids have merely the value of a reference grid.

(4) The 1:200,000 General map: The territory of present Hungary would be covered by 23 sheets, but there are 37 sheets of the first edition. These sheets represent the revised Austro-Hungarian general map provided with Hungarian nomenclature and with 8 km ticks of the stereographic grid. Otherwise there are

no considerable changes in respect to the old Austro-Hungarian general map.

Second edition is also constructed in polyhedric projection with superimposed stereographic 8 km grid. The relief is expressed by combination of 50 m contours and shading. The highways are printed in red colour. Only one sheet - Miskolc - was published.

(5) The 1:400,000 operational and aerialnaviagation chart: This new compiled map is constructed in Gauss-Lambert projection. The graticule sheets with the dimensions 3^o_ϕ x 3^o_λ and starting meridian of Ferro are printed in 5 colours. Of the 8 sheets planned in 1944 only 4 were completed.

(6) The 1:600,000 road map consists of two rectangular sheets with the dimensions 79.5 x 112 cm, constructed in Gauss-Lambert projection. The railroads are represented in black, the highways and roads in red and the canals and rivers in blue colour.

(7) From the sheets and parts of the sheets of the 1:75,000 and 1:200,000 maps there were combined various maps covering environs of the cities, garrisons, mountainous regions and Balaton Lake Area. These maps usually appeared in polychromy with the woodland, vineyards, roads and drainage reproduced in colours.

IIIb. The surveying and mapping activities in the People's Republic Hungary.

Following the Czech example the Hungarian surveying and mapping agencies after World War II underwent successive reorganizations until there was established in 1952-54 an organizational structure (following the USSR pattern) in which all civilian surveying and mapping agencies are centralized. Up to the present time no significant changes have occured. This structure is composed as follows:

National Administration of Geodesy and Cartography. (Állami Földmérési es Térképészeti Hivatal - AFTH) is the supreme civilian agency responsible for the research, planning and execution of the work in the field of geodetic astronomy, triangulation, leveling, topographical and cadastral survey and map reproduction. The AFTH is subordinated directly to the Council of Ministers (Ministertanacs). Under the AFTH are the following agencies:

- Geodetic and Cartographic Enterprise of Budapest (Budapesti Geodeziai es Térképészeti Vállalat-BGTV); with affiliated
- Geodetic and Cartographic Enterprise of Pécs (Pécsi Geodesiai es Térképészeti Vállalat-PGTV);

- Cartographic Enterprise (Kartografiai Vállalat) in Budapest:

- Central Archives for Geodesy and Cartography (Kozponti Geodeziai es Térképészeti Adattar)

- County Surveying Branches of AFTH;

The Geodetic and Cartographic Enterprise of Budapest is the principal surveying agency which carries out the astronomic and geodetic surveys, leveling of high precision and precise leveling, topographic surveys at 1:10,000 (1:5000) scale and cadastral surveys. It has the following divisions: Geodetic, Leveling, Topographic, Photogrammetric, City-Survey, Agricultural and Cartographic.

The surveying and mapping activities in the Army and its topographic maps are secret. The Military Cartographic Institute Honvéd Térképészeti Intezet-HTI) responsible for military survey and mapping, is an independent agency which closely collaborates with the AFTH. The Military Cartographic Institute has the following divisions: Administrative, Topographic, Photogrammetric, Cartographic, Reproduction, Library and Schools.

The scientific research in the field of geodesy is directed by the High Council of Geodesy of the Hungarian Academy of Science under which are working the Geodetic Research Group of the Academy of Science and Geodetic Research Laboratories at Technical Universities. The High Council of Geodesy closely cooperates with the National Administration of Geodesy and Cartography and the Military Cartographic Institute.

1. Geodetic foundation:

   a. Ellipsoid of Krasovskiy. Adopted in 1954.

   b. Projection: Gauss-Krueger (Transverse Mercator) projection with 6° zones, central meridians 15° and 21° East of Greenwich, scale factor = 1, false origin 500 km West and 5000 km North since 1957, used in the mapping at 1:5000 and 1:10,000 scale. (Prior to 1957 in the mapping at 1:5000 Gauss-Krueger projection with 3° zones central meridians 18° and 21° was used). Meanwhile the Military Cartographic Institute since 1950, is using this projection in the mapping at 1:25,000, 1:50,000, 1:100,000, 1:200,000 and 1:500,000 scale with the false origin 500 km West. In the cadastral survey at 1:2500 and larger scales the Gauss-Krueger projection with 2° zones, central meridians 17°, 19°, 21° and 23°, scale factor = 1, false origin 100 km West and 5000 km North has been used since 1957.

Along with the adoption of the Gauss-Krueger projection in the compilation of Hungarian maps at 1:5000 - to 1:500,000 scale the USSR sheet division and code in the system of 1:1,000,000 International map was prescribed. Hungary falls on L-33, L-34, M-33, and M-34 sheets of the International map. (See Inclosure 19.)

In order to facilitate a rapid conversion of the rectangular plane coordinates of stereographic and oblique cylindric systems referring to Bessel ellipsoid to GK's referring to Krasovskiy ellipsoid (so called provisional system of military grid) used in the recent topographical survey and mapping, various tables were computed and for cartographic purpose nomograms constructed.

c. Triangulation: Since in the spring of 1945, due to the disturbance of the war events, all of the work on the new (1925-45) triangulation and a considerable part of the data of the old net had been destroyed the Hungarian authorities in 1948 decided that a new triangulation has to be established. This new triangulation has to be composed of the first order chains forming two polygons and of supplementary nets. (See Inclosure 20).

(1) The first order net: It consists of 132 triangles and includes 112 stations of which 34 are towers and 98 pyramids. It is composed of seven chains placed between six base lines of which six chains running along the boundary form around the Hungarian territory a circumference which is divided into two polygons by the seventh chain, extending along the Danube River.

The total length of chains is	1250 km;
The length of western polygon is	720 km;
The length of eastern polygon	710 km;
The average length of chains is	172 km;

The average length of the sides of triangles is 30 km.

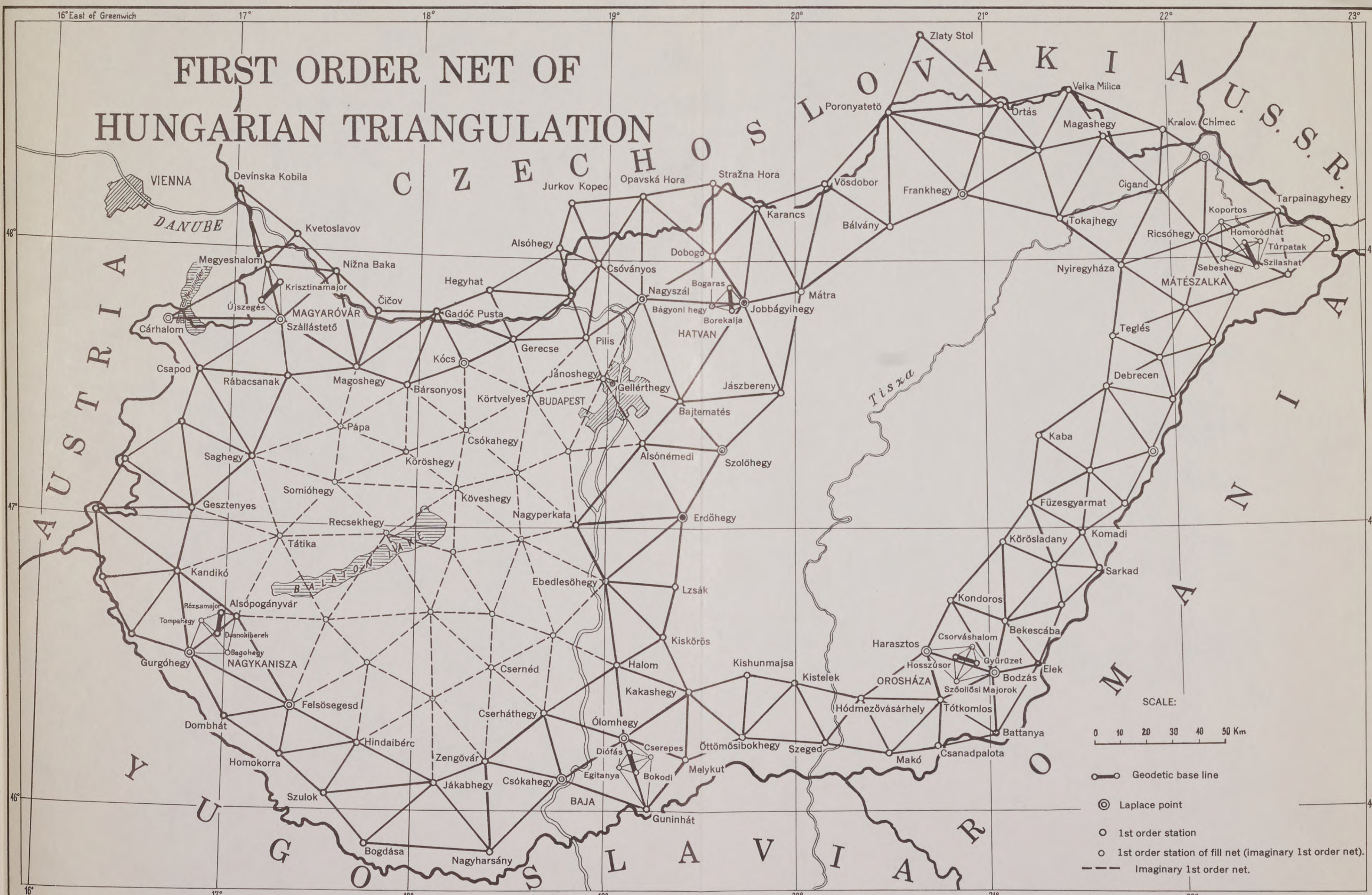
Northern two chains, extending along the Czechoslovakian boundary have 13 stations in Czechoslovakian territory, of which 11 stations are identical with the stations of the new Č.S. Basic trigonometric net - ZTS and stations Hegyhat and Alsóhegy belong to the pre-war Č.S. Basic cadastral trigonometric net. (See Inclosure 14).

The observations were carried out by the method of Schreiber with the weight 24 and the Wild T3 theodolites were used. In order to reduce the influence of lateral refraction the observations were executed partly by day and partly by night. During the day heliotropes and during the night reflectors were observed. The accuracy of observations would be expressed as follows:

The error of closure is smaller than 2".

Inclosure 19

Inclosure 20



The average error of closure $= \pm \frac{[|f|]}{n} = \pm \frac{85.903}{132} = \pm 0\overset{''}{.}551$

The mean square error of a direction computed by formula of Ferrero

$$m_d = \pm \sqrt{\frac{[f^2]}{6n}} = \pm 0\overset{''}{.}327 \quad (m_a = \pm 0\overset{''}{.}462)$$ [150]

The scale is determined from the measurements of the following 6 base lines:

Baja (1951)	8450.601 m ± 1/2,650 000	(net of 4 stations)
Hatvan (1950)	8040.150 m ± 1/2,485 000	(net of 3 stations)
Magyaróvár (1951)	9934.276 m ± 1/1,493 000	(net of 2 stations)
Mátészalka (1951)	10392.434 m ± 1/1,814 000	(net of 5 stations)
Nagykanisza (1951)	8015.930 m ± 1/1,616 000	(net of 5 stations)
Orosháza (1952)	10176.501 m ± 1/2,844 000	(net of 4 stations)

The measurements of base lines were carried out by Jäderin base apparatus with 6 wires which were compared prior and after the measurement of each base line at the 864 m long fundamental (comparative) base line at Gödölö. The base extention nets were observed by method of Schreiber with the weight 48 using the Wild T3 theodolites. In order to reduce the lateral refraction the same principles as in triangulation were followed and a half of observations on each station were carried out during the day and other half during the night. The ratio of exit sides in respect to the length of corresponding base lines vary from 1/2.2 to 1/3.5. The accuracy of derivation of exit sides through the extension nets expressed by the mean total relative error vary from 1/173000 to 1/773000 (5.8 - 1.3 mm/km). [75]

The adjustment of the first order net composed of two polygons was carried out by method of Boltz on the ellipsoid of Hayford. The results of observations were reduced to the sea level. Reduction due to the deviation of the vertical was not applied. The exit sides included into adjustment were considered as the results of measurement with the weights derived from the independently adjusted base extention nets. The accuracy of the net after adjustment would be expressed as follows:

- Western polygon with error of closure
  in latitude 1.01 m
  in longitude 1.18 m
  in azimuths $1\overset{''}{.}175$
  relative error of closure 1/460 000.

- Eastern polygon with error of closure
  in latitude 2.39 m
  in longitude 2.14 m
  in azimuth 3."51
  relative error of closure 1/220 000.

- The mean square error of a direction after the adjustment of the net is ± 0."408. [150]

In the adjustment of first order net the positions of 17 Laplace stations determined in 1951-1953 were utilized. The net primarily was oriented at the first order (Laplace) station Jobbágyihegy (north of Hatvan) having the coordinates

$$\phi = 47^\circ\ 49'55."15$$
$$\lambda = 19^\circ\ 42'40."56$$
$$\alpha = 9^\circ\ 15'19."67 \text{ to Karancs.}$$ [67]

For the new national geodetic datum the first order (Laplace) station Erdőhegy located at the center of the country was chosen. The net was reoriented and recomputed on the Krasovskiy ellipsoid. The data (ϕ, λ and α) by which the datum Erdőhegy is defined are not published nor the incorporation of the Hungarian first order net into system Pulkovo 1942, used in the military mapping of the Warsaw pact countries is discussed.

(2) The fill net: In order to reduce the time and the expense needed for a normal development of the triangulation nets, which would uniformly cover the entire territory, the Hungarians adopted a new method of triangulation proposed by Dr. Emil Regőczi. According to this method the entire territory will be covered with a net of triangles having an average length of the sides about 7 km, as in a third order net. The observations of this "third order" net are carried out with Wild T3 theodolites using the directional method in 12 positions (first order accuracy). The old first and second order stations are reoccupied where it is possible. The diagonal directions are not observed. From the "third order" fill net an "imaginary first order net" is composed by selection of dominant stations (where it is possible former 1st order stations) and imaginary triangles with the sides of 30-35 km are formed. The "third order" triangles about 20 within each imaginary first order triangle are simultaneously adjusted and the internal angles of first order triangles computed. After the completed computation of all imaginary 1st order triangles composing the imaginary 1st order fill net within a polygon this is adjusted holding the polygon fixed and the final coordinates of the imaginary 1st order stations are computed. Holding the computed 1st order stations fixed the remaining 3rd order stations within the imaginary net are adjusted. Up to 1956, about two thirds of the territory was covered in this manner by 1248 triangles of the supplementary triangulation. Within this work the observations and the

adjustment of the fill net of the western (Transdanubian) polygon were completed. This fill net is composed of 902 "third order" observed triangles (average side 7 km) and 59 first order imaginary triangles (average side 30 km) with the angles derived from the adjusted third order triangles. The accuracy of observations would be expressed as follows:

The average error of triangle closure

$$d_\Delta = \pm \frac{[|f|]}{n} = \pm 0''866$$

The mean square error of a direction computed by formula of Ferrero

$$m_d = \pm \sqrt{\frac{[f^2]}{6n}} = \pm 0''422 \ (m_a = \pm 0''626).$$

It would be of interest to know the accuracy of the imaginary 1st order net composed of triangles with the derived angles. This would be explained as follows:

The error of triangle closures vary from 0''01 to 1''42.

31 triangles have positive error of closure with $\Sigma f = + 13''36$

28 triangles have negative error of closure with $\Sigma f = - 12''33$

The average error of closure $d_\Delta = \pm \frac{[|f|]}{n} = \pm \frac{25.69}{n} = \pm 0''436$

The mean square error of closure $m_\Delta = \pm\sqrt{\frac{[f^2]}{n}} = \pm\sqrt{\frac{17.5699}{59}} = \pm 0''546$

The mean square error of an angle by Ferrero $m_a = \pm 0''316$

and the mean square are of a direction by Ferrero $m_d = \pm 0''223$. [68]

These values of the mean square errors m_a and m_d appear to be superior to the $m_a = \pm 0''462$ and $m_d = \pm 0''327$ expressing the accuracy of observations of the first order net (West and East polygon. but it should be remembered that the derived angles of the imaginary 1st order net are results of the adjustment of the observed "3rd order net". Due to this fact the mean square error of the derived angles improves for about 50% and give a false impression of superiority of the imaginary 1st order net in respect to the observed 1st order net. Meanwhile the quality of the derived angles is close to the quality of the observed angles and would justify the application of the described method in the establishment, observation and adjustment of a fill net well framed into a first order polygon.

(3) The fourth order net: According to the present project the detail (4th order) triangulation will not be newly established, but the cadastral 4th order net observed in 1860-1950, will be incorporated into the system of the recently established Hungarian triangulation. This incorporation has to be carried out within the period 1958-1968. In respect to various ages and densities of the 4th order net covering the Hungarian territory the incorporation will be executed partly by reobserving the old parts of the net (and restoring the lost points) and partly by recomputing the old points (particularly that established after 1910) by use of old observations. The computations will be carried out in Gauss-Krueger projection. The old 1st, 2nd, 3rd and also principal 4th order stations reoccupied in the observation of the first order net and fill net (3rd order net) will facilitate the incorporation. [65]

d. Elevations: A large percentage of the benchmarks established in 1921-1939, by the leveling of high precision and precise leveling, among them also the basic benchmark Nadap (I) were destroyed at the end of World War II. Due to this fact the National Geodetic Institute (Orzágos Földmerestani Intezet - OFI) in 1950 started with the establishment of the new leveling nets of high precision and precise leveling (See Inclosure 21). The elevation of basic benchmark No. 11257 Nadap (I) determined in 1888

$$H = 173.83850 \text{ m}$$

above the mean level of Adriatic Sea again was adopted as starting horizontal plane. Since the basic benchmark Nadap (I) in 1945 was destroyed 124 m southeast of its place the basic benchmark Nadap II in 1951 was established. The elevation of Nadap II marked by a system of three marks (one of special glass and two of stainless steel) placed into a concrete vault covered by four marble plates (system Krupp) was determined in respect to two undamaged reference marks N_1 (H = 174.52584 m) and N_2 (H=174.53219 m) of the Nadap I. The three marks N', N" and N"' have the follwing elevations:

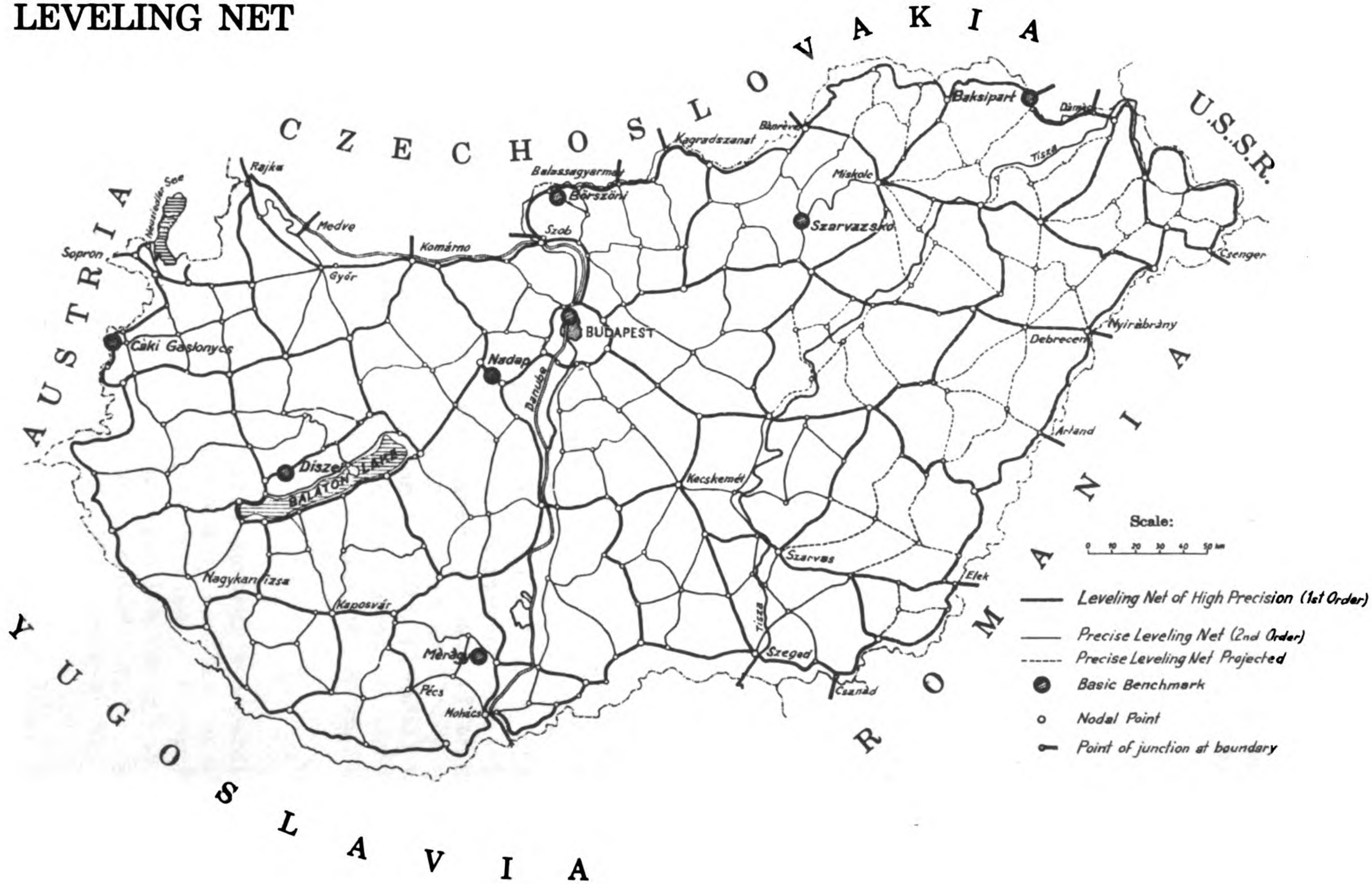
N'	(glass)	= 176.631 663 m	
N"	(V_4 A)	= 176.691 345 m	
N"'	(V_2 A)	= 176.908 422 m	[8]

Seven more basic benchmarks in geologically stable hilly regions of the country in the same manner were established.

The measurement of the leveling net of high precision begun in 1950, was completed in 1956. The observations were carried out by Wild NIII precise leveling instruments having telescope magnification 43, plane parallel glass plate (optical micrometer with reading 0.01 mm) and invar precision leveling rods with 1 cm interval. (The same instruments were used in the precise leveling).

Inclosure 21

HUNGARY
LEVELING NET



The sections of level lines were observed forward and backward. The maximal length of the sight permitted in the observing from the center was 40 m. The requiredaccuracy standards were the same as in the 1921-1939 leveling of high precision and precise leveling, but it is known that because of lack of well trained personnel they were not achieved. The adjustment of the entire leveling net is in process. The orthometric corrections were computed on the basis of the effective values of gravity by the somewhat modified formula of Helmert. [30]

The leveling net of high precision was tied with the leveling nets of Czechoslovakia and Romania. The mean difference of the connections with Czechoslovakia is

$$H_{Nadap} = H(\check{C}SJN)_{Li\check{s}ov} + 252 \text{ mm} \pm 16 \text{ mm}.$$

The difference obtained from the results of the connection with Romania is unknown.

The leveling net of high precision is included into the international system of the eastern leveling nets but the results were not published. The elevations are considered secret and are no longer shown on the benchmark plaques.

In the topographical survey carried out in 1952-1957, the elevations of the 1921-1939 leveling net and elevations determined by means of trigonometrical leveling based upon the 1921-1939 leveling net were used. These elevations used in the topo survey and shown on the maps in order to be in sympathy with the mean sea level of the Baltic Sea (referring to leveling datum Kronshtadt 1840) were reduced by 68 cm. Consequently the elevation of the basic benchmark Nadap I for mapping purposes is considered 173.16 m above the mean sea level of the Baltic Sea.[3] Since 1957 in the topographical survey the elevations of the 1950-1956, leveling net and the elevations determined by means of trigonometrical leveling in sympathy with this net are used. By the official order for the execution of the 1:10,000 (1:5000) topographical survey issued in 1957 by AFTH the elevations used in this survey should refer to the national basic benchmark Nadap. [2]

2. Topographical Survey:

After World War II the topographical surveys are carried out by the Military Cartographic Institute and by civilian agencies i.e. by the Geodetic and Cartographic Enterprise of Budapest and its field office in Pécs. The civilian agencies carry out the 1:5000 and 1:10,000 topographical surveys, meanwhile the Military Cartographic Institute executes the 1:25,000 topographical survey.

a. <u>The topographical survey at 1:5000 scale</u>: This survey started in 1952, with the aim to produce the topographic manuscripts for the compilation of the basic national topographical map needed in the planning of national economy. Nevertheless this map should also serve as the basic cartographic material in the compilation of the 1:25,000 topographical map compiled for the purpose of national defense. At the beginning of the 1:5000 topo-survey it was planned that 1:5000 map with about 18,000 sheets will cover the entire country.

The sheet lines of the plane table sheets are trapezoids cut on graticule constructed in Gauss-Krueger projection with 3^{o} zones (after 1957 the sheet lines of 1:10,000 trapezoidal sheets constructed at 1:5000 scale in Gauss-Krueger projection with 6^{o} zones are divided into four parts) having dimensions $1'15''_{\phi} \times 1'52''.5_{\lambda}$ (about 46.3 x 47.5 cm at $\phi = 47^{o}$). The sheets are provided with 10 cm (0.5 km) 3^{o} GK grid intersections. The surface of the sheet, about 5.5 km^2, represents 1/256 part of the 1:100,000 sheet. Since the sheets are cut and numbered in the system of the International map with each 1:1,000 000 sheet divided into 144 1:100,000 sheets and each 1:100,000 sheet subdivided into 256 sheets at 1:5000 scale the code number for one 1:5000 sheet would be for instance L-34-59- (178). Below the code number the name of the largest settlement located within the sheet is included. [3]

(1) In the first three years (1952-54) the survey was in the testing stage. Because of lack of trained topographers and of topographic (plane table) and photogrammetric equipment the survey mostly was carried out by former cadastral surveyors applying the method of numerical tachymetry and in settlements the orthogonal method. 150 surveyors participated in the survey. As a result of the experience of the first three years the provisional instructions for 1:5000 topographical survey were published in 1955-56. According to the instructions a brief explanation of the execution of 1:5000 survey would be as follows:

The survey has to be carried out by the numerical or graphical method. In the areas with adequate cadastral maps the cadastral planimetry is utilized. The density of the established control should be 7-14 trig points and at least 3 benchmarks per sheet (5.5 km^2). This basic control has to be densified with about 100 detail stations determined by means of numerical intersections (5th order TP's) or by transit traverses. The observations are carried out with transits having reading to 20". The maximal error of triangle closure permitted is 60". The maximal positional error of detail stations permitted is ± 0.40 m. The traverses should be no longer than 1500 m with the length of sides up to 150 m and a linear error of closure up to ± 4 m (0.8 mm). The elevations of detail stations are determined by means of trigonometrical leveling (in the flat land by spirit leveling). The maximal error permitted for the elevations of detail stations is ± 0.10 m.

The detail points ordinarily are determined tachymetrically by the polar method. The limit of distances measured by stadia is 200 m. In the closed settlements usually the orthogonal method is used.

The planimetric detail points are classified into three orders:

- 1st order detail points (tachymetrically measured permanent marks such as kilometer stones, boundary pillars, property stones, corners of buildings, objects, and crossings of railroads and roads, canals etc.) have to be determined with a positional error not larger than ± 0.4 mm (2 m).

- 2nd order detail points (permanent marks, sharply shaped planimetric features graphically intersected or interpolated, and measured or intersected corners of vegetation lines) have to be determined with a positional error not larger than ± 0.6 mm (3 m).

- 3rd order detail points, planimetric points which are not clearly shaped and relief features (salient points) have to be determined with a positional error not larger than ± 0.8 mm (4 m).

The elevations of the detail points also are classified into three orders:

- 1st order elevations, i.e. permanent marks objects and crossings of railroads and paved roads determined by spirit leveling may have a vertical error not larger than ± 0.10 m.

- 2nd order elevations, i.e. permanent marks etc. determined by means of trigonometric leveling or tachymetrically may have a vertical error not larger than ± 0.30 m.

- 3rd order elevations, i.e. salient points (points of relief features) may have a vertical error within limits expressed by formula

$$Eh_3 = \pm (0.40 + 5 \operatorname{tg} \alpha) \text{ meters.}$$ [4]

Depending on the shape of the relief and density of the cultural features there are measured per 1 km^2:

100 - 1000 detail points [58]

50 - 400 elevations. [4]

In the survey by the numerical method the surveyors are provided with the data of horizontal and vertical control, the topographical map at 1:50,000 and 1:25,000 scale and the blue lines of the cadastral planimetry reduced to 1:5000 scale with sheet lines and 10 cm (0.5 km) 3^{o} GK grid drawn in pencil. The sheets of 1:50,000 and 1:25,000 map are used for orientation in the field and in the planning. The blue line of the reduced cadastral planimetry serves as a base for all overlays which together with the field manuals including data of observations and measurements are used in the compilation of the topographical manuscript.

During the winter time the computations are completed and the topographical manuscript compiled by plotting of all measured features. By use of computed elevations and contour skeleton outline included into the master sketch of the field survey the relief expressed by contours on a special overlay is constructed and than copied into manuscript. In the expression of the relief the contours with 1 m interval, 5 m index, 0.5 m and 0.25 m auxiliary contours are used.

The vertical error permitted in the drawing of contours would be expressed as follows:

$$Eh_2 = \pm (0.40 + 5 \text{ tg } \alpha) \text{ meters}$$

$$Eh_3 = \pm (1 + 15 \text{ tg } \alpha) \text{ meters.}$$ [4]

(The same standards for the accuracy of contours as prescribed for German 1:5000 map). The manuscript is drawn in three colours, i.e. cultural features and vegetation lines in black, relief in brown and hydrography in green. Up to 1955 in the drawing of manuscripts a provisional edition of topographic symbols published in 1952 was used. In 1955, the Ministry of National Defense together with AFTH, along with the instructions for 1:5000 topo-survey, published a new edition of topographical symbols and lettering types for 1:5000 map consisting of 369 symbols and 30 types of lettering. (Similar to USSR topographical symbols).

The complete cartographic material for each 1:5000 map sheet consists of the topographic manuscript with the following enclosures:

- Operational description (progress report) which beside the name and number of sheet, names of surveyors and supervisors, types and number of instruments used, time of the survey, compilation, inspection and drawing includes also the number of given trig points, number of stations for detail survey and number of detail points determined.

- diagram of the determination (computing) of stations for detail survey;

- master sketch of survey with the contour skeleton outline;

- manuals of horizontal angles, vertical angles, and of spirit leveling;

- computation sheets of coordinates and elevations;

- overlays of elevations, planimetry with vegetation lines, nomenclature with selected spot elevations, and of inspection (field check);

- diagram of field check with profile, vertical and horizontal error of contours.

In the topographical survey by method of numerical tachymetry various types of transits, such as: Zeiss, Kern, Fennel, Suess, Szepessy and MOM with reading 6"-30" are used.

(2) The method of plane table tachymetry began to be applied in 1953. The plane table equipments with telescopic alidades of Zeiss, Suess and MOM are utilized in the survey. The blue lines of the cadastral planimetry reduced to 1:5000 scale and provided with sheet lines, grid and points plotted by coordinatograph are pasted on alumimum sheets and mounted upon the plane tables. In areas without, or with obsolete, cadastral survey the plane table sheets include only plotted control and topographers have to survey planimetry and relief. The survey is executed in accordance with the same principles as applied in the numerical method, except that horizontal positions of stations are determined by graphical intersections and in wooded regions by plane table traverses, detail points plotted and planimetry as well as relief expressed by contours drawn immediatelly i.e. topographic manuscript compiled in the field. (This is the advantage of the plane table method.) The accuracy standards in general are the same as in the numerical method except that graphically determined stations should not include positional errors larger than ± 0.1 mm (0.5 m) and traverse stations not larger than ± 0.2 mm (1 m).

(3) In addition to using both the numerical and the graphical method, the combined method including the advantages of each is also utilized. In the combined method stations and traverses are determined numerically, coordinates computed in the field and stations plotted into blue lines mounted upon the plane table. The detail survey then is carried out graphically. Since the stations determined by the numerical method have a greater positional accuracy than those determined graphically and the planimetry and relief expressed

by contours drawn in the field included more details and finesses this method, combining the advantages of the numerical and graphical methods, should be considered the most suitable for the topographical survey at such a large scale as 1:5000. One disadvantage of the combined method is that it requires two surveying instruments i.e. transit and plane table with alidade.

(4) Aerial photogrammetry: Since BGKV is in possession of very limited photogrammetric equipment aerial survey is not applied at a large scale. So far as it is known the BGKV has a Zeiss C-8 stereoplanigraph (obtained in 1956), a Zeiss SEG-V automatic rectifier and a stereocomparator.

The aerial photography is carried out by the Military Cartographic Institute (HTI) using a prewar Zeiss RMK 18 x 18 cm, f = 21 cm. camera. The existing trig points are panelled and the photographs at 1:8000 - 12,000 scale are taken in the spring time, prior to the time the trees have leaves. In the photogrammetric compilation the universal method (stereocompilation) and the combined method (one plate photogrammetry) have been applied.

(a) Universal method (stereocompilation): Vertical photographs with 60% stereo-pairs and 30% strip overlapping are used. The compilation is carried out by stereoplanigraph. The tie points, except panelled trig points, are selected on the photographs and determined in the field numerically by triangulation or traverses. Each photograph should have 5 tie points and 25 elevations identified and determined in the field and encircled on the photograph. Together with the determination of tie points in the field a classification sketch based upon the reduced cadastral map at 1:5000 scale is made. The sketch includes classification of roads, railroads, buildings, vegetations etc. The photographs with the identified tie points, computed coordinates and elevations and classification sketch are sent from the field to BGKV to be utilized in the stereocompilation. In this manner compiled manuscripts only in the forest region would need to be revised in the field.

(b) Combined method (one plate photogrammetry): In the flat land (60% of Hungary) since 1953, the combined method has been applied. The photographs are rectified on the basis of panelled trig points and identifiable points taken from 1:2000 cadastral map. The average error of rectification is ± 0.3 mm. The rectified photographs have been composed into photo maps provided with plotted sheet lines, grid and trig points, photographically reduced to 1:5000 scale and blue lines on drawing paper produced. Blue lines are pasted upon aluminum sheets, mounted on plane tables and the survey carried out by the method of plane table tachymetry in the same manner as in the case of the plane table sheets composed of the photoreduced cadastral planimetry.

(5) The average norm achieved by one topographer in the first three years of survey (1952-54) is 3.7 hectars per day (in mountainous and wooded areas 3 hectars and in flat land 5 hectars). One sheet with the surface 5.5 km^2 was completed in 5 months, hence in the 6 months of survey an average norm achieved was 6.7 km^2. Total surface completed in three years is 2732 km^2 or 3% of the territory of Hungary. Another 1533 km^2 were started but not completed; hence an average yearly coverage would be 1000 km^2. [38] Since in 1956 in the 1:5000 topographical survey there were already employed 250 topographers with added experience and since larger application of photogrammetry has been made the yearly production probably has increased to 2000 km^2. Consequently, it would take about 45 years to cover the entire territory of Hungary by 1:5000 topographical survey.

Because of such slow progress the AFTH in 1957, made the same decision as did the Cezchoslovakian surveying authorities in 1953, i.e. to continue the 1:5000 topographical survey only in the industrial and largely populated areas and the largest part of the country to be covered by the topographical survey at 1:10,000 scale. [2]

b. The topographical survey at 1:10,000 scale: Since in 1957, it was decided that the basic national topographical map needed in the planning of national economy for the entire territory has to be published at 1:10,000 scale, and only for certain areas at 1:5000 scale, the AFTH had ordered initiation of the 1:10,000 topographical survey. The survey has been carried out by application of the methods which are used in 1:5000 topographical survey described in the previous paragraph evidently with the standards of accuracy prescribed according to the 1:10,000 scale.

The sheet lines of the plane table sheets are graticule-trapezoids constructed in Gauss-Krueger projection with 6° zones having dimensions $2'30"_\phi \times 3'45"_\lambda$ (about 46.3 x 47.5 cm at $\phi = 47°$). The sheets are provided with 10 cm (1 km) 6° GK grid intersections. The surface of the sheet about 22 km^2 represents 1/64 part of the 1:100,000 sheets, 1/16 part of 1:50,000 sheet and 1/4 of the 1:25,000 sheet and its code number includes the code numbers designating all smaller scale sheets in which the 1:10,000 sheet is located, for instance L - 33-81-D-d-4. (See Inclosure 19). Below the code number the name of the largest settlement located within the sheet is included. (The new 1:5000 rectangular trapezoidal sheet constructed in 6° GK projection is 1/4 of the 1:10,000 sheet having the same code number added with ENY, EK, DNY and DK - NW, NE, SW and SE).

The elevations refer to the national basic benchmark Nadap, (but it is not mentioned which elevation of Nadap is used, the primary elevation which refers to the mean sea level of Adriatic

Sea or the elevation referring to the mean sea level of Baltic Sea.) The relief is expressed by contours with an interval of 2 m, 10 m index, lm and 0.5 m auxiliary contours. [2]

Considering the present Hungarian capacity in topographical survey the 1:10,000 (1:5000) topographical survey consisting of about 4300 sheets will be completed in about 15 more years.

c. <u>The topographical survey at 1:25,000 scale:</u> The topographical survey at 1:25,000 scale is carried out by the Military Cartographic Institute. Since all military surveying activities are kept secret very little is known about this survey.

The plane table sheets with sheet lines cut in the system of International map are trapezoids with dimensions $5'_\phi \times 7'30''_\lambda$ (about 37 x 38 cm) and with 4 cm (1 km) grid constructed in Gauss-Krueger projection with 6^o zones referring to Krasovskiy ellipsoid and Pulkovo 1942 datum. False origin is 500 km West. The plane table sheet with a surface 88 km^2 ($\phi = 47^o$) is 1/16 part of the 1:100,000 sheet and is coded for instance L-3-81-D-b. (See Inclosure 19).

(1) The Military Cartographic Institute has about 500 employees; among them the field personnel consists of about 60 topographers and 15 triangulators which constitute the topographic division composed of 6 topographic sections. The activities of triangulators are confined to densification of 4th order triangulation, establishing of 5th order triangulation, numerical traverses and technical leveling needed as a basis for the topographical survey and to determination of tie points for the photogrammetric compilation.

The photogrammetric division consists of two sections, i.e. the stereo and the rectifying section. Among the photogrammetric equipment mentioned in various articles were the following:

1 Zeiss C-5 stereoplanigraph
2 Wild A-4 autographs
1 Zeiss aerial projector-multiplex
1 Zeiss RMK 18 x 18 cm; f = 21 cm camera and
Rectifiers (probably Zeiss SEG IV and Wild-Odencrants)

(2) In 1948-1951, the Military Cartographic Institute was occupied with the revision of the 1:25,000 map. The revision was not carried out uniformly. The largest part was revised semi-instrumentally by use of a light reconnaissance plane table and by sketching, and the rest of the sheets brought up to date by photo revision.

The revision was confined to the bringing up to date of cultural features and vegetation and was carried out in a rapid manner with an average surface revised in one month about 100 km^2. (See pp. 56-57). The relief expressed by contours with 10 m interval 50 m index and 5 m auxiliary contours is the relief retained from the manuscripts of the III topographical survey of the Austro-Hungarian Empire with very few corrections, but 10 m and 5 m contours included merely by interpolation. The elevations refer to the mean sea level of Adriatic Sea. The revised 1:25,000 sheets (stereographic 60% and polyhedric 40%) were recasted into sheets cut in the system of International map. The sheet lines are constructed in Gauss-Krueger projection with 6° zones (Bessel ellipsoid) referring to Gellérthegy with geographic coordinates:

$$\phi = 47^\circ 29' 15''.321$$
$$\lambda = 19^\circ 02' 59''.536 \text{ East of Greenwich.}$$
$$(\text{Greenwich} = 17^\circ 39' 46''.02 \text{ East of Ferro}).$$

Consequently, in this recasting the GK coordinates of the Hungarian triangulation obtained by transformation of the stereographic coordinates ordered in 1944 by the Hungarian Triangulation Office were utilized.[127] Due to the new geographic coordinates of datum point Gellérthegy the graticule of the Gauss-Krueger sheets (cut in the system of International map) in respect to the graticule of stereographic sheets is shifted toward southwest for:

$$\Delta\phi = 5''.683 \ (175.5 \text{ m})$$
$$\Delta\lambda = 8''.017 \ (167.8 \text{ m})$$

Since the topographic survey at 1:25,000 scale carried out in the period between the two World Wars cover merely 25% of the Hungarian territory and the reambulated sheets with plotted cadastral planimetry in stereographic projection cover about 35% of the territory the map revision carried out in 1947-51 includes also the revision of the old (1875-1884) manuscripts of the III topographical survey of the Austro-Hungarian Empire which after World War II still represents the sole topographical survey covering about 40% of the Hungary. The revised 1:25,000 sheets were used in the correction of the 1:50,000 map and smaller scale maps.

(3) In 1952, the Military Cartographic Institute began a new topographical survey at 1:25,000 scale in which aerial photogrammetry has been largely applied. The flat area with differences of elevation smaller than 16 m is surveyed by

the combined method, meanwhile the regions with the differences in elevation larger than 16 m have been surveyed by the universal method (stereo-compilation) or by the method of plane table tachymetry. The areas covered by the 1922-38 Hungarian topographical survey are not newly surveyed but the stereographic manuscripts have been recasted to the new sheet system, reambulated and redrafted according to the new (USSR) symbols adopted in 1951.

In the survey by plane table method the plane table sheets are provided with the plotted horizontal and vertical control and reduced cadastral planimetry. Hence the survey actually consists of the checking of planimetry and bringing it up to date and of the vertical survey resulting in the expression of the relief by contours. In mountainous regions 10 m contour interval with 50 m index 5 m and 2.5 m auxiliary contours is used.

In the survey by application of the combined method the aerial photographs are rectified on the basis of panelled triangulation and points taken from the cadastral map. The rectification and composing of photo maps are carried out at 1:20,000 scale. The photo maps provided with plotted sheet lines, grid and control are photoreduced to 1:25,000 scale and blue lines made on the drawing paper. The blue lines are pasted on aluminum sheets, mounted on plane tables and checked by topographers in the field. The field check includes a complete vertical survey in the plain carried out by plane table spirit leveling, drawing of the relief, classifying and supplementing of the planimetry, particularly in the forest regions.

The relief in the flat land is expressed by contours with interval of 5 m (auxilliary 2.5 and 1.25 m) contours.

In the stereocompilation the vertical aerial photographs with 60% stereo-pair and 30% strip overlappings are utilized. The photographs at 1:16,000 scale have been taken in the spring time. The existing control is panelled by white circles and additional tie points are identified on the photographs and determined in the field by numerical intersections and traverses. The coordinates of the tie points should not have an error larger than ± 0.3 m. The tie points are plotted by coordinatograph into plane table sheets. In addition to the numerical method the graphical method of determination has sometimes been used and tie points determined by plane table triangulation and traverses. The compilation at 1:20,000 scale is carried out on Zeiss stereoplaingraph and Wild autographs. The stereocompiled manuscripts are checked in the field by topographers.

By the application of photogrammetry the average norm achieved by an topographer in six months is 170 km^2. At the present time the survey covers the region west of the Danube River and of the region east of Danube the part located south of the Budapest-Oradea railroad. The survey should be completed in 1960. 1134 sheets would cover the entire territory of Hungary.

3. Maps:

In Hungary the maps published prior to World War II are still used. The post World War II large and medium scale maps showing the territory of Hungary are classified. According to the information released in professional periodicals the following post war maps are published or have been in the process of compilation and reproduction:

a. Cadastral map at 1:2500 scale: This map consists of the quadratic sheets with the dimensions 60 x 60 cm (1.5 x 1.5 km) with 10 cm (250 m) grid intersections constructed in the Gauss-Krueger projection with 2^o zones. The sheets are coded by a combination of figures expressing the kilometers in Easting and Northing of the coordinates of the southwestern sheet corner, for instance 067.5-129.0. The sheets of this map are reproductions of the manuscripts compiled at 1:2500 scale (or compiled at 1:2000 and reduced to 1:2500 scale) from the records of numerical field survey. At present they include only cadastral planimetry but the inclusion of elevations and relief is projected. [2]

   The map is drawn according to the symbols (Egyezményes jelek) published in 1956. Altogether 241 symbols are used.

b. Cadastral map at 1:10,000 scale: The sheet lines are 60 cm (6 km) squares provided with 10 cm (1 km) grid intersections constructed in the Gauss-Krueger projection with 2^o zones. The map is compiled from the photoreduced 1:2500 manuscripts, where 16 manuscripts (4 x 4) at 1:2500 scale compose one 1:10,000 sheet. The sheets are coded in the same manner as 1:2500 sheets for instance 072-120. [2]

c. Basic national topographical map at 1:10,000 (1:5000) scale: The sheets are polychrome reproductions of the topographical manuscripts at 1:10,000 (1:5000) scale, retaining the same sheet lines, dimensions and grid. The manuscripts are photo enlarged to 1:8000 (1:4000) scale, blue-lines on drawing paper reproduced and colour separations drawn. In the drawing of colour separations the symbols published in 1955 have been used. For the areas surveyed at 1:5000 scale the sheets at the same scale and the sheets at 1:10,000 scale (each compiled

The topographic manuscripts and colour separations are drawn at BGTV, but the maps considered secret are reproduced at the Military Cartographic Institute (HTI).

d. Topographical map at 1:25,000 scale: The sheets of this map are reproductions of the topographical manuscripts (revised or newly surveyed) which at the same time are used as cartographic manuscripts. The topographical manuscripts are photoenlarged to 1:20,000 scale and blue lines processed on which the colour separations are drawn. The map sheets are cut in the system of International map having the same sheet lines dimensions, grid and code numbers as 1:25,000 topographical manuscripts (plane table sheets). There are two post World War II editions of the 1:25,000 topographical map of Hungary.

(1) First edition: This edition published 1949-1953 by the Hungarian General-staff (Magyar Néphadsereg Vezérkari Fönökség) covers the entire territory of Hungary. The sheets are redrafted manuscripts of the 1948-1951 revision. Those sheets which cover the boundary regions of Czechoslovakia, USSR and Romania are completed by cartographic material obtained in the mutual exchange. Since Austria and Yugoslavia did not participate in the exchange of cartographic material, the sheets covering Austrian and Yugoslav boundary regions are completed with the cartographic material obtained prior to or during World War II.

The colour separations are drawn according to the symbols adopted in 1951. These symbols are the same as used in USSR, but with the abbreviations in Hungarian language. The "topographic key" (Jelkucs a katonai térképekhez) consisting of 242 symbols was published in 1954 by the Ministry of National Defense (Honvéd Miniszterium). Among the 242 symbols used in the 1949-53 mapping 19 symbols published in this topographic key were changed in 1953. The relief is expressed in the same manner as in the topographic manuscripts. The reproduction has been made in six colours, i.e. sheet lines, grid, cultural features nomenclature and marginal information in black, hydrography in blue, relief in brown, forests in green, first order roads with red, second and third order roads with yellow fill. It should be mentioned that the stereographic sheets of the Hungarian 1:25,000 topographical map published in the period between the two World Wars include 2.5 m auxiliary contours and more details in expressing of settlements and vegetations. The stereographic sheets appear to be prepared with greater care, but the new sheets published in 1949-1953 are more legible.

(2) Second edition: The sheets of this edition are reproductions of the topographical manuscripts surveyed in 1952-1960, or of the reambulated and recasted stereographic manuscripts of the 1922-1938 topographical survey. The sheets covering the regions surveyed at 1:10,000 (1:5000) scale have been compiled from the manuscripts of the 1:10,000 (1:5000) topographical survey. The drawing and reproduction have been carried out in a manner similar to that of the first edition. In the drawing of the topographic manuscripts which serve as cartographic manuscripts and in drawing of colour separations the topographic symbols published in 1954 have been used. The relief is expressed in the same manner as in the 1:25,000 topo manuscripts. The elevations refer to the mean sea level of the Baltic Sea (Kronshtadt 1840). The sheets of the maps published by the Military Cartographic Institute with the elevations referring to the Kronshtadt vertical datum include this remark: "Egységes magassági rendszerben" (Uniform elevation system).

The sheets of the second edition over the sheets of first edition show a great improvement. No records in respect to accuracy are known and no sheets to be cartographically analyzed are available. From the manner in which the topographical survey and compilation of the map are carried out it should be assumed that the second edition would meet the contemporary requirements prescribed for a 1:25,000 topographical map. It is planned that all 1134 sheets which cover the territory of Hungary up to the end of 1960 have to be published.

e. <u>Topographical map at 1:50,000 scale</u>: The basic cartographic material used in the compilation of the 1:50,000 topographical map are the sheets of the second edition of the 1:25,000 topographical map reduced to 1:40,000 scale. The compilation of a 1:50,000 sheet starts immediately after the completion of the respective four 1:25,000 sheets. The sheets are trapezoids cut in the system of International map with dimensions $10'_\phi$ $15'_\lambda$ and the 4 cm (2 km) grid constructed in Gauss-Krueger projection with 6^o zones. The surface of a sheet at the center of Hungary ($\phi = 47^o$) is 352.1 km^2. The sheets are similar to those of the USSR 1:50,000 topographical map. In the drawing of colour separation the topographical symbols published in 1954 are used. The progress of compilation and present coverage are unknown. 318 sheets would cover the entire territory of Hungary. The code number for an 1:50,000 sheet is for instance L-33-81-B. (See Inclosure 19).

f. Topographical map at 1:100,000 scale: The compilation of 1:100,000 sheets startsimmediately after the completion of the respective four 1:50,000 sheets which serve as basic cartographic material. In the drawing of colour separations the topographical symbols published in 1954 are used; hence the sheets have an appearence similar to the sheets of the USSR 1:100,000 topographical map. 92 sheets would cover the entire territory of Hungary. The sheets are trapezoids with dimensions $20'_{\phi}$ x 30_{λ} with 5 cm (5 km) grid constructed in Gauss-Krueger projection with 6^{o} zones. One sheet represents 1/144 part of the 1:1,000,000 sheet of International map and at the center of Hungary ($\phi = 47^{o}$) covers 1408.5 km^{2}. The code number for 1:100,000 sheet for instance is L-33-81. (See Inclosure 19). The progress in compilation and present coverage are unknown.

g. Topographical map at 1:200,000 scale: The sheetsof this operational map are composed each of four 1:100,000 sheets which in its compilation serve as basic cartographic material. The sheets are trapezoids with dimensions $40'_{\phi}$ x 1^{o}_{λ} with 5 cm (10 km) grid constructed in Gauss-Krueger projection with 6^{o} zones. One sheet represents 1/36 part of the 1:1,000 000 sheet of the International map, covers at center of Hungary ($\phi = 47^{o}$) 5634 km^{2} and is coded for instance L-33- XVII (See Inclosure 19). The entire territory of Hungary would be covered by 28 sheets. The compilation follows immediately after the completion of the respective four 1:100,000 sheets. Nothing is known about the progress and present coverage.

h. Synoptical map at 1:500,000 scale: The entire territory of Hungary will be covered by eight sheets having dimensions 2^{o}_{ϕ} x 3^{o}_{λ}. Progress in compilation of this map is not known.

i. International map at 1:1,000 000 scale: Hungary is covered by the sheets M33, M34, L33 and L34 of the International map. There is no information to show whether the map is already in process of compilation.

j. The National Geodetic and Cartographic Administration - AFTH is publishing numerous school maps, atlases, city plans, tourist maps, administrative maps and road maps, all for public use. The compilation and reproduction are carried out by the Cartographic Enterprise in Budapest. Among these altlases, plans and maps the following should be mentioned:

Atlas for elementary schools, 32 pages
Atlas for high schools, 52 pages.
City plans of: Budapest, Debrecen, Györ, Keczkemét, Pécs, Szeged and pocket map of Greater Budapest.
Tourist maps of: Bakony, Balaton Lake and vicinity,

Bőrszony, Budai hegyek, Bűk, Mátra, Mecsek, Pilis, Zempléni hegyseg.

1:500,000 administrative map of Hungary.
1:400,000 road map of Hungary, 27 sheets, and
1:600,000 road map of Hungary.

ITALY

IV. ITALY

After World War I the Austro-Hungarian Empire disintegrated and Italy succeeded in pushing its northeastern frontiers to the watershed separating the Adriatic Basin from the Danubian Basin. In order to assure a more favorable boundary from a military aspect, Italy annexed parts of the former Austrian provinces Tyrol, Carinthia, Carniola, Dalmatia and the entire province Littoral including the Cities of Trieste and Fiume (Rijeka) with a total surface of about 23,000 km^2. This chapter includes a detailed discussion about the various topographic surveys utilized in the compilation of the Italian topographic maps covering the annexed territory, which constitutes the Italian provinces Venezia Tridentina (South Tyrol), Venezia Giulia (Littoral) and Zara (Zadar), as well as a general review of the Italian mapping.

The Italian Military Geographic Institute (Istituto Geografico Militare created in 1872 as Istituto Topografico Militare and renamed in 1882 Istituto Geografico Militare), the agency responsible for the topographical survey and mapping, after World War II in 1948 initiated extensive works which were intended to cover within a reasonable time the entire national territory with new topographical maps based on a new geodetic foundation. Consequently the Italian mapping at the present time is in a stage of transition which includes revision, recasting and regriding of the existing tavolettas and sheets of 1:50,000, 1:100,000 and 1:200,000 maps.

1. New Geodetic Foundation:

   a. International Ellipsoid since 1945 used in Italian mapping.

   b. Projection: Gauss-Boaga conformal projection.

This projection is well known Gauss conformal (Transverse Mercator) projection previously used in Italian cadastral survey; for which simplified application Prof. Boaga computed formulae and tables. [132] By its adoption by military authorities the Italian mapping, topographical and cadastral, became uniform. The projection has two 6° zones with central meridians 9° and 15° East of Greenwich. Since the linear distortion factor in 6° zones varies between 1 and a maximum 1.0008 the scale factor 0.9996 was introduced in order to assure in the construction of 1:25,000 tavolettas (9.2 x 9.6 km) a higher graphical approximation than 0.2 mm (0.15 mm). In order to preserve the old graticule sheet-division of the polyhedric projection (Projezione naturale) of the system of Carta d'Italia with meridians counted from Rome, Monte Mario = 12°27'08."40 East of Greenwich (Determination 1940) the two grid systems of Gauss-Boaga projection are limited:

West Zone (I):
from 6° to 12°27'08."40 East of Greenwich (Meridian of Monte Mario).

East Zone (II):
from $11^{\circ}57'08''.40$ (Meridian 30' West of Monte Mario) to $18^{\circ}30'$ East of Greenwich.

Overlapping Zone:
of 30' limited by meridians of $11^{\circ}57'08''.40$ and $12^{\circ}27'08''.40$ East of Greenwich concide with the column of the 1:100,000 sheets of Carta d' Italia confined between the - $0^{\circ}30'$ and $0^{\circ}00$ (Monte Mario) meridians. (See Inclosure 22). Rectangular plane coordinates of Gauss-Boaga projection are expressed by:

N (Northing) = x (4,000.000 - 5,300.000 North of Equator).

E (Easting) = 1,500.000 ± y in Zone I

2,520.000 ± y in Zone II

where "1" and "2" are index numbers for zones, 500,000 and 520,000 false eastings and y departure from central meridian. [178]

c. Triangulation: The Italian First Order Net (Rete Geodetica Italiana Fondamentale). Because the new observations would not have any influence of practical value on the accuracy of the coordinates obtained from the old adjustment published in 1908 and 1919 in the Elementi della Rete Geodetica Fondamentale (Ellipsoid Bessel, datum Genova 1908), the old Italian first order net with all restorations and attachments (Triangulation of Venezia Tridentina in 1930-36 and Venezia Guilia-Dalmatia chain in 1942) was retained.[128] (See Inclosure 23). After the adoption of the International Ellipsoid in 1942, the geographic coordinates of the first order net in terms of Bessel Ellipsoid with Genova 1908 datum:

$$\phi = 44^{\circ}25'08''.235$$

$$\lambda = 0^{\circ}00'00''.00 = 8^{\circ}55'15''.709 \text{ East of Greenwich}$$

$$\alpha = 117^{\circ}31'08''.91 \text{ to M del Telegrafo}$$

were transformed to geographic coordinates which refer to International Ellipsoid oriented at Rome, Monte Mario with:

$$\phi = 41^{\circ}55'25''.51 \pm 0''.027$$

$$\lambda = 0^{\circ}00'00''.00 = 12^{\circ}27'08''.40 \text{ East of Greenwich}$$

$$\alpha = 6^{\circ}35'00''.88 \pm 0''.12 \text{ to Monte Soratte}$$

(Determination of Italian Geodetic Commission in 1940). Special care is given to the revision and maintainance of the first order net i.e. the existence of markers is checked and the lost markers restored by the method of "ripristino" with an maximal error ± 0.15 m. Records from reobservations would serve for a new adjustment in the future, which would have scientific rather than practical significance. In the observations made since 1932, the Wild T3 theodolites have been used. The observations are carried out by Schreiber's method with weight 24. The accuracy of observations expressed by the mean square error of an observed angle computed by formula of Ferrero is:

$$m_a = \pm \sqrt{\frac{[f^2]}{3n}} = \pm 0''.46$$ [14] [15]

Since the lower order triangulation is relatively old, and lacks uniformity and since a large number of markers already had disappeared it was decided to establish a completely new II, III and IV order net with a density of 7-10 trig points per one tavoletta (90 km^2). The extensive field work on lower order triangulation is in process along with the revision of the first order net. In order to cover various current needs in the time of transition, the coordinates of old lower order trig points were brought into sympathy with the transformed coordinates of the reoriented first order net, but the new topographical survey at 1:25,000 scale trailing the new triangulation, is based on newly determined trig points. [128]

d. Elevations: The Italian Geodetic Commission in 1940, decided to establish a completely new vertical net. The project includes a leveling net of high precision consisting of 36 polygons with a total length of 14,000 km connecting together about 20,000 benchmarks. (See Inclosure 24). The work started in 1949 and is expected to be completed within 12 years. By the end of 1956 there had been observed 8000 km with 14000 benchmarks. The duplicate level lines are divided into sections with the length of 25 km and stabilized by four types of benchmarks i.e:

1st class: Starting benchmarks and benchmarks at mareographs, nodal benchmarks and benchmarks at junctions with leveling of neighbouring countries;

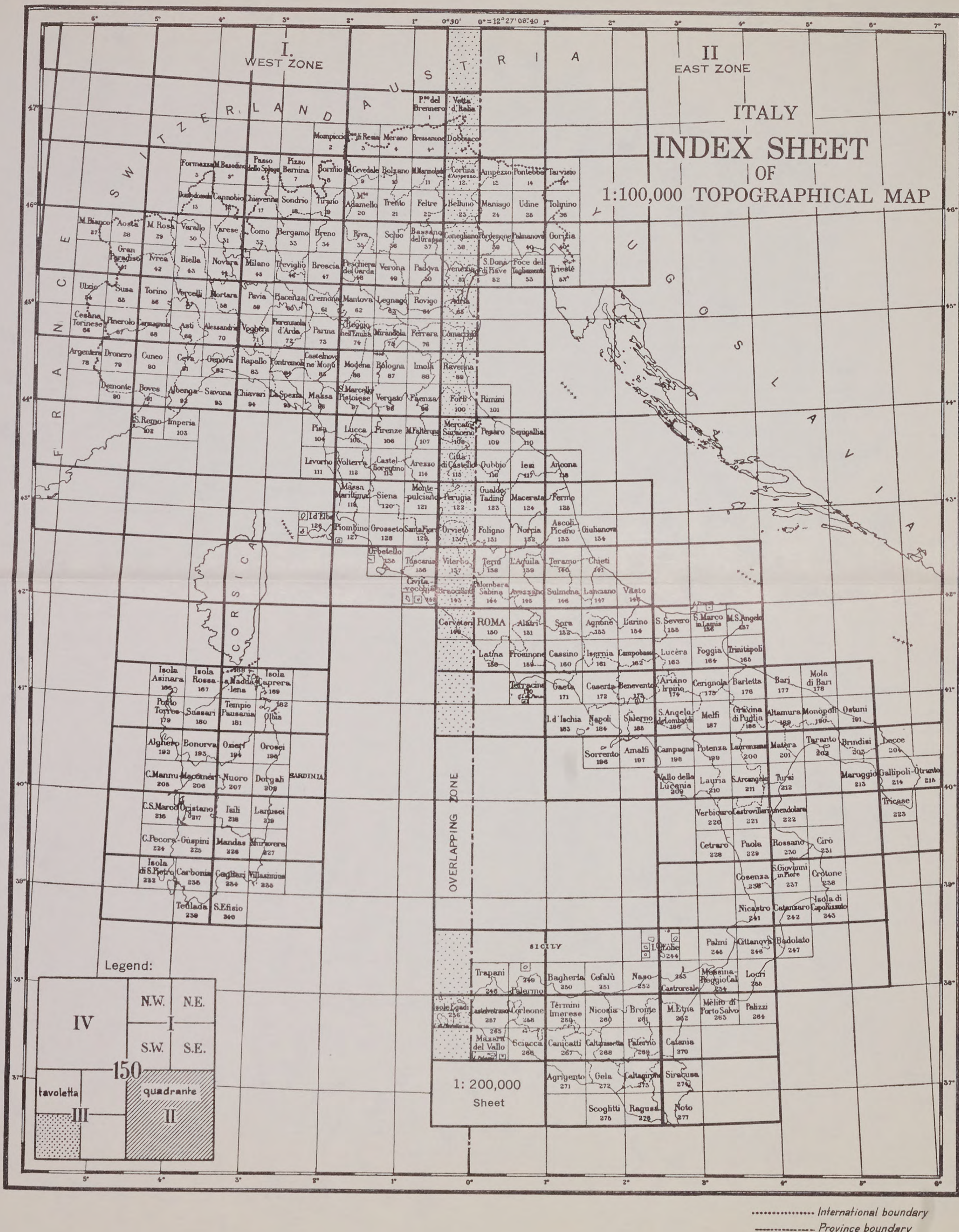
2nd class: fundamental benchmarks limiting the 25 km sections;

3rd class: principal benchmarks two placed at a distance of 1 km at intervals of 5 km;

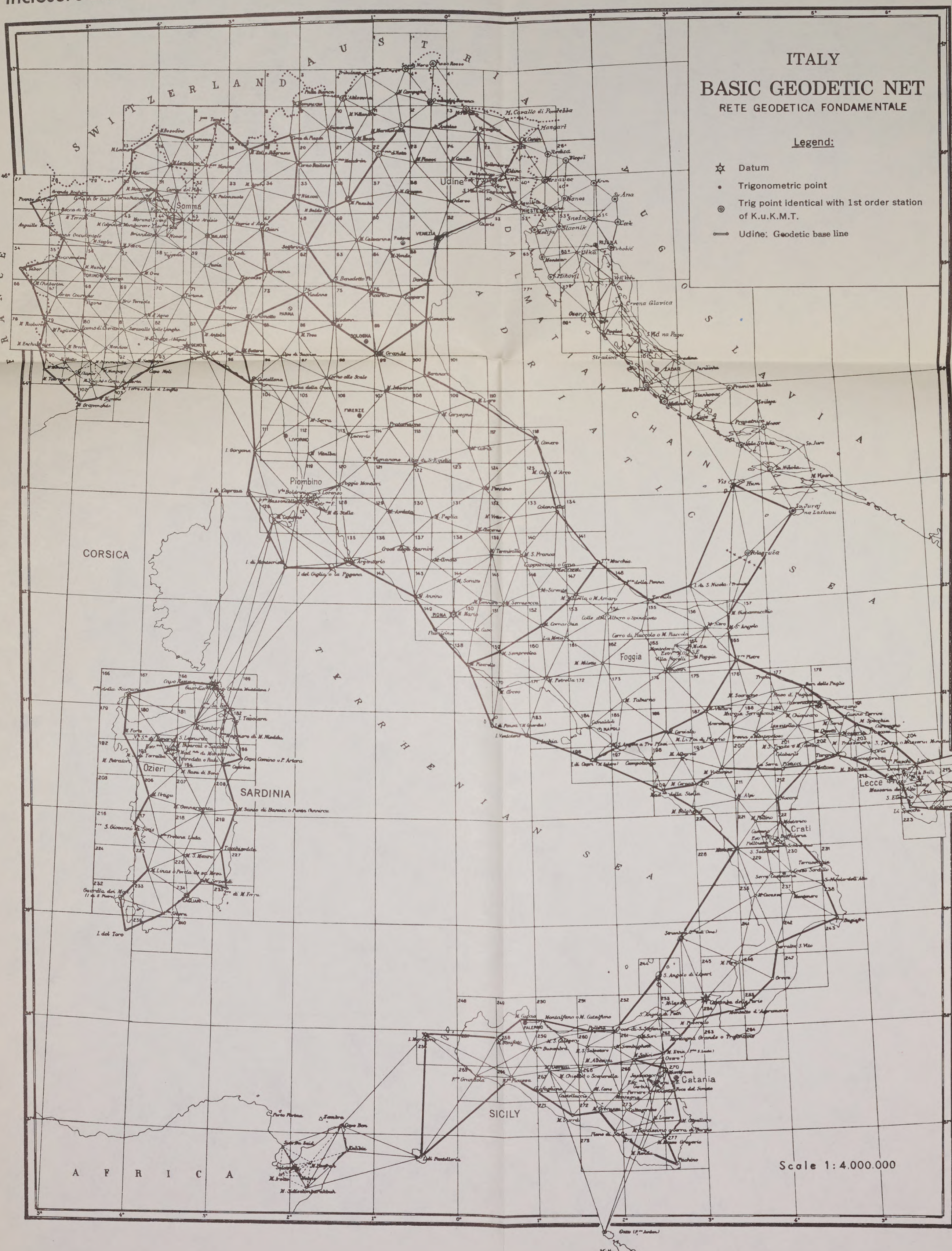
4th class: line benchmarks placed at limits of the line observed in one day - about 1 km.

The observations have been carried out with the Zeiss III and Zeiss A precise leveling instruments having optical micrometers and invar rods with 0.5 cm intervals. The parts of level lines with a length about 1 km the same day are observed in both directions

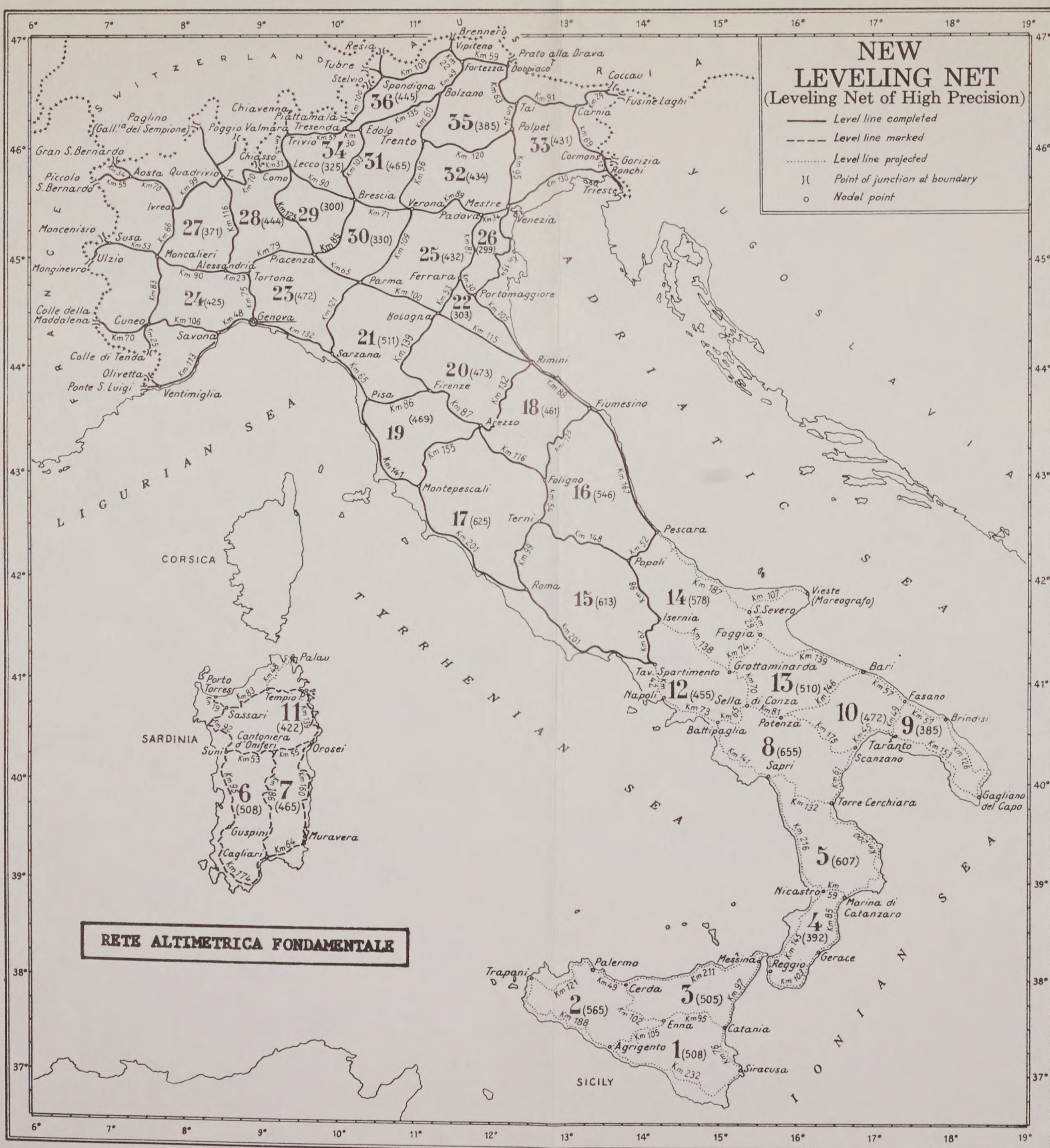
Inclosure 22



Inclosure 23



Inclosure 24



by the application of the method of observing from the center with a maximal length of the sight permitted 40 m. The maximal difference permited in the duplicate level lines is $\pm$ 2.5 mm$\sqrt{L}$ km.

The new vertical net is designed to completely satisfy the standards established in 1948 by the International Geodetic and Geophysical Association. (Convention in Oslo). The accuracy computed by the International formulae (defined in Oslo) utilizing the elements:

ρ = difference between forward and backward observations of an interval limited by two consecutive benchmarks; with the length R;

λ = difference between forward and backward observations of a level line having length L

obtained from 2500 km observed duplicate level lines is expressed as follows:

probable accidental error $\eta = \pm 0.40$ mm/km
probable systematical error $\zeta = \pm 0.60$ mm/km
probable total error $\tau = \pm\sqrt{\eta^2 + \zeta^2} = \pm 0.72$ mm/km [157]

According to the decision of the International Geodetic and Geophysical Association (Florence 1955) the Italian leveling net of high precision (only 2250 km of the northern part running through provinces Piemonte, Liguria, Lombardia and Venezia) has to be included into the European uniform leveling net. For the purpose of the adjustment based upon the potential of gravity along the principal leveling lines the gravimetric measurements with gravimeters Worden were carried out with an accuracy of ± 0.5 mgal and geopotential elevations of the basic, nodal fundamental and principal benchmarks determined. The measurements were attached to the basic Italian gravimetric net (Rete Gravimetrica Italiana) with the reference value of gravity

$$g \text{ Milano} = 980{,}5640 \text{ gal.}$$

The gravimetric measurements (1600 station) along the leveling lines (2250 km) included into the European uniform leveling net were completed in 1956.[158] The Italian Geodetic Commission decided to extend this gravimetric measurements along the principal leveling lines of the entire leveling net of high precision. In 1958, the observations of leveling net of high precision have been continued in Southern Italy and Sardinia and the gravimetric measurements are carried out along the leveling lines in Central Italy.

Leveling datum: The elevations of the newly established leveling net of high precision and upon it based vertical control refer to the mean sea level of the Sea at Genova defined from the registrations of the mareograph in the 1937-1946 period and called: leveling datum Genova 1942. (1942, is the mean year in the 1937-1946 period).

The mareograph is located at pier near the Harbour master's house in the part of Harbour of Genova called Porto Ponte di Morosini. The elevation of the starting benchmark (Caposaldo Ponte Morosini) derived from the 1937-1946 tidal observations is

+ 3.2490 m

above the mean sea level Genova 1942.[157] By the decision of the Italian Geodetic Commission in 1952, the elevations of the vertical control have to refer to the leveling datum Genova 1942.

Since the Italian leveling datum until 1952 was the mean sea level of the Mediterranean Sea, determined in 1904 from the observations of mareographs at Ancona (8 years), Civitavecchia (8) Genova (20), Livorno (20) Napoli (8), Porto Corsini (20) and Venezia (20), it is of interest to know that the mean sea level Genova 1942 is

0.0537 m

higher than the mean sea level Genova 1897 derived from the observations of the mareograph placed in Bacino Carenaggio, northwest of the location of present instrument, carried out in the 1884-1909 period.[157]

The elevations of the new leveling net in respect to the elevations of the old leveling net at common points show the variations (new-old) within limits:

from + 12 cm to - 32 cm.

It could be stated that these differences are of magnitude important rather for scientific than for mapping purposes.

e. <u>The new catalogues of Italian triangulation are published in two editions:</u>

(1) With geographic coordinates of Rome, Monte Mario system (determination 1940) and rectangular plane coordinates of Gauss-Boaga projection referring to International ellipsoid. (Native system).

(2) With geographic coordinates of ED and rectangular plane coordinates of UTM projection.

2. <u>Old geodetic foundation:</u>

a. Ellipsoid of Bessel.

b. Polyhedric projection, (Projezione naturale):

Polyhedric, sometimes called also polycentric or natural projection is an equal - area projection with the meridians and parallels framing the sheets considered as straight lines. The 1:100,000 sheet (foglio) with dimensions $20'_\phi \times 30_\lambda$ until 1895 was regarded as the projecting plane, touching the ellipsoid at the sheet center. Since a plane trapezoid regarded as a projection of a spheroidal trapezoid with dimensions $20'_\phi \times 30'_\lambda$ at 1:25,000 scale show an unpermissible distortion in 1895 a plane table sheet of $5'_\phi \times 7'30_\lambda$ (tavoletta) was introduced as an individual projecting plane. The sheets are trapezoids cut according to the graticule with starting meridian Roma, Monte Mario. The 1:100,000 sheet (foglio) of $20'_\phi \times 30'_\lambda$ is composed of four $10'_\phi \times 15'_\lambda$ 1:50,000 sheets (quadrante) or 16 $5'_\phi \times 7'30'_\lambda$ plane table sheets (tavoletta) at 1:25,000 scale. (See Enclosure 22). Evidently, "projezione naturale" is identical with the polyhedric projection used in Austro-Hungarian mapping except for a different sheet size and starting meridian.

Until the introduction of kilometric grids of Gauss-Boaga and UTM projections in 1948, the sheets of 1:100,000, 1:50,000 and 1:25,000 maps were provided with 1' graticule.

c. Triangulation. The fundamental and uniform Italian map Grande Carta d' Italia was created in 1862, by decision of the parliament of the United Kingdom Italy. The topographical survey for the new map, constructed in the Bonne modified conical projection with the origin in intersection of meridian of Capodimonte Observatory

$14^\circ15'27''91$ East of Greenwich and
40° parallel,

begun together with a rapid triangulation. In 1875, along with the decision to extend the topographical survey from the regions of the former Kingdom Naples over all territory of the united Italy, the polyhedric projection (Projezione naturale) was adopted and the topographical system of Carta d' Italia was established with the datum I order trig station Rome, Monte Mario (vertical axis of round turret) with:

$$\phi = 41^\circ55'25''.42$$

$$\lambda = 0^\circ00'00''.00 = 12^\circ27'14''.00$$ East of Greenwich, geodetically derived from the astronomic observatory Capodimonte near Naples.[133] Despite the fact that datum Rome, Monte Mario

later was astronomically determined in 1904/5 and 1940 and that values, obtained from astronomical observations, in longitude differ considerable from the primary geodetic determination (-7".16 and - 5".60 respectively) the above given value geodetically derived from Capodimonte was used until the introduction of International ellipsoid in Italian mapping. There was not any uniform triangulation at that time which would cover all the territory of Italy. The observations of first order net which includes 340 stations together with measurements of base lines: Somma, Udine, Piombino, Ozieri, Foggia, Lecce, Crati, Catania, as well as the observations of lower order triangulations were still in process. (See Inclosure 23).

The base lines were measured with the Bessel base apparatus consisting of bimetallic bars (iron and tin). The data about year of measurement, length and accuracy are given as follows:

Foggia (1859-60)	3930.4206 m ± 1/1,319000
Catania (1865)	3692.1800 m ± 1/ 587000
Crati (1871)	2919.5530 m ± 1/ 751000
Lecce (1872)	3044.2301 m ± 1/ 836000
Udine (1874)	3248.5785 m ± 1/1,504000
Somma (1878)	9999.5380 m ± 1/2,288000
Ozieri (1879)	3402.2287 m ± 1/1,890000
Piombino (1895)	4621.5696 m ± 1/ 945000

The accuracy of the observation of the angles in the base extention nets is expressed by the mean square error of an angle

$$m_a = \pm 0''.53 \quad [148]$$

Considering the shape and topography of Italy it was decided to cover the entire territory with a closed first order net. Due to the better adaption to the topography the net is composed of triangles the shapes and sizes of which considerably vary, for instance the triangles in Liguria, along French boundary, in Puglia and on Sicly have an average side 22 km, meanwhile the average side of the triangles in Central Italy is 55 km. The smallest first order side M. Trazzonara-Trasconi in province of Puglia has a length of 12.5 km and the largest side M. Capanna-Punta Maggiore di M. Nieddu connecting Elba and Sicily islands has a length of 232 km.

The location of base lines was selected in such a manner that the connecting chains consist of 20-25 triangles and do not exceed a length of 400 km.

The observations were carried out by use of the Pistor, Repsold, Reichenbach-Brunner, Starke and Salmoiraghi theodolites with the reading of 1" or 2". Since 1932, the Wild 3 theodolit has been used. At the outset of triangulation the directions were observed in 10-12 positions by method of Bessel (similar to Struve method) but later the Schreiber's method of observation of angles in all combinations with a weight 24 has been applied. Since various types of instruments were utilized and observations carried out with different methods the accuracy of observations differ considerably. The accuracy of observations carried out prior to 1932, with old types of instruments, would be expressed by mean square error of an angle

$$m_a = \pm\sqrt{\frac{[f^2]}{3n}} = \pm 0''.93$$

The first adjustment by the method of least squares of the first order net was accomplished in 1889, but in 18 partial nets having different scale and orientations. Geographic coordinates resulting from this adjustments of partial nets belong to various systems, i.e:

System Genova for Northern and Central Italy, determined in 1874.

System Rome, Monte Mario determination 1874/75 of Prof. Respighi for parts of Central Italy (not identical with topographical system);

System Castanea della Furie for South Italy and Sicily; (Longitudes partly refer to Rome, M. Mario 1874/75).

System Guardia Vecchia for Sardinia with longitudes refering to Rome, M. Mario 1874/75.

The relation of each of the four systems in respect to the system Genova 1908 expressed in the geographic position which the datums Genova 1874, Rome, Monte Mario 1874/75, Castanea delle Furie and Guardia Vecchia obtained in the adjusted and uniformly oriented first order net (Rete Geodetica Fondamentale) is shown in the following table:

Datum		ϕ, λ, α	ϕ, λ, α in system Genova 1908
Genova 1874	ϕ	44° 25' 08".48	44° 25' 08".235
		0 00' 00.00	0 00' 00.00
East of Greenwich	λ	8 55' 21.08	8 55' 15.709
to M. del Telegrafo	α	117 31' 08.86	117 31' 08.91
Rome, M. Mario	ϕ	41 55' 24.585	41 55' 24.399
Prof. Respighi 1874/75		0 00' 00.00	+3 31' 51.133
East of Greenwich	λ	12 27' 12.50	12 27' 06.842
to M. Gennaro	α	62 38' 20.03	62 38' 21.36

Castanea delle Furle	ϕ	38° 15' 53".380	38° 15' 53".028
	λ	0 00' 00.00	+ 6 35' 57.056
East of Greenwich		15 31' 18.435	15 31' 12.765
to Milazzo	α	271 09' 16.26	271 09' 20.45
Guardia Vecchia	ϕ	41 13' 21.15	41 13' 18.491
West of Rome. M. Mario	1874/75	-3 03' 13.29	+0 28' 39.613
East of Greenwich	λ	9 23' 59.21	9 23' 55.322
to La Curi	α	156 51' 01.34	156 51' 02.40

Lower order triangulation including 27,000 trig points is based on partial nets or was incorporated into partial nets (as for instance the triangulation in the region of former Kingdom of Naples.) The geographic coordinates of I-IV order points computed in the above mentioned four systems are published in the "Elementi Geodetici dei punti contenuti nel foglio---della Carta d' 1:100,000", separate trig list for each 1:100,000 sheet. (The new lower order triangulation of Calabria since 1935 is computed in the system of finally adjusted I order net. In regions of North and Central Italy only some of the new editions of trig lists of 1:100,000 foglios include the coordinates brought by linear conformal transformation into sympathy with finally adjusted first order net.)

After 1890, the first order net (Rete Geodetica Italiana Fondamentale) was revised, partially resurveyed and destroyed markers were restored. The revision was sufficiently accurate in the part north of parallel of Rome, therefore this part including the attached net of Sardinia was adjusted and the geographic coordinates referring to Genova (pillar on the terrace of the observatory of Naval Hydrographic Institute; coordinates given in chapter New Geodetic Foundation) published in 1908. The adjustment was carried out by the method of least squares in three partial nets named for respective base lines Somma, Udine and Piombino serving in determination of scale. The linear agreement among these three nets was obtained by a connecting chain of triangles having a compromising scale. The mean square error of a direction in the connecting chain resulting from the adjustment is:

$$m_d = \pm 1''.52$$

The partial net of the Island Sardinia with the scale derived from the base line Ozieri was attached as a whole to the northern part of the Italian first order net. [148]

Due to a lower degree of accuracy the part south of the parallel of Rome was reobserved. The adjustment was carried out in four partial nets referring to the base lines from which each net obtained the scale, i.e: Foggia, Lecce, Crati and Catania. In order to preserve the uniformity of the entire first order net the adjustment of the southern part was carried out, giving consideration to the conditions imposed by the tie with the northern part. The geographic coordinates referring to Genova 1908 datum were published in 1919. To this first order net were attached:

(1) First order net in Venezia Giulia (Littoral) extended from the sides Udine - M. Canin (Kanin) and Udine - Aquileia was observed in 1930-31. All first order stations, except station Učka (Monte Maggiore), are identical with first order stations of the K. und k. III Austro-Hungarian Military triangulation. Lower order net was observed in the same years, but was supplemented in 1938-39. After the adjustment of the triangulation of Venezia Giulia the geographic coordinates were published in "Catalogo Generale degli Elementi trigonometrici". This catalogue, published in 1943 in form of trig lists covering one 1:100,000 sheet, includes geographic coordinates referring to Monte Mario datum which are in sympathy with the system of Carta d'Italia. [74]

(2) First order net in Venezia Tridentina (South Tyrol). The triangulation for the purpose of the delimitation between Italy and Austria executed in 1921-23 established a preliminary relation between the K. und k. III Austro-Hungarian Military triangulation in South Tyrol and Italian first order net. This preliminary relation between two nets is expressed by the average differences

$$\Delta \phi = 1''.75$$

$$\Delta \lambda = 30^\circ\ 07'\ 10''.02$$

obtained from the comparisons of geographic coordinates of the K. und k. MT first order stations in South Tyrol oriented on Hermannskogel with the coordinates of the same stations in Monte Mario system, computed by using of Austro-Hungarian observations and Italian data of starting side M. Peralba-Birkenkofl (Croda dei Baranci) common to K. und k. MT and Italian first order net.[137] In 1934-35, the Italian first order net was extended over South Tyrol and the K. und k. III Military triangulation was replaced by newly-determined Italian first order stations. Only the following 9 Austro-Hungarian first order stations coincide with Italian first order stations: M. Baldo, M. Pasubio, Cma. d'Asta, L'Altissima (Hochwildspitze), M. Marmolada, Sasso Nerro, Pizzo Rosso, Croda di Baranci (Birkenkofl) and M. Peralba. In 1944-45, the net was rigorously adjusted and oriented in the system of Genova of Rete Geodetica Fondamentale a Nord del parallelo di Roma. [116]

In this adjustment the net was attached to the polygon formed of the Italian first order stations: M. delle Grazie - Corno Baitone - Cma. Blacca - M. Baldo - M. Pasubio - Cma. d' Asta - M. Marmolada - M. Antelao - M. Peralba which was held fixed.[15] Of lower order nets based on new first order net only II order net was by 1953 completed.[129] The III and IV order nets are still in work.

(3) Dalmatian chain. During World War II the Eastern Coast of Adriatic Sea was occupied by the Italian Army and in 1942 the Dalmatian chain was established. This chain including 37 stations represents a first order link between base lines of Udine and Foggia. The old passage across the Adriatic Sea was readjusted and retained and observations executed only north of the side 304 Hum na Visu - 308 Hum na Lastovu (S. Giorgio) including first order net in Venezia Giulia (Littoral) which was established in 1931, and reobserved in 1942. Stations 202 Kanin (M. Canin) and 183 Učka (Monte Maggiore) are not identical with the stations occupied in 1930-31. They also do not coincide with first order stations of the K. und k. III Austro-Hungarian MT which differ for:

$d = 2,07m$; $\alpha = 5^\circ\ 23'40$ and $d = 8.93m$; $\alpha = 357^\circ\ 32'29''$ respectively. [105]

(4) First order stations: M. Verzagins, Cavallo di Pontebba and Mangart were in 1953 in the works on connections of Austrian, Italian and Yugoslav triangulations added to Italian first order net. [5]

(5) Connections: The Italian first order net was tied:

1876 with triangulation of Tunis
1900 with Malta
1928 with triangulation of France, new connection was projected in 1955 and observations carried out in 1957
1941 with triangulation of Greece
1951 with French triangulation on Corsica.
1953 with triangulations of Switzerland, Austria and Yugoslavia. [6]

In order to follow the relation between the Italian triangulation and topographical survey from which the present Italian maps were compiled a chronological review of development of topographical survey along with the already explained development of triangulation has to be made:

- In 1834-60, the Topographical Office of Kingdom of Naples (L' Ufficio Topografico del Regno di Napoli) carried out a topographical survey at 1:20,000 scale. It consists of 168 sheets constructed in Flamsteed modified conical (Bonne) projection with the origin in intersection of Capodimonte meridian with 40° parallel. From this survey after 1862 were compiled 1:50,000 plane table sections constructed in the same projection of Bonne.

- In 1862, there was initiated a topographical survey at 1:50,000 scale in Bonne projection covering the territory of former Kingdom of Naples.

- In 1875, the polyhedric projection with starting meridian of Rome, Monte Mario was adopted and topographical system of Carta d' Italia established. In order to have a uniform map the sheets of Bonne projection were recasted into polyhedric sheets. (This recasting caused considerable errors and shifts in the position of parts of the map.) [133]

- In the same year the topographical survey was extended to the North where 93 sheets of Carta d' Italia were covered by topographical survey at 1:50,000 scale (quadranti) and 25 sheets around large cities, in Toscana, and in Po Valley were completed by tavolettas at 1:25,000 scale. Survey on peninsula was accomplished in 1895 and in 1900 all territory of Italy including the last surveyed Sardinia was covered by the topographical survey executed for the compilation of Grande Carta d' Italia.

- A new topographical survey began in 1900 at 1:25,000 scale (sometimes also at 1:20,000 scale and than photomechanically reduced to 1:25,000 scale) of the region in Northern Italy, on Western Coast, Sicily and Sardinia primarily surveyed at 1:50,000 scale. Meanwhile, the East Coast and entire Southern Italy still have the maps based on topographical survey of 1870-75 at 1:50,000 scale. They will be by recent topographical survey gradually replaced. [7]

In annexed regions a new topographical survey was executed:

- In 1920-27, in Istria south of 45°30' parallel at 1:20,000 scale;
- In 1930, in city of Zara (Zadar) and environs at 1:25,000 scale:

- In 1942-43, on Cherso (Cres) and Lussino (Lošinj) Islands at 1:25,000 scale (photogrammetrically).

In the Venezia Tridentina (South Tyrol) and Venezia Giulia (Littoral) north of 45° 30 parallel the plane table sheets of former IV Austro-Hungarian topographical survey were revised in the field and recasted into Carta d' Italia.

This chronological review of topographical survey along with the development of triangulation undoubtedly show:

- That all the territory of Italy was covered by topographical survey prior to the adjustment and uniform orientation of the first order net;

- That a large part of Italy was topographically surveyed prior to the adjustment of triangulation in 18 partial nets;

- That the topographical survey in annexed provinces is based on Austro-Hungarian triangulation.

Hence the sheet corners of the Carta d' Italia are not in sympathy either with the adjusted and uniformly oriented first order net (1908-19), nor, except of sheets covering Sardinia, with in 1889 preliminary adjusted net. Consequently they are inconsistent, moreover - unhomogenous.

Italy, particularly after the reunion (17 March,1861) had a passionate desire for a uniform map which would cover the entire united territory. There, as in other European countries, no time necessary for the completion, rigorous adjustment and uniform orientation of the entire triangulation was available; therefore the statement usually used for the geodetic foundation of Italian maps: "Carta d' Italia bases on fundamental net computed in topographical system with meridian of Rome Monte Mario as starting meridian" requires an explanation as follows:

- In the first phase of Italian mapping after the adoption of polyhedric projection in 1875, to the preliminary adjustment in 1889, the plane table sheets and maps are positioned on the geographic coordinates computed from closed triangles with the angles corrected by ± 1/3 v. These coordinates in same regions refer to Rome, Monte Mario datum, geodetically derived from Capodimonte; in other regions the coordinates refer to some Laplace stations and have only longitudes added with the differences referring to Rome, Monte Mario. [133] [178]

- After 1890, in Italian mapping the coordinates of preliminary adjustment of partial nets referring to Genova (first determination 1874) Rome, Monte Mario (determination 1874/5 by Prof. Respighi), Castanea delle Furie and Guardia Vecchia with longitudes geodetically derived from Rome, Monte Mario, topo datum, were used.

- After 1941,newly compiled Italian maps as well as topographical survey based on geographic coordinates of final adjusted first order net oriented on Rome, Monte Mario determined in 1940.

- In the recasting of Austro-Hungarian plane table sheets and maps and in the topographical survey (1920-27) of Istria, geographic coordinates of the K. und k. Austrian Military triangulation and geographic coordinates obtained by the transformation of Soldner rectangular plane coordinates of system Krim (Krimberg) of Austrian Cadastral triangulation were used. By the algebraic addition of blanket corrections these coordinates were for cartographical purposes brought within the limit of graphical accuracy required by 1:25,000 scale into topographical system of Carta d' Italia. [73]

Regarding the previously explained utilization of geographic coordinates of different origins, unadjusted, as well as of various stage of adjustment, in the construction of plane table sheets (tavolettas), plane table sections (quadrante) and sheets (foglio) of Carta d' Italia it should be understood that the so-called topographical system of Carta d' Italia has a common - 0^{o} - starting meridian of Rome, Monte Mario with longitudes to the East positive and to the West negative, but there is no homogenity in the positioning of the sheets. The computations and coordinates of the topographical system never were published.[133] For the use of geographic coordinates of I-IV order trig points published in the "Elementi Geodetici dei punti contenuti nel foglio della Carta d' Italia al 1:100,000" together with the maps the Military Geographic Institute compiled a list of mean differences between the coordinates of the topographical system and coordinates referring to one of the four origins used in the system of "Elementi Geodetici---". This mean differences determined for each 1:100,000 sheet should be in terms of blanket corrections algebraically added to coordinates published in corresponding volume of Elementi Geodetici in order to be within limits of graphical accuracy in sympathy with the scaled positions . Though the coordinates of Elementi Geodetici refer to four different origins, the variances of blanket corrections in the area of each origin are incontestable evidence of heterogeneous positioning of the sheets.

In the strategically important regions along the Italian frontiers and on the islands of Sicily and Sardinia the Artillery Inspectorate of War Ministry by its own survey executed in in 1928-37, considerably densified the net of Italian triangulation. The Artillery Net was developed from the I-IV order trig points of existing triangulation of which the geographic coordinates are published in the Elementi Geodetici. It was adjusted and computed in the system of the Elementi Geodetici, but by algebraic addition of the aforementioned blanket corrections transformed into the topographical system of Carta d'Italia. In the annexed territories the artillery net was developed:

- in Venezia Tridentina (South Tyrol) from the triangulation executed in 1921-23, for the delimitation between Italy and Austria, based on the first order net of the K. und k. III. Austro-Hungarian Military triangulation, preliminarily oriented to Rome, Monte Mario datum.

- in Venezia Giulia (Littoral) from the K. und k. III. Austro-Hungarian Military triangulation. Adjusted and computed in Hermannskogel system it was by use of the constants:

$$\Delta\phi = -0''.89$$

$$\Delta\lambda = -30^\circ\ 07'\ 11''.82$$

transformed into the topographical system of Carta d'Italia. The geographic coordinates referring to the system of Carta d' Italia together with other information are published in the volumes of the special trig list "Elementi Geodetici-Topografici dei Punti della Rete d' Artigleria Zona di---". The volumes cover regions (Zones) which are not congruent with the foglios of Carta d' Italia. In addition to geographic coordinates in the system of Carta d'Italia some volumes include geographic coordinates transformed into system Genova 1908 of Rete Geodetica Italiana Fondamentale. [123]

Accuracy of the old Italian triangulation after its incorporation into Uniform European System (Potsdam) would be expressed by the following mean positional error of the coordinates:

I Order	net ± 0.1 m	
II Order	net ± 0.3 m	
III Order	net ± 0.5 m	
Artillery	net ± 0.8 m	
IV Order	net ± 1.0 m	[133]

d. Elevations: After the two years of experimental work on precise leveling the Military Geographic Institute in 1878 started with systematical work on the establishment of precise leveling. Two main lines of the first order precise leveling and many transversals (71 duplicate level lines) with a total length about 9100 km connect the tidal gauges and form 19 loops including 10,500 first order benchmarks. (See Inclosure 25). Into this leveling net are included 13.500 km of II order leveling lines, and leveling lines established by other institutions. By 22,600 km of first and second order lines of precise leveling are tied about 43,000 benchmarks upon which the Italian vertical control, determined by means of trigonometrical leveling, used in the topographical survey bases. [49] [157]

The observations of the 1878-1903 precise leveling net were carried out with the precise leveling instruments Pistor, Starke and Berthelemy having magnification 24-30 and sensitivity of spirit level 4".125 - 4".500/1mm. The 3 m long wooden level rods with 1cm intervals were used in observations carried out by method of observing from the center. The rods prior to, during and after the field work were compared with normal meter and results of comparisons included into the adjustment of the differences of elevations. The maximal differences permitted between forward and backward observations in duplicate level lines where those defined in 1867 by the International Geodetic Association at the convention in Berlin i.e:

$\pm$ 3 mm $\sqrt{L}$ km in the plain regions

$\pm$ 5 mm $\sqrt{L}$ km in the mountainous regions. [147]

The elevations obtained from the field records were provided with orthometric corrections and then adjusted. In the adjustment carried out in order to satisfy the conditions of the figure of the net and the conditions imposed by the attachment of the leveling net to 7 mareographs having various periods of registration, i.e: Ancona (8 years), Civitavecchia (8), Livorno (20) Genova (20), Napoli (8), Porto Corsini (20) and Venezia (20), 25 condition equations (19 polygonal and 6 of mareographs) were solved.

The accuracy of the old Italian first order precise leveling net (Rete Altimetrica Fondamentale) after the adjustment is expressed by the mean square error

$$\mu = \pm 1.325 \text{ mm/km};$$

or probable error:

$$\eta = \pm 0.894 \text{ mm/km}. \quad [157]$$

Since the starting level defined in 1904, was obtained from the adjustment of the registrations of 7 mareographs located on the

Adriatic and Tyrrheno-Ligurian coasts of the peninsula the elevations of the old leveling net and the elevations of vertical control determined in sympathy with it refer to the mean sea level of the Mediterranean Sea (0.307 m below N.N.)

The old precise leveling net did not cover the islands Sicily and Sardinia, furthermore in the Southern Italy and in the eastern part of the Central Italy it was established after the execution of the topographical survey, therefore the vertical control upon which the topographical survey in this regions bases was determined solely by means of the trigonometrical leveling and is not in sympathy with the precise leveling net. The primary elevations of trig points in Southern Italy in respect to the elevations determined later by means of trigonometrical leveling attached to the precise leveling net vary within limits of + 5 m to -7 m. In the map revision carried out after 1906 the primary elevations of trig points were corrected to be in sympathy with the precise leveling.

The elevations of the new topographical survey in Istria, Zara (Zadar), Cherso (Cres) and Lussino (Lošinj) as well of the revised Austro-Hungarian plane table sheets of the annexed territory recasted into system of Carta d' Italia are based on Austro-Hungarian precise leveling referring to the mean sea level of the Adriatic Sea determined in vertical datum Trieste, Molo Sartorio (1875). Because vertical datum Trieste, Molo Sartorio in respect to N.N is only 0.071 m below the Italian vertical datum this difference is negligible for any mapping purpose.

3. Recasting and construction of grid:

The sheet lines of Italian maps in system of Carta d' Italia (tavolettas, quadranti and foglios) compiled prior to 1945, refer to the Bessel ellipsoid. With the adoption of the International ellipsoid in 1945, the newly compiled sheets are framed into sheet lines which refer to the International ellipsoid. In order to bring the Italian maps into sympathy with the coordinates of the reoriented Italian triangulation and to assure, insofar as possible, the uniformity of the maps at 1:25,000, 1:50,000 and 1:100,000 scale the following extensive works on recasting and griding were done:

a. 1:25,000 plane table sheets (tavolettas):

(1) All newly surveyed, reambulated or revised and redrafted sheets are constructed with sheet lines referring to the International ellipsoid.

The newly constructed sheets are provided with the 1 km

Inclosure 25

(4 cm) grid of Gauss-Boaga projection (or with UTM grid and Gauss-Boaga ticks). These sheets printed in colours have the grid, which is considered as final, printed in black colour.

(2) The old plane table sheets with sheet lines referring to Bessel ellipsoid were recasted to the sheets which refer to the International ellipsoid. The recasting of the plane table sheets of East (II) Zone and of West (I) Zone south of 43° 40' parallel was completed in 1951. The plane table sheets of the West (I) Zone north of 43° 40' parallel will be gradually replaced by newly surveyed or resurveyed sheets referring to the International ellipsoid. The recasted plane table sheets were along with the recasting provided with superimposed provisional grid of Gauss-Boaga projection printed in red colour.

(3) The plane table sheets in West (I) Zone north of 43° 40' parallel not covered by new topographical survey, resurvey or a general map revision, were not recasted and remained with the sheet lines referring to the Bessel ellipsoid. These sheets also were provided with 1 km grid of Gauss-Boaga projection (or UTM grid and Gauss-Boaga ticks). The provisional kilometric grid is superimposed in red colour and in order to preserve the uniformity of the map refers to the International ellipsoid. Consequently plane table sheets referring to various ellipsoids - Bessel and International - could be combined and matched by uniform grid.

To avoid the errors the newly compiled, recasted or grided sheets have a legend in the northern right-hand corner with the information concerning datum, ellipsoid, graticule and grid. [178]

b. <u>1:50,000 plane table sections (quadranti)</u>: These sheets cover only the regions for which the 1:25,000 topographical survey does not exist. Because the 1:50,000 map will be gradually replaced by the 1:25,000 map of the new topographical survey it has not been recasted. The polyhedric sheets which refer to Bessel ellipsoid were provided with 2 km (4 cm) Gauss - Boaga or UTM grid referring to the International ellipsoid. The grid is superimposed in red colour and should be considered provisional. Because it refers to the same - International ellipsoid - it is in sympathy with the grid of 1:25,000 sheets. [178]

c. 1:100,000 sheets, compiled from the new topographical survey at 1:25,000 scale, are constructed with the sheet lines referring to the International ellipsoid and provided with 1 km (1 cm) grid of Gauss-Boaga projection.

The old 1:100,000 sheet referring to Bessel ellipsoid were not recasted, but were provided with 1 km (1 cm) Gauss-Boaga grid which refers to the International ellipsoid. The grid is superimposed in red colour and is in sympathy with the grid superimposed on 1:25,000 and 1:50,000 sheets. [178]

The recasting and griding of the maps of the system of Carta d' Italia is based upon the newly oriented triangulation which refers to Rome, Monte Mario 1940 datum and to International ellipsoid. Considering the heterogeneity in the positioning of the sheets belonging to topographical system of Carta d'Italia, in construction of which the geographic coordinates referring to various values of the origins Rome Monte Mario, Genova, Castanea delle Furie and to various stage of adjustment were used, as well as the distortion of the old plane table sheets used prior to 1895 (up to 30 m at the edges of 20_{ϕ} x $30'_{\lambda}$ sheet considered at that time as projecting plane), the recasting and providing of these sheets with a uniform grid based upon uniformly adjusted and oriented triangulation represent an extensive work, but of limited accuracy. Hence the editions of Italian maps, which were by recasting of sheets and superimposing of Gauss-Boaga grid brought into sympathy with the new geodetic foundation, should be considered provisional. Meanwhile the new maps compiled of new topographical survey based on the new geodetic foundation are final.

4. Topographical Survey:

At the beginning of topographical survey for the Grande Carta d'Italia the 1:50,000 plane table section (quadrante) of $10_{\phi}'$ x 15_{λ} ' covering about 360 km^2 was used, but later the $5'_{\phi}$ x $7'30_{\lambda}$ plane table sheet (tavolleta) at 1:25,000 scale normally was used in the survey. In the regions with many details as environs of cities, industrial centers and in the Karst the survey in the field usually was executed at 1:20,000 scale and the manuscripts photographically reduced to 1:25,000 scale. (The projection and the construction of the sheets were already discussed in the chapters 1b, 2b, c, and 3.)

Prior to the adoption of Gauss-Boaga projection, the geographic coordinates of the trig points in order to be plotted into plane table sheets were transformed to plane rectangular coordinates of polyhedric projection (projezione naturale) considering the tangent plane touching the ellipsoid at the center of sheet (touching point of projecting plane) with meridian as X axis positive to North and perpendicular to the meridian at center as Y axis positive to East. In the transformation the following formulae were used:

$$X = I_o \cos (\lambda - \lambda_o)''$$

$$Y = II_o \quad (\phi - \phi_o)'' + III_o (\lambda - \lambda_o)''^2$$

where:

ϕ and λ (ω in some Italian sources) are geographic coordinates of trig point

ϕ_o and λ_o are geographic coordinates of origin (center of the sheet)

N_o and M_o are radius of curvatures in the prime vertical and meridian of the origin

$$I_o = N_o \sin 1''$$

$$II_o = M_o \sin 1''$$

$$III_o = \tfrac{1}{4} N_o \sin 2\phi_o \sin^2 1'' \quad [133]$$

The largest part of topographical survey for Grande Carta d'Italia was accomplished by plane table tachymetry. The plane table (tavoletta pretoriana) with alidade having telescopic sight and stadia equipment in Italy was in use from the outset of this survey. The plane table survey still covers 64% of the entire territory of Italy (300.875 km^2). The survey is based on the triangulation established by Military Geographic Institute with a density of about 10 trig points on plane table sheet (1 trig point per 9 km^2). The cadastral planimetry never was utilized in the Italian topographical survey. The triangulation was densified by plane table triangulation and in the open areas from graphically determined stations surveyed detail by polar method. In the forest regions the survey bases upon compass traverses placed among the trig or graphical points. The drawing of planimetry and relief expressed by contours of a plane table sheet (90 km^2) was based upon:

- At scale 1:25,000 about 3000 measured detail points with elevations, i.e. about 33 points per 1 km^2.

- At scale 1:20,000 about 4500 detail points with elevations, i.e. about 50 points per 1 km^2. [27]

The cultural features and vegetation in Italian mapping is expressed by symbols which considerably differ from those used in the Austro-Hungarian mapping as well as from the Austro-Hungarian similar symbols used in the mappings of successor states. Special attention is given to the classification of the woodland in respect to the types and density of the woods and to the orchards where a particular type of Italian agriculture, so-called "coltura mista", with mixed trees, fruit trees, shrubs and vegetable interwoven by vines, represents a considerable obstacle for the movement of troops.

The relief is expressed by contours with a contour interval of 5, 10, 20, or 25 meters, according to the terrain and epoch of survey: After 1940 the contour interval was standardized to 25 m (1 graphical mm equidistance) with 5 m auxiliary contours dashed. In the topographical survey at 1:50,000 scale a 10 m contour interval was used at first, but later was replaced by a 50 m (1 graphical mm) contour interval. The contours are drawn in brown colour except for glacial areas which are expressed by blue contours. The rocky regions are artistically expressed in black drawing by imagined oblique illumination coming from the northwest and producing a pictorial plastic effect, but a less shaded, brighter drawing of rocks added with brown 100 m contours (index contours) would better serve military purposes.

The plane table photogrammetry (terrestrial photographs utilized in the mapping method by graphical construction) was introduced in Italian mapping in 1878 by Eng. Pio Pagannini in the survey of Apuan Alps and then in 1879-85 applied in the survey of Maritime Alps and Grainan Alps executed at 1:20,000 scale and covering 295 km^2.

Prior to World War I, the terrestrial stereophotogrammetry was used in the topographical survey of Carnic Alps (1913). After World War I in 1921 the Italian Military Geographic Institute inherited from Austro-Hungarian M.G.I. von Orel's stereoautograph which was utilized in stereocompilation of the 1:25,000 survey along the Switzerland boundary.[48] In 1935, the high mountainous region of Sondrio (Valtelina) was partially surveyed stereophotogrammetrically and an area of 762 km^2 was compiled at 1:25,000 scale by stereocartograph of Santoni. [170] The terrestrial stereocompilation covers about 4000 km^2 (1.3%) of Italian topographical survey. After World War II the terrestrial stereophotogrammetry in the general map revision (reambulation) of the 1:25,000 tavolettas has been utilized. In this map revision not to extensive areas of high mountains, originally surveyed by plane table, are resurveyed by method of the terrestrial photogrammetry.

Experiments with aerial photogrammetry started in Italy in 1927, with the survey of 60 km^2 of mountainous area near Ragusa (Sicily). In 1931 aerial photogrammetry covered 100 km^2 of survey along the frontier of Switzerland and 300 km^2 of Caltanissetta province. In 1941, the plane table survey was practically replaced by the aerial photogrammetry covering about 150 tavolettas at 1:25,000 scale. Hence, aerial photogrammetry with a yearly production of about 150 tavolettas at 1:25,000 scale, covering 13,500 km^2 or 4.5% of entire territory became a normal method of Italian topographical survey.[13] The plane table method is still in use, but only in the topographic courses of Military Geographic Institute for training purposes, then in checking and completing of photogrammetric compilations and in the map revision.

In order to provide an adequate number of fixed points on which the stereocompilation, next to existent triangulation and terrestrially determined tie points, has to base the aerial triangulation by solar method of Santoni (Metodo Solare Santoni) found extensive application in contemporary Italian mapping.

In the stereocompilation of terrestrial and aerial photography there are mostly utilized domestic instruments, stereocartograph and stereosimplex of Santoni and photostereograph, photocartograph and photomultiplo (multiplex) of Nistri. In rectifying photogrammetry the Zeiss SEG I and IV automatic rectifiers are used.

Since 1955, in the aerial photogrammetrical survey for the new tavolettas of Carta d'Italia next to Military Geographic Institute various private companies as contractors are engaged. [7]

The norms achieved in topographical survey by plane table method show from epoch to epoch considerable differences, but an average norm achieved by one topographer in 6 months would be about:

50 km^2 in the survey at 1:20,000 scale;

70 km^2 in the survey at 1:25,000 scale.

Considering the average norm achieved by 1 topographer and the amount of measured detail points and elevations per 1 km^2, as well as the fact that in the Italian topographical survey the cadastral planimetry was not utilized, the Italian topographical survey could not be rated much higher than the IV Austro-Hungarian topographical survey. Actually the planimetry of Italian topographical survey should be regarded as less accurate and less complete than that of the IV Austro-Hungarian topographical survey based upon reduced cadastral planimetry. The expression of the relief in the Italian topographical survey bases on a considerably larger number of measured elevations (35-50) with contours drawn in the field than in the part of the IV Austro-Hungarian topographical survey, surveyed exclusively by plane table method, with up to 22 measured elevations per 1 km^2 and contours drawn in the office; meanwhile the part of IV Austro-Hungarian topographical survey completed by utilization of photogrammetry should be considered superior to Italian topographical survey. Evidently, such an evaluation of the IV Austro-Hungarian topographical survey influenced the Italian military authorities in the decision to include the plane table sheets of this survey, covering the part of annexed territory, into system of Carta d' Italia and at the same time for the part of annexed territory which was covered only by the much less accurate III Topographical survey to carry out a new topographical survey according to Italian standards.

Comparisons between the old tavolettas surveyed by plane table method and new tavolettas compiled photogrammetrically, possible at the present time, in the expression of relief do not show any extreme differences, as in the III Austro-Hungarian topographical survey were discovered by reambulation and by new topo-surveys. Meanwhile, considerable differences in the shape and position of shore lines and in the expression of bluffs along the coasts are evident. As should be expected, the photogrammetrical compilation gives a more detailed and exactly-positioned planimetry, and particularly a superior geometrical expression of the relief including the details which the contouring of an artist-topographer based on a sparse number of measured elevations can not express. These comparisons are also an indisputable proof that 35 or 50 detail points are insufficient for an exact mapping of 1 km^2 at 1:25,000 or 1:20,000 scale respectively. The 1:25,000 tavolettas surveyed photogrammetrically would completelly satisfy artillery requirements.

The positional and vertical accuracy of the tavolettas surveyed by plane table method is of such a degree that they almost meet the artillery requirements except for the part originally surveyed at 1:50,000 scale (quadranti) and than photomechanically enlarged to 1:25,000 scale. From the comparisons of quadranti with the contemporary tavolettas surveyed photogrammetrically it is evident that the purpose of the 1:50,000 topographical survey was merely to produce topographic material for the map which would serve for a general orientation in the field.

5. Mapping of former Austro-Hungarian territory annexed by Italy in 1919:

The field test carried out by Italian Military Geographic Institute showed that the IV Austro-Hungarian topographical survey would satisfy the standards of Italian topographical survey; therefore the Austro-Hungarian plane table sheets of the IV topo-survey were included into Carta d' Italia. [27]

a. South Tyrol (Venezia Tridentina): Austro-Hungarian 1:25,000 plane table sheets of the IV topographical survey, positioned on in 1905 preliminary adjusted K. und k. III Military triangulation oriented on Hermannskogel datum with longitudes referring to Ferro, were in 1921-1927 revised in the field, redrafted according to Italian standard symbols and recasted into Italian plane table sheets (tavolettas) of system Carta d' Italia with starting meridian

$$\text{Rome, Monte Mario } 0^\circ = 12^\circ\ 27'14''.00 \text{ East of Greenwich}$$
$$= 30^\circ\ 07'00''.02 \text{ East of Ferro.}$$

Since the K. und k. Military Triangulation in South Tyrol at that time was not yet geodetically incorporated into Italian I order net, for the purpose of recasting of Austro-Hungarian plane table sheets into system of Carta d'Italia the GP's of K. und k. III Austro-Hungarian Military Triangulation obtained only the following blanket corrections:

$$\Delta\phi = \quad -1''.34$$

$$\Delta\lambda = -30^\circ\ 7'12''.16 = (30^\circ\ 07''00''.02 + 12''.14) \quad [27]$$

Evidently, the geographic coordinates in Rome, Monte Mario system obtained by the subtraction of blanket corrections from the geographic coordinates in Hermannskogel system would merely meet the cartographical requirements.

Since the meridian of Rome, Monte Mario Topographical system was defined by:

$$30^\circ\ 07'\ 00''.02 \text{ East of Ferro}$$

the corresponding meridians of the graticule on Austro-Hungarian plane table sheets in the recasting to the Italian plane table sheets (tavolettas) were shifted for

$$12''.14 = 259 \text{ m} = 10.4 \text{ mm}/1{:}25{,}000 \text{ to the East;}$$

meanwhile the parallels were shifted for

$$1''.34 = 41 \text{ m} = 1.6 \text{ mm}/1{:}25{,}000 \text{ to the North,}$$

considering ϕ 46° 30' and λ 29° 00' as center of the mapping area.

The tavolettas composed in 1921-27 from the recasted Austro-Hungarian plane table sheets in the region north of the 46° 40 parallel in 1938 were generally revised by plane table method. In the region south of 46° 40' parallel they were in 1931-35 brought up to date by partial revision. From the comparison of the Austro-Hungarian plane table sheets with the corresponding Italian tavolettas published before and after the revision it is evident that partial as well as general revision included only supplementing and correcting of cultural features and woodland. The relief remains practically unchanged, which is easily understandable in the light of knowledge that an average norm achieved in general revision by 1 topographer was:

1 tavoletta (90 km^2) per month. [27]

The map revision included also the italianization of geographical names. It should be noted that in the northern part of South Tyrol the native German toponymy was completely italianized largely by literary translation and partly by transliteration into Italian orthography. The original names were by translation and transliteration distorted to such a degree that they lost all meaning.

b. Littoral (Venezia Giulia): The Austro-Hungarian plane table sections of the IV Topographical survey, carried out in 1895-1904 cover the area north of 45° 30' parallel and east of 30°30' meridian east of Ferro. These sheets are based on the third order points of the K. und k. Military Triangulation, executed in 1896-1902 particularly for the purpose of the IV Topo-survey, and into this triangulation incorporated cadastral trig points for which the markers were found. The geographic coordinates of these points used in the mapping are in sympathy with the "Positions Rechnungen, M.G.I. Protocol 290 A and B" and therefore refer to Vienna University datum. After its utilization in the topographical survey in 1904, this triangulation was tied by a sparse 2nd order net into the first order net of the K. und k. III Military triangulation oriented on Hermannskogel datum and its newly computed geographic coordinates published in the volume IV of the "Ergebnisse der Triangulierungen. (See chapter BIV, lc pp 48-49). In the transformation of geographic coordinates of Austro-Hungarian Military Triangulation in Venezia Giulia referring to Hermannskogel into system of Carta d' Italia by Italians were used the constants

$$\Delta\phi = \quad - 0''.89$$

$$\Delta\lambda = - 30^{\circ}\ 07'\ 11''.82\ (30^{\circ}\ 07'00.02 + 11''.80), \quad [27]$$

meanwhile the plane table sections of the IV topographical survey are based on geographic positions of Vienna University system which in the area concerned - Venezia Giulia north of 45° 30' parallel - vary from GP's of Hermannskogel system for a mean difference

$$\Delta\phi = + 1''.20$$

$$\Delta\lambda = - 5''.00$$

Consequently, in the recasting of the plane table sections with graticule in Vienna University system longitudes for which refer to the meridian of Ferro into tavolettas with graticule in the system of Carta d' Italia with starting meridian Rome, Monte Mario (30° 07'00.02 East of Ferro) the sheet corner values of the Austro-Hungarian plane table sections obtained the following blanket corrections:

$$\Delta\phi = \quad -2''.09$$

$$\Delta\lambda = - 30^{\circ}\ 07'06''.82 = (30^{\circ}\ 07'00''.02 + 6''.80).$$

These corrections represent at center of the area concerned ($\phi = 46^{\circ}$; $\lambda = 31^{\circ}$ 30 East of Ferro) a shift of the graticule (parallel and corresponding meridian)for

$$\Delta\phi = 64.52\text{m} = 2.58\ \text{mm}/1{:}25{,}000$$

$$\Delta\lambda = 146.25\text{m} = 5.85\ \text{mm}/1{:}25{,}000$$

which would in the limits ± 1.25 m and ± 1.05 m satisfy the shifts needed at the periphery of the area concerned. Evidently such a shift of the graticule would be also along the periphery within the limits of graphical accuracy. (See Inclosure 26)

The tavolettas composed in 1925-27, from recasted Austro-Hungarian plane table sections in the Littoral (Venezia Giulia) north of 45° 30' parallel were in 1938 generally revised by plane table method. This general revision, as well as the earlier revisions were confined merely to the correcting and supplementing of cultural features and woodland with particular attention to the details on highways and main roads. The relief remains unchanged except that the 10 meter contour lines were included by interpolation. The native Slavic toponymy was italianized in the same manner as the German toponymy in the tavolettas covering the northern part of South Tyrol. (See Inclosure 12).

c. Istria: Former Austro-Hungarian territory of the peninsula of Istria (Istra) south of the 45° 30' parallel, as well as islands Lussino (Lošinj) and Cherso (Cres) were not covered by the IV Topographical survey, but by the plane table sections of the III Topographical survey of Austro-Hungarian Empire reambulated in 1908. The Italian military authorities properly considered the III Topographical survey inadequate to meet the post World War first military requirements and consequently in 1920-27 ordered the topographical survey of Istria south of 45°30' parallel according to Italian standards. The islands Lussino and Cherso were not included in the 1920-27 topographical survey executed in the field at 1:20,000 scale.

The topographical survey started in 1920, with the survey of Pola Naval base and during the same year covered the mainland of peninsula south of 45° parallel. Because the lower order net of Austro-Hungarian Military Triangulation did not cover the area south of 45° 30' parallel, Italians for the purpose of topographical survey in 1919 established a triangulation net of fortress of Pola (Triangolazione di Pola 1919), based upon the side connecting the first order stations 186 S. Michele di Vale and 187 Pola, Naval Observatory of the K. und k. III Austro-Hungarian Military triangulation, transformed into system of Carta d' Italia by means of constants

$$\Delta\phi = -0\overset{''}{.}94$$

$$\Delta\lambda = -30^\circ\ 07'11\overset{''}{.}78$$

On triangulation of Pola are positioned the tavolettas south of 45° parallel. Meanwhile the tavolettas surveyed in 1921-27, covering the area between the 45° and 45°30' parallel are positioned on the trig points of Austrian cadastral triangulation system Krim (Krimberg). For this purpose the rectangular plane coordinates with origin Krim (I order station of MT):

$$\phi = 45^\circ 55'43\overset{''}{.}75$$

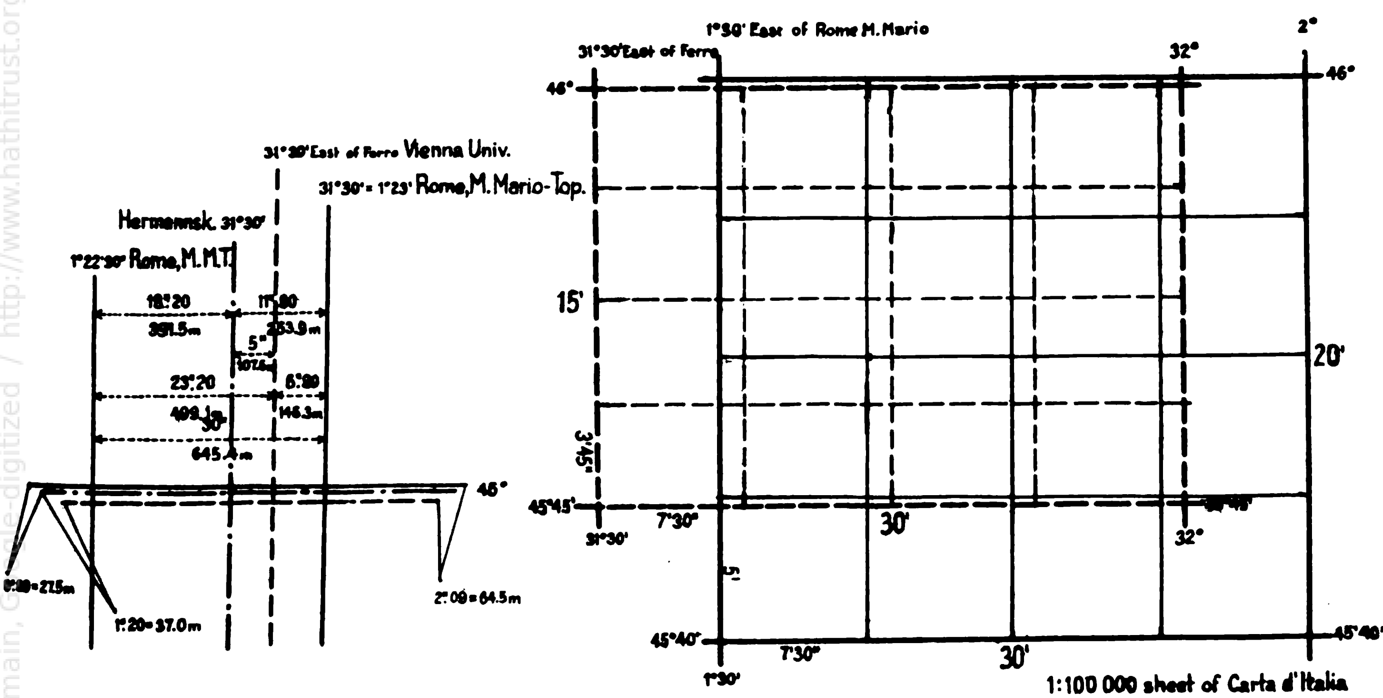
$$\lambda = 32^\circ 08'18\overset{''}{.}71 \text{ East of Ferro}$$

Inclosure 26

LITTORAL (VENEZIA GIULA)

Comparisons of the GPs of "Positions Rechnungen" on Vienna University Datum with the GPs in the System of "Carta d'Italia" on Monte Mario, Topo Datum

No.	Station Name	φ		Δφ		λ		Δλ	
		Vienna University	M. Mario	"	m	Vienna University	M. Mario	"	m
1	Matajur	46°12'46".48	44".36	+2".12	65.44	31°11'43".40	36".61	+6".79	145.52
2	Mrzavec (M.Frigido)	45 58 43.58	41.50	+2.03	64.21	31 28 17.97	11.17	+6.80	146.35
3	Nanos (M.Re)	45 47 44.83	42.75	+2.08	64.20	31 42 54.58	47.82	+6.76	145.96
4	Aquileia	45 46 14.04	11.91	+2.13	65.77	31 02 11.68	04.94	+6.74	145.59
5	Opcina	45 40 58.65	56.55	+2.10	64.82	31 26 34.06	27.26	+6.80	147.12
6	Snežnik (M.Nevoso)	45 35 20.86	18.81	+2.05	63.28	32 06 49.27	42.57	+6.70	145.20
7	Slavnik (M.Taiano)	45 32 04.28	02.19	+2.09	64.51	31 38 31.09	24.30	+6.79	147.30
8	Piran	45°31'48".29	46".19	+2".10	64.82	31°14'04".78	13'58".03	+6".75	146.44
			$\frac{[\Delta\phi]}{n}$ =	+2.09	64.63		$\frac{[\Delta\lambda]}{n}$ =	+6.77	146.18



were transformed to geographic coordinates of Rome, Monte Mario Topo-system. Despite the fact that the above mentioned geographic coordinates used as origin of cadastral triangulation differ from the GP's of K. und k. MT first order station 172 Krimberg published in the "Ergebnisse der Triangulierungen" for $\Delta\phi = +0.03$ and $\Delta\lambda = -0''.09$ the same constants

$$\Delta\phi = \quad -0''.89$$

$$\Delta\lambda = -30^{\circ}07'11''.82$$

as used in the transformation of military triangulation were in the transformation of cadastral coordinates applied to the origin Krim ($\phi = 45^{\circ}\ 55'\ 43''.75$; $\lambda = 32^{\circ}08'18''.71$) which in the Rome, Monte Mario system obtained the coordinates

$$\phi = 45^{\circ}55'42''.86$$

$$\lambda = 2^{\circ}01'06''.89$$

Application of slightly varying constants, disorientation of the axes of cadastral system in respect to the meridian and prime vertical of origin Krim determined in the military triangulation as well as distortion of cadastral coordinates computed without consideration of curvature of the Earth caused disparities between the geographic coordinates of K. und k. MT points and geographic coordinates of cadastral points resulting from this transformation. These systematical (to a certain degree) disparities were derived from differences on common stations to K. und k. Military and cadastral triangulations and north of 45° 30 parallel would amount to

$$\Delta\phi = 0''.75;\ \Delta\lambda = 1''.20;$$

published in form of blanket corrections for each 1:100,000 foglio and should be subtracted from geographic coordinates of cadastral stations. By means of this subtraction the coordinates of cadastral trig point would be brought within limits of graphical accuracy required for 1:25,000 scale into sympathy with GP's of the K. und k. Austro-Hungarian military trig points transformed to Rome, Monte Mario Topo-system.

In order to bring the transformed geographic coordinates into sympathy with the GP's of triangulation of Pola and to coincide the graticule of the plane table sheets, which would otherwise along the 45° parallel have a gap and a disorientation, the cadastral GP's for the purpose of mapping were corrected within limits:

$$\Delta\phi \text{ to } -0\overset{''}{.}75$$

$$\Delta\lambda \text{ to } +0\overset{''}{.}75$$

The mean corrections for each 1:50,000 quadrante in the zone between 45° and 45°30 parallel are published and the corrections applied to each trig point were obtained by interpolation. The rectangular plane coordinates of Krim system and the geographical coordinates as well as the discussed corrections are published in the "Catalogo Generale della Triangolazione Ausiliaria in Venezia Giulia" (File No. B-641. 3016).

The topographical survey was carried out by plane table method mostly by officers attending the topographic course at Military Geographic Institute. The tavolettas at 1:20,000 scale were provided with 10-12 trig points and the survey completed by about 4500 measured detail points with elevations per tavoletta or 50 points per 1 km^2. The cadastral planimetry was not utilized. The relief was expressed by 10 m contours drawn in the field.[27] The norm 30-42 km^2 achieved by 1 topographer in 6 months should be regarded as too high for a beginner in the survey of a karstic region like Istria.

d. Cres (Cherso) and Lošinj (Lussino) Islands: These two islands included into sheets 77A and 77B of Carta d' Italia were in 1942-43, covered by aerial photogrammetric survey with application of Santoni's solar method of aerial triangulation, at that time still in the experimental stage. The survey is based on the new 1942 Italian triangulation. The coordinates used in the mapping are GP's of the system of Carta d'Italia. The relief is expressed by contour lines with the interval of 25 meters (in flat land 5 m). The compilation at 1:25,000 scale was carried out by the stereocartograph of Santoni; because it was not revised in the field it should be considered incomplete.

Regarding the solar method of aerial triangulation by Santoni it should be mentioned that it was in 1938-40, successfully applied in the survey of Libia at 1:100,000 scale covering 34,500 km^2; meanwhile its application in the aerial survey at 1:25,000 scale until 1952 was still in the testing stage. The experiments in bridging of a 107 km long strip covered by 57 photographs at 1:10,000 scale in four independent bridging carried out in 1950, by Santoni's method show an accuracy expressed by the relative mean errors of

$$x = \pm 3.25 \text{ m}$$
$$y = \pm 3.50 \text{ m}$$
$$h = \pm 3.25 \text{ m}$$

which would practically satisfy the accuracy requirements of the 1:25,000 mapping particularly in respect to the horizontal position ($\Delta S = \pm\sqrt{x^2 + y^2} = \pm 4.78$ m = 0.19 mm). [179]

Aerial compilation without checking and completion in the field based upon aerial triangulation in experimental stage caused the tavolettas covering the islands Cres and Lošinj not to be regarded as maps of the highest accuracy.

e. Zadar (Zara) and environs (Sheet 3971): The City of Zadar with environs in 1918-45 belonging to Italy was in 1930 topographically surveyed by plane table method at 1:25,000 scale. The survey was based on K. und k. III Austro-Hungarian Military Triangulation incorporated into system of Carta d' Italia by means of constants

$$\Delta\phi = -0''.94$$
$$\Delta\lambda = -30^\circ 09' 11''.78$$

with an accuracy which would meet only cartographical requirements. In order to cover the surrounding Yugoslav territory by Italian map the Austro-Hungarian plane table sections of the III Topographical survey, reambulated in 1914, were in 1940 recasted into tavolettas of Carta d' Italia and redrafted according to Italian standard symbols.

f. Accuracy of plotted trig points: Comparing the geographic coordinates of "Catalogo Generale degli Elementi Trigonometrici" obtained from the triangulation of Venezia Giulia executed in 1930-31, and supplemented in 1938-39, adjusted and oriented in the system of Carta d' Italia the following average differences were obtained:

- In the area north of 45°30' parallel covered by the plane table sections of the IV Austro-Hungarian Topographical survey revised and recasted into tavolettas of Carta d'Italia

$$\Delta N = \pm 7.41 \text{ m}$$
$$\Delta E = \pm 6.27 \text{ m}$$
$$\Delta S = \pm 9.71 \text{ m}$$

It should be mentioned that in the construction of Austro-Hungarian plane table sheets preliminary coordinates were used.

- In the area south of 45°30 parallel covered by tavolettas of the Italian topographical survey

$$\Delta N = + 5.56 \text{ m}$$
$$\Delta E = + 7.21 \text{ m}$$
$$\Delta S = + 9.04 \text{ m}$$

The differences are systematical and evidently result from comparison of coordinates of an adjusted triangulation with the scaled values of trig points obtained by the transformation of cadastral coordinates provided later by blanket corrections. In the survey of tavolettas south of 45° parallel surveyed in 1920 among the trig points of the triangulation of Pola a few cadastral stations, with transformed coordinates at that time not yet provided by blanket corrections derived for each sheet, were used. Scaled values of these cadastral stations (M.S. Daniele, M. Turcian) differ by about 0."5 in latitude and more than 1" in longitude, and therefore were disregarded in the computing of average differences.

- The tavolettas covered by aerial survey executed in 1942-43, are based upon the triangulation of 1942 and in respect to 1930-39 triangulation show an average shift of graticule for 16 m to the north and for 4 m to the east.

g. Positional accuracy of the 1:25,000 plane table sheets (tavolettas): In the comparisons of the geographic coordinates of the trig points listed in the Catalogo Generale degli Elementi Trigonometrici with the scaled positions of 50 trig points plotted in 16 plane table sheets (tavolettas) i.e:

40A - III NE, IV NE, IV SW;
40B - II NW, II NE, IV NW,
53B - II NW, II NE,
77A - I NW, I NE, I SW, I SE, II NE,
77B - I NE, I SE, II NE,

the following mean square error and probable error were obtained:

mean square error $E_2 = \pm$ 12.09 m = 0.48 mm/1:25,000

probable error $E = \pm$ 8.15 m = 0.33 mm/1:25,000

From the testing of plane table sheets surveyed in various European countries between the two World Wars it appears that the orientation points determined by plane table triangulation and sharply-shaped points of the planimetry were plotted with a

probable error $E = \pm$ 0.3 mm

Considering the manner in which the 1:25,000 topographical survey was carried out in Venezia Giulia by the K. und k. M.G.I. (IV topo-survey only) and by the Italian M.G.I. it should be assumed that the probable error with which the orientation and detail points were plotted does not exceed

$\pm$ 0.3 mm. Consequently the orientation and detail points on the 1:25,000 sheets (tavolettas) of Carta d'Italia covering the former Austro-Hungarian territory annexed by Italy in 1919 could be determined by a probable error

$$E = \pm \sqrt{0.33^2 + 0.3^2} = \pm 0.45 \text{ mm } (11.35 \text{ m}) \text{ or}$$

a mean square error

$$E_2 = \pm 0.67 \text{ mm } (16.75 \text{ m}).$$

Hence, 54% of the positions of planimetry could be scaled from this map with an accuracy of $\pm$ 0.5 mm; or 86% with an accuracy of $\pm$ 1 mm.

6. Revision of Italian Maps:

Due to extensive activities of the Military Geographic Institute carried out in the colonies the maps covering the mother-country became largely obsolete. There are sheets of the 1:25,000, 1:50,000 and 1:100,000 maps never generally revised since:

1887 in Southern Italy
1905 in Central Italy
1922 in Northern Italy.

After 1946, the map revision is carried out in a large scale, particularly the 1:100,000 foglios are revised for the compilation of the new 1:200,000 map.

Until 1933, in Italy the map revision was carried out by plane table method in a manner similar to that applied in the revision of the Austro-Hungarian 1:75,000 special map. (See chapter C-IV pg. 56). Since 1933, in the map revision of flat regions aerial photogrammetry is utilized; meanwhile the maps covering mountainous regions still are revised by plane table method. The revision, ordinarily is confined to correcting and supplementing of planimetry.

7. Maps:

The information about the projection, size of sheets, graticule and grid of the maps at 1:25,000, 1:50,000 and 1:100,000 scale of the system of Grande Carta d'Italia could be found in the previous paragraphs of this study. Chapters describing the geodetic foundation, on which the topographical survey bases and the execution of topographical survey from which the maps were compiled, include the data about the accuracy of the above mentioned maps. Hence this chapter should be limited to general characteristics of the maps published by the Italian Military Geographic Institute.

a. Topographical map of Italy at 1:25,000 scale: The sheets of 1:25,000 map are reproductions of the tavolettas (plane table sheets) and of plane table sections (quadranti) added by nomenclature and elevations. Until 1942, there were 2447 sheets reproduced from the tavolettas surveyed at 1:25,000 (1:20,000) scale and 1027 sheets photomechanically enlarged from at 1:50,000 scale surveyed plane table sections (quadranti). Altogether there were 3474 sheets of which 334 cover the territory annexed in 1919. After 1942 some 1200 tavolettas are surveyed photogrammetrically of which a large part cover the regions previously surveyed at 1:50,000 scale.

The map was photolithographically reproduced (zincography) in black color. The relief is expressed by contour lines with contour intervals of 5, 10, 20 and 25 meters which vary from time to time. Index contours are 25, 50 m and 100 meter contours respectively. Hachuring is used merely in expression of some fine details. Since 1940, the 25 m contour interval with 5 m auxiliary contours was adopted.

After 1946, the new edition of 1:25,000 map is published in three colors; Planimetry and cliffs in black, hydrography in blue and relief in brown color. The old black edition will be gradually replaced by the new sheets printed in color. These sheets, as already mentioned, refers to the International ellipsoid and are provided by Gauss-Boaga or UTM kilometric grid.

b. Topographical map of Italy at 1:50,000 scale: At the outset of the topographical survey at 1:50,000 scale it was merely intended to use the plane table sections (quadranti) in the compilation of 1:100,000 topographical map. Meanwhile in 1876, there was started the photozincographical reproduction of quadranti in black color. This black edition, at the outset with the relief expressed by 10 m but later by 50 m contour lines, in 1903 constitutes 681 sheets of the 1:50,000 topographical map. Because the 1:50,000 topographical survey has to be gradually replaced by 1:25,000 topographical survey the number of quadranti in 1942 dropped to 286 sheets which in a few years also will be replaced by tavolettas. [48]

In 1929-1941, the Military Geographic Institute started to reproduce 1:50,000 map in colours, i.e. the cultural features and nomenclature black, relief brown, hydrography blue and woodland green. These sheets were compiled from tavolettas.

The compilation and drawing were carried out at 1:25,000 scale and then it was photographically reduced to 1:50,000 scale. In respect to the expression of the relief and woodland the sheets reproduced in colours are not uniform. In the expression of relief the contour lines with the intervals of 25 m and 50 m and the combination of contour lines and shading were used. Actually there are two types of sheets i.e. with the relief expressed only by contours and with the relief expressed by combination of contours and shading. The woodland on some of the sheets is shown by green colour; on other sheets by black circles.

The edition printed in colours consists of 133 sheets covering the regions as follows:

- 37 sheets the region along Yugoslav boundary east of 1° meridian;
- 58 sheets the region along French boundary west of the 4° 30' meridian;
- 16 sheets in provinces Parma and Modena;
- 11 sheets in environs of Salerno and Benevento east of Naples; and
- 9 sheets at Trapani in western part of Sicily.

The compilation of the 1:50,000 sheets reproduced in colours in 1941 was discontinued. The 1:50,000 map is not included into present project of Italian mapping. After the complete coverage of Italy by 1:25,000 topographical survey the reproduction of quadranti will terminate.

c. Topographical map of Italy at 1:100,000 scale: The 1:100,000 topographical map of Italy called officially "La Grande Carta Topografica del Regno d'Italia" is compiled from 1:25,000 tavolettas and 1:50,000 quadranti. The compilation and drawing are carried out at 1:75,000 scale. The map consists of 297 sheets (foglios) covering the territory of Italy prior to World War II. Included in this number are 44 sheets which cover the territory (annexed in 1919) of Venezia Tridentina and Venezia Giulia. The regions surrounding the continental boundaries of Italy are covered by 50 more sheets compiled from the maps of adjacent countries. Since the regions of Venezia Giulia, Zadar and Eastern Adriatic Islands, covered by 10 sheets and parts of 4 sheets (8861 km^2) largely compiled from tavolettas, in 1947 came under Yugoslav sovereignty the present Italian territory is completely covered by 283 sheets (foglios).

The first foglio was published in 1878 in black colour with the relief expressed by the combination of 50 m contours and hachuring. Within an epoch of 80 years in the compilation and particularly in the reproduction of the 1:100,000 topographical map many changes and improvements were introduced. Hence the editions in respect to the expression of the relief, use of the standard-symbols and application of colours in the reproduction differ; moreover some editions do not cover all the territory of Italy. Various types of the foglios could be summarized as follows:

(1) The old editions covering the parts or entire territory of Italy which are no longer reproduced nor kept up to date. (Some of these sheets or parts of them are still utilized as environ-maps of cities or tourist maps):

(a) The edition reproduced in black colour with the relief expressed by combination of 50 m contours and hachuring at modified zenital illumination. These black sheets cover all territory of prior to 1915 Italy.

(b) The black edition with the relief expressed merely by 50 m contour lines (without hachuring or shading) covering Central Italy and parts of North and South Italy.

(c) The edition with the relief expressed by 50 m contours and with blue hydrography, which largely covers North Italy.

(d) The edition started in 1895 with black planimetry, dark gray 50 m contours and blue hydrography, which covers the western part of North Italy, Sardinia and some sheets of South Italy.

(e) The edition in colours with shading. This edition initiated in 1903, was reproduced by the Gliamas method of photo-engraving. The planimetry and nomenclature are printed in black colour except for roads which are shown in red colour; the relief is expressed by combination of 50 m black contours (250 m index contours) and gray-brown shading with light-gray flat land (plains, plateaus and terraces) and green vegetation (woodland). Some provisional sheets of this edition covering the eastern part of North Italy and southern part of Sardinia show the flat land in bright green colour.

(2) The present editions:

(a) With the introduction of photomechanical reproduction of maps in 1908, there was initiated a new edition of the 1:100,000 map. The sheets of this edition show the planimetry and nomenclature in black colour, relief expressed by the combination of 50 m contours and shading in pastel-brown colour, hydrography and glaciers in blue and woodland in green colour.

(b) Contemporary edition of the same map shows the relief expressed merely by 50 m (200 m index contours) contour lines without shading.

(c) Brown edition with administrative division. The map shows the planimetry and relief in brown colour, the hydrography blue and the international, province and community boundaries in violet colour.

(3) There are certain variances among the 1:100,000 sheets within the above mentioned editions:

- The sheets published in 1908-1945, do not have index contours. The sheets published prior to 1913 (Gliamas edition) have 250 m index contours. The sheets published after 1945 have 200 m index contours.

- The sheets of both editions - shaded and contoured - include woodland and were reproduced also without woodland.

- Woodland is shown by various symbols as green tinted areas, and green or black circles.

(4) Province maps: Military Geographic Institute published 1:100,000 maps which cover areas of various Italian provinces. In order to cover the entire area of each province many 1:100,000 sheets are joined together. The colours in which the province maps were reproduced slightly differ from. the colours of the regular edition. These maps are provided with superimposed province and community boundaries.

d. The map of Italy at 1:200,000 scale: The 1:200,000 map is compiled from 1:100,000 sheets. There are two editions of the 1:200,000 map:

(1) The old edition was started in 1907: It was planned that this edition would consist of 117 sheets of which 91 sheets would cover the territory of Italy and 26 sheets the boundary regions of adjacent countries. Only 71 sheets which cover the Northern half of Italy were compiled. The polyhedric sheet framed by meridians and parallels with the dimensions of $40'_{\phi} \times 1^{\circ}_{\lambda}$ is composed of four 1:100,000 foglios.[48] Regarding the manner of compilation and reproduction there are the following types of sheets:

(a) The sheets reproduced by method of Gen. Gliamas (photochemical engraving) with black planimetry and nomenclature, but red main roads, blue hydrography and glaciers, relief expressed by combination of dark gray 100 m contours (500 m index countours) and brown-gray shading and with woodland shown by green tint or green circles.

(b) The same sheets without shading.

(c) The sheets of Sardinia with relief expressed by hypsometric tints, planimetry and nomenclature printed in black and hydrography in blue colour.

(d) The sheets published in 1939-40, with black planimetry and nomenclature but the main roads shown by double black lines superimposed by red colour, relief expressed by combination of 100 m contours (500 m index contours) and shading in brown colour, hydrography blue, without woodland.

With these sheets the compilation of 1:200,000 map in 1940 was discontinued.

(2) The new edition started in 1950: The sheets framed by meridians and parallels with the dimensions $40'_{\varphi} \times 1^{\circ}\, 30'_{\lambda}$ are constructed in Gauss-Boaga projection and refer to International ellipsoid; starting meridian Rome, Monte Mario (determination 1940). The sheets are provided by 10 km UTM grid and ticks of Gauss-Boaga projection referring to the International ellipsoid. Each sheet covers six 1:100,000 foglios. The entire territory of Italy would be covered by 66 sheets. At the present time, there are completed about 70 sheets which cover that part of Italy north of Napoli the larger part of Sicily and boundary regions of adjacent countries. With 21 more sheets which would cover Italy southeast of Napoli and Sardinia the entire Italian territory will be covered by the new 1:200,000 map. The sheets covering the territory south of Napoli are in the process of compilation. These sheets are compiled from generally revised or newly-compiled 1:100,000 sheets. The polychrome reproduction is photomechanical with railroads, boundaries, nomenclature, graticule, grid, and marginal information in black colour, settlements and roads in brown, relief expressed by combination of 100 m contours (500 m index contours) in dark-gray colour with gray-brown shading; hydrography in blue colour and forests shown in green tint. The main roads are superimposed by yellow colour if they have hard surface, and by green colour if they have loose surface, and are provided with red ticks with figures showing the distances. The objects of military importance in violet colour are included into the restricted edition. This map is a successful combination

of a topographic map and a road map. Considerable generalized cultural features and relief compiled from 1:100,000 sheets, expressed artistically in polychrome reproduction made this map an excellent, highly legible marching map for motorized units as well as an operational map.

e. The additional maps published by Military Geographic Institute are:

(1) The road map at 1:300,000 scale consisting of 26 sheets in Bonne projection.

(2) The General Map of Italy and adjacent regions at 1:500,000 scale with 25 sheets in Bonne projection. There are three editions of this map:

- in three colors with shaded orography,
- in two colors without orography, and
- polychrome edition with orography represented by hypsometric tints.

(3) The International World Map at 1:1,000,000 scale with 6 sheets in modified polyconical projection with the relief expressed by hysometric tints.

(4) The environ-maps at 1:50,000 and 1:25,000 scale and the plans at 1:10,000 and 1:5,000 scale of numerous cities were published.

f. The maps of the Italian Touring Club (Consociazione Turistica Italiana): The Italian Touring Club published various maps compiled from corresponding military maps. The compilation and reproduction are made artistically with special consideration given to the highways and roads. These are:

- The 1:650,000 road map of Italy (two sheets North and South)
- The 1:500,000 general map of Italy
- The 1:250,000 map of Italy
- The 1:200,000 road map
- The 1:65,00 road map. [133]

These maps together with the large geographic atlas brought to the Italian Touring Club considerable fame in the circle of map makers.

Remarks:

The inadequacy of contours to produce a plastic effect of the relief, if it is not expressed by a dense contouring, created various aspects in respect to the use of contour intervals in the mapping. Some mapping schools advocate a dense contouring; others prefer the expression of relief by sparse contours. Because the practice of the contemporary Italian cartographic school, by its use of 1 graphical milimeter contour interval, typically represents the practices of the advocates of sparse contouring, this short discussion about the use of contour intervals should be appropriate.

A proper choice of contour interval is of primary importance in mapping and it depends on the shape of the relief, scale of the map, and purpose of the map. In the mapping of a country, a uniform contour interval for each scale is usually selected. It should be of such magnitude as to serve in the expression of relief for the entire country. The contour intervals used in the maps of various scales of a country should have a systemmatical relation. The inclusion into the map of all details of the relief of flat land or of rolling regions would require a small contour interval; meanwhile, in the expression of the steep relief of a mountainous region, the magnitude of contour interval is limited by the graphical impossibility of the drawing of contours less than 0.2 mm apart. Therefore, if a uniform contour interval should be used in the mapping of an entire country with high mountains there should not be used a smaller contour interval than such as where the horizontal distance between two consecutive contours at 60° slope would be less than 0.2 mm, i.e., at the scale:

1:25,000	10 m
1:50,000	20 m
1:100,000	40 m.

All details within these contour intervals would be expressed by auxiliary contours if included in the map. In order even to increase the density of contours (particularly in the 1:100,000 and 1:200,000 maps) the map makers of some countries (Germany, Greece, Iceland, Poland, Russia, Yugoslavia) considered the 0.2 mm graphical possibility of drawing contours at 45° slope and expressed greater steepness by index contours only.

Meanwhile, the increasing of the density contours would in certain degree decrease the legibility of the map. This is particularly true if the map is reproduced in one color; therefore a monochrome map requires sparse contouring. On the other hand, the modern polychrome map permits dense contouring without too great a sacrifice of legibility which results in more accurate expression of the relief and produces a plastic effect quite important to less trained map readers.

Nevertheless it should not be forgotten that the contemporary topographical map is highly loaded with details, particularly in the densely populated areas and in respect to legibility would hardly endure the maximal density of contours permitted by the graphical possibility of drawing 0.2 mm at 60° slope. Hence the majority of European countries in contemporary mapping apply the 0.4 graphical milimeter contour interval. It should be mentioned that Switzerland, a high mountainous and densely populated country, has a new 1:50,000 topographical map compiled for military purposes with the relief expressed by 20 m contour lines, i.e. contour interval of 0.4 graphical milimeter. [162]

In the Italian mapping until 1900 the 1:25,000 tavolettas and 1:50,000 quadranti, reproduced in black color only, also in mountainous areas show the relief by 5 m and 10 m contours respectively; i.e. 0.2 graphical milimeter contour interval. Later the contour interval used in the tavolettas was gradually increased (5,10,20,25 m) to 1 graphical milimeter, meanwhile at 1:50,000 quadranti the interval of 0.2 mm was replaced by the contour interval of 1 graphical milimeter.

After 1940 the relief in 1:25,000 tavolettas is expressed by 25 m contours and 5 m auxiliary contours - where they are needed. Due to this liberal requirement there is a very limited use for the auxiliary contours and also the ridges, bottoms of valleys, hilly and rolling areas are ordinarily expressed merely by 25 m contour lines. Evidently the relief expressed by the contour interval of 1 graphical milimeter is lacking in any plastic effect. Considering that the 1:25,000 map has to serve for technical and artillery purposes the plastic effect of the relief is really not essential, but a contour interval of 10 m, i.e. 0.4 graphical milimeter would be highly desirable.

In the expression of the relief in the Italian 1:100,000 and 1:200,000 map since 1878 the 0.5 graphical milimeter contour interval is applied; it should be considered suitable especially because these maps have an edition with the relief expressed by the combination of 50 m contours and shading producing an excellent plastic effect.

YUGOSLAVIA

V. YUGOSLAVIA

The Yugoslav state was created after the disintegration of the Austro-Hungarian Empire in 1918. The Yugoslav (Southern Slavic) people, Slovenes, Croats and Serbs liberated from Austro-Hungarian domination, joined together with the Serbs of independent Kingdoms Serbia and Montenegro in the Kingdom of the Serbs, Croats and Slovenes. The national territory of the newly created state (247,542 km^2) was composed of:

- The entire territory of Kingdoms Serbia and Montenegro (106,377 km^2);

- Austrian provinces: Carinthia (part), Styria (part) Carniola (part) Littoral (part) and Dalmatia;

- Autonomous Hungarian province Croatia and Slavonia as well as parts of Hungary known as Prekmurje, Medjimurje, Baranja, Bačka and Banat; and

- Common Austro-Hungarian province Bosnia and Hercegovina. (Total surface of former Austro-Hungarian territories 141,147 km^2).

The Federative People's Republic of Yugoslavia in 1946, after World War II, obtained from Italy the parts of former Austrian provinces Littoral, Carniola and Dalmatia (8,262 km^2).

The activities of various surveying agencies in this composed territory prior to World War I as well as during the World War II largely affected the Yugoslav survey and mapping.

In the epoch between the two World Wars (1918-1941), the Military Geographic Institute of the Kingdom of Yugoslavia (Vojni Geografski Institut Kraljevine Jugoslavije), the agency responsible for geodetic survey and mapping, made a great effort towards unification of the triangulation and production of a uniform map covering the entire national territory a considerable part of which never was surveyed. World War II prevented the completion of this project. After World War II, under different circumstances, the Geographic Institute of the Yugoslav People's Army (Geografski Institut Jugoslovenske Narodne Armije-GIJNA) has been quite successfully proceeding with the work initiated by its predecessor.

Since the former Austro-Hungarian territory covers more than a half (58%) of the present Yugoslavia and considering the fact that the triangulation and precise leveling covering the rest of the territory - Serbia, Macedonia, and Montenegro - were attached to the III Austro-Hungarian Military triangulation and precise leveling, it is intended in this chapter chronologically to explain the complexity of problems in the surveying and mapping of Yugoslavia for the entire national territory. (255,804 km^2).

1. Geodetic foundation:

a. Ellipsoid of Bessel: All Yugoslav mapping refers to Bessel ellipsoid but in the computing of the triangulation there are two exceptions.

(1) From 1917-24, the Clarke 1880 ellipsoid was used by the Military Geographic Institute. In order to obtain geographic coordinates uniform with the geographic coordinates of the Austro-Hungarian Military Triangulation which covers the western part of Yugoslavia and because the Direction General of Cadaster and State Domains (Generalna Direkcija Katastra i Državnih Dobara) already had adopted the Bessel ellipsoid, the geographic coordinates of Serbian triangulation referring to Clarke 1880 ellipsoid were transformed to Bessel ellipsoid.

(2) The degree survey which includes the arc along the 22° meridian observed in 1927-30, and the arc along the 45° parallel observed in 1931-36, was computed on the International (Hayford) ellipsoid for the puropses of the International Geodetic Association.

b. Projection. The Military Geographic Institute of Y.P.A. adopted for its new topographical survey and map compilation the Gauss-Krueger (Transverse Mercator) projection, but the maps compiled prior to World War II, still reproduced and predominantely used, are constructed in the polyhedric projection.

(1) The Gauss-Krueger (Transverse Mercator) projection of 3° zones with starting meridian Greenwich, central meridians 15°, 18° and 21° East of Greenwich and scale factor 0.9999, used since 1924 in the Yugoslav Cadastral survey, was in 1949 introduced in the construction of sheets of the Yugoslav military maps. The sheets are cut in the graticule system of the International map. The L33, L34, K33 and K34 sheets at 1:1,000 000 scale with dimensions $4^{o}_{\varphi} \times 6^{o}_{\lambda}$ cover the area of Yugoslavia. The subdivision of the sheets of the maps compiled at various scales which are used in the Yugoslav mapping could be explained as follows:

The sheet of International map is divided into four $2^{o}_{\varphi} \times 3^{o}_{\lambda}$ sheets at 1:500,000 scale coded with the numbers 501, 502, 503, 504.

The 1:500,000 sheet is divided into four $1^{\circ}_{\phi} \times 1^{\circ}\ 30'_{\lambda}$ sheets of 1:300,000 scale having the numbers 301, 302, 303 and 304.

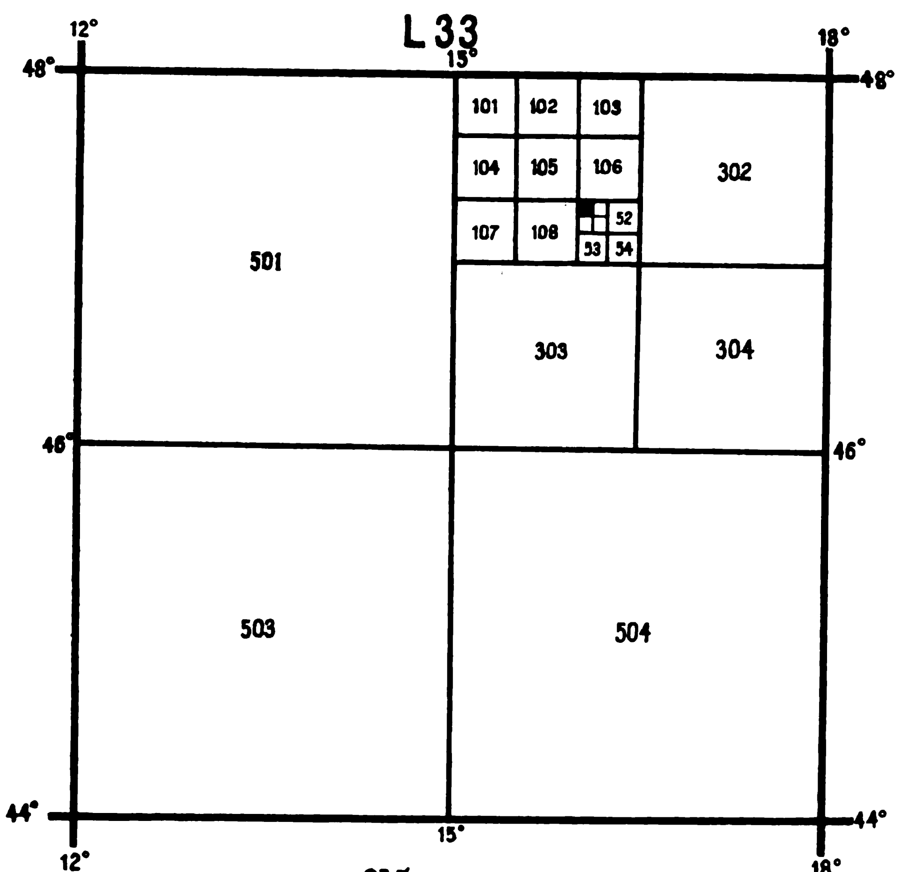
The 1:300,000 sheet is subdivided into nine $20'_{\phi} \times 30'_{\lambda}$ sheets at 1:100,000 scale coded by numbers 101-109.

The 1:100,000 sheet is divided into four $10'_{\phi} \times 15'_{\lambda}$ sheets at 1:50,000 scale coded by numbers 51, 52, 53, and 54.

The 1:50,000 sheet is divided into four $5'_{\phi} \times 7'30''_{\lambda}$ sheets at 1:25,000 scale having the numbers 25/1, 25/2, 25/3 and 25/4. Consequently in the contemporary Yugoslav mapping the quadriform subdivision is rigidly kept, with the exception of 1:300,000 sheet divided into nine 1:100,000 sheets.

In order to located an 1:25,000 sheet the following system of code is used:

L 33-502-301-109-53-25/1



Beside the code number the sheets have the name of the largest settlement included. [112]

This index sketch would completely explain the subdivision as well as system of code.

(2) The polyhedric projection. In an attempt to assure continuity with the Austro-Hungarian mapping the Military Geographic Institute of the Kingdom of Yugoslavia in the construction of the plane table sheets and maps used the polyhedric projection with starting meridian of Paris (20° East of Ferro or 2° 20' 13."98 East of Greenwich). The sheets were cut along the meridians and parallels.

As individual projecting planes there were considered the trapezoidal plane table sheets as follows:

In the topographical survey at 1:10,000 scale the plane table sheet with the dimensions $1'52."5_{\phi} \times 3'45"_{\lambda}$.

In the topographical survey at 1:25,000 scale the plane table sheet with dimensions $3'45"_{\phi} \times 7'30"_{\lambda}$;

In the topographical survey executed in 1920-28 at 1:50,000 scale the plane table sheet with the dimensions $6'_{\phi} \times 10'_{\lambda}$.

The map sheets have a quadripartite subdivision considering the 1:200,000 sheet with the dimensions $1^{\circ}_{\phi} \times 1^{\circ}_{\lambda}$ as a base; consequently the sheet sizes of the sheets within this subdivision are as follows:

1:100,000	sheet	$30'_{\phi} \times 30'_{\lambda}$
1: 50,000	sheet	$15'_{\phi} \times 15'_{\lambda}$
1: 25,000	sheet	$7'30"_{\phi} \times 7'30"_{\lambda}$
1: 10,000	sheet	$3'45"_{\phi} \times 3'45"_{\lambda}$

Even though the same projection and sheet-division was used, continuity between Austro-Hungarian and Yugoslav mapping was never achieved because various datums of the control were used in the mapping. Austro-Hungarian maps (except of IV topographical survey in Tyrol) belong to Vienna University and Arad, St. Anna Systems whereas the Yugoslav maps compiled from the new topographical survey at 1:10,000, 1:25,000 and 1:50,000 scales were based upon the triangulation oriented on Hermannskogel datum.

c. Triangulation:

(1) On the territory inherited by Yugoslavia after disintegration of the Austro-Hungarian Empire there were 5 base lines (Maribor, Sinj, Dubica, Sarajevo and Vršac) and 163 first order stations established by K. u. k. Military Geographic Institute of Vienna the records for which are published in Volumes I and II of the Ergebnisse der Triangulierungen. To the first order net there were attached second and third order nets covering the western and northern parts of Slovenia, southern part of Croatia and Slavonia (Frontier Regions), Vojvodina, Bosnia and Hercegovina. Of this lower order triangulation only the records for 980 trig points of the triangulation covering the western part of Slovenia (1:200,000 sheets Ljubljana and Trieste) in Volume IV of the Ergebnisse der Triangulierungen were published. At this stage of development in 1918, the K. und k. III Military Triangulation covering the inherited territory was found. To this triangulation the triangulation of Serbia, Macedonia and Montenegro under certain conditions was attached. In order to cover the entire national territory with a solid first order net, the first order chains of K. und k. III Military Triangulation were partially resurveyed, supplemented, and filled by first order net. The development of the triangulation covering the territory of Yugoslavia up to the present stage will be discussed in the following subparagraphs.

(a) The first order net in Serbia, Macedonia and Montenegro: The works on the triangulation in Serbia (pre Balkan War Serbia) started with the reconnaissance of the terrain and construction of the markers and signals in 1900. In the time from June till October 1904 the following four base lines were measured:

Paraćin	5603.037 m ± 1/11,073 500
Negotin	4656.209 m ± 1/ 1,432 700
Vranje	4970.421 m ± 1/ 3,731 500
Loznica	5029.376 m ± 1/ 1,105 100 [22] [160]

The first order net consists of 114 triangles with 82 stations including 12 stations of four base extention nets. The base lines were measured by the Jäderin base apparatus.[160] (See Inclosures 27 and 28).

The directions were observed by Struve method in 12 positions (24 observations of each direction) using the theodolites Kern and Starke and Kammerer with microscopes and reading of 1" and 2" respectively. Accuracy of observations would be expressed with the mean error of one direction ± 0".70. The net was tied to the Austro-Hungarian first order net in the west on station: 261 Džep Brdo, 270 Konjuh, 271 Veliki Stolac in the north on stations: 491 Dumača, 496 Antina Livada, 501 Moldavica, 502 Kukujova and it was adjusted by the method of least squares in 10 groups. In the adjustment Austro-Hungarian sides and angles were held fixed. The geographic coordinates were computed on the ellipsoid of Bessel. Serving as starting points were the first order stations of K. und k. III Military Triangulation 261 Džep Brdo and 270 Konjuh with coordinates published in Volume I of the Ergebnisse der Triangulierungen. The disparities between Austro-Hungarian and Serbian GP's resulting from this adjustment at station 502 Kukujova amount:

$$\Delta\phi = (\phi \text{ Serb} - \phi \text{ Austr.}) = +0''.01$$

$$\Delta\lambda = +0.30$$

$$\Delta\alpha = -7.0 \quad [160]$$

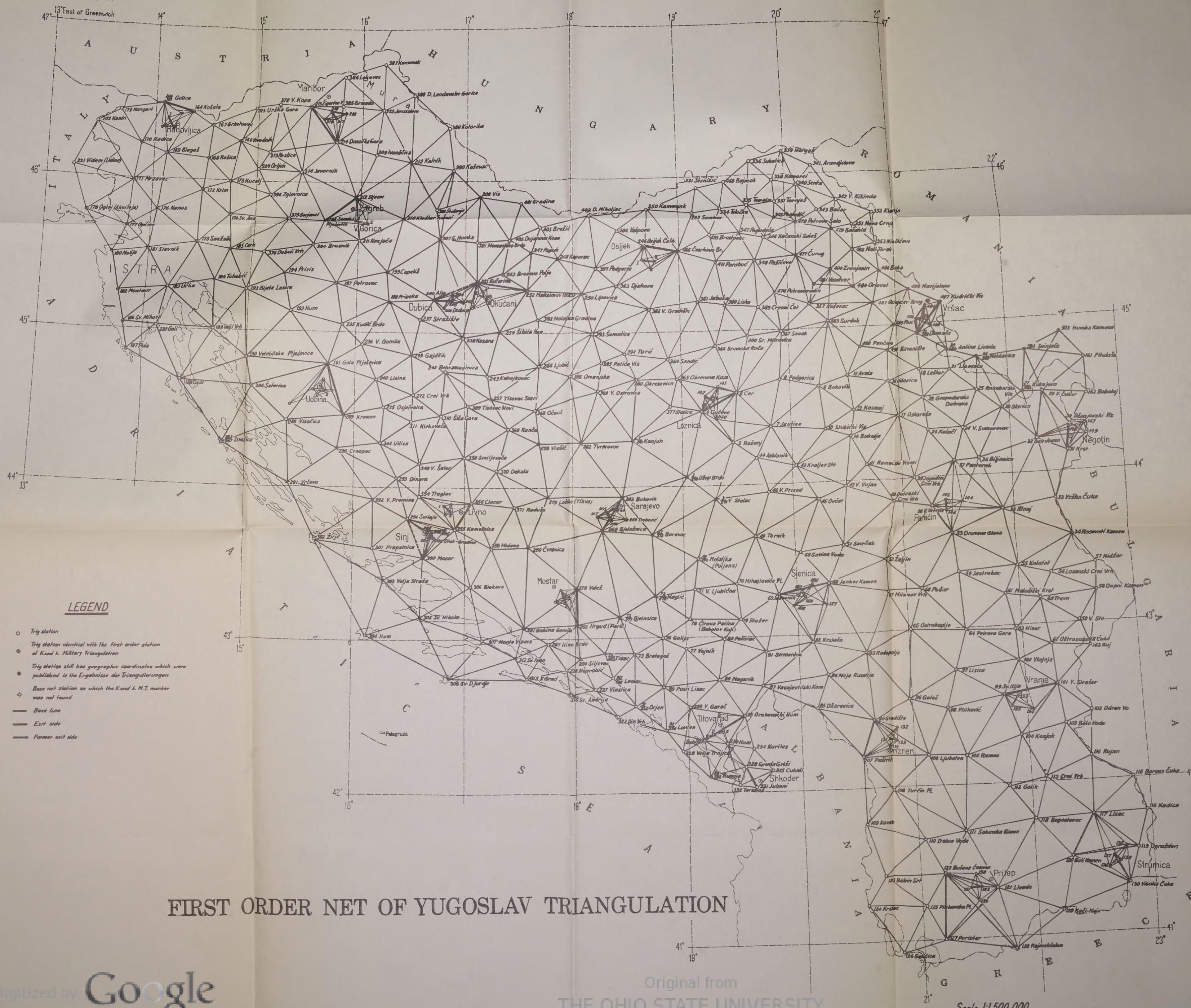
It was assumed that these disparities representing 6 m in linear value were accumulated in the successive attachments of groups in the adjustment. In order to cover the need of fixed points for topographical survey from the first order net the second and third order nets were developed with a density of 5-7 km from point to point. Since during World War I the records of Serbian triangulation were missing and a large proportion of markers destroyed after World War I the net was surveyed together with the establishment of triangulation in Macedonia and Montenegro by the Military Geographic Institute. Hence the first order net covering the entire territory of Serbia, Macedonia and Montenegro is considered as a homogenous net.

In addition to the four base lines measured in 1904 the following base lines were measured:

Prizren	(1922)	5379,959 ± 1/4,374 000	
Strumica	(1922)	6623,806 ± 1/2,158 000	
Prilep	(1922)	5982,555 ± 1/5,489 000	
Sjenica	(1924)	5570,334 ± 1/1,053 000	[22]

The measurements were carried out by the same Jäderin base apparatus applying the same method as in the previous measurements of Serbian base lines.

Inclosure 27



FIRST ORDER NET OF YUGOSLAV TRIANGULATION


Inclosure 28
East of Greenwich
LEGEND
Trig station
Trig station identical with the First order station of Kund k. Military Triangulation
Trig station still has geographic coordinates which were published in the Ergebnisse der Triangulierungen
Base net station on which the Kund k. M.T. marker was not found
Base line
Exit side
Former exit side
First Order Net of Yugoslavia
Scale 1:1,500 000

Concerning the accuracy of measurement of base lines it should be mentioned that the ± $\frac{\Delta S}{S}$ fraction given with the lengths of base line represent so-called internal accuracy of the base line derived from the difference between the forward and backward measurements. This internal error does not include systematical errors caused by the apparatus and its constants (calibration of invar wires by the Bureau International des poids et measures Sevres, France is carried out by a mean error up to ± 22 microns which would produce an accumulation of systematical error up to 0.92mm/km). After a careful analysis of the Paračin and Strumica base lines the Federal Geodetic Administration published the following mean total relative errors:

Paraćin base line $E_r = \pm \frac{11.9mm}{5603.161m} = \pm 1/470{,}000$ or $\pm 2.1mm/km$

Strumica base line $E_r = \pm \frac{9.4mm}{6623.806m} = \pm 1/700{,}000$ or $\pm 1.4mm/km$. [160]

From the analysis of German and Russian base lines with approximate lengths of 5 km and accuracy of 1.9 - 2.3 mm/km was obtained. An accuracy comparable to this is evident from the records of the adjustment of Central European Net and should be considered more than sufficiant to match the accuracy with which the angles are observed by means of contemporary instruments. Consequently the accuracy obtained in the measurements of the eight base lines would meet completely the present standards. Meanwhile the base line nets in respect to the accuracy of observations (maximal error of triangle closure 0."85 - 4."14) as well as strength of figure (factor R = 22 - 44) are below the standards required in contemporary instructions. The Geographic Institute of the Y.P.A (GIJNA) in order to obtain the factor R within the limits of 20 units of 6 log place and the triangle closures within 1" has been reconstructing and reobserving the base line nets and in the future adjustment of first order net intends to use the exit sides computed from the reconstructed and reobserved base line nets.

The first order net of Serbia, Macedonia and Montenegro (A) consists of the 8 mentioned base lines 31 stations of base line nets 130 first order stations, 209 triangles and 676 directions. The average side has a length of 34.7 km, minimal 8.9 km and maximal 60.6 km. Three angles are smaller than 25°. The smallest angle has 19° 41' 35". The observations were made by method of Struve in 12 sets (positions) using the same theodolites Kern and Starke and Kammerer as in previous triangulation of Serbia. The accuracy of the net prior to adjustment would be expressed by:

- mean square error of triangle closure

$$m_\Delta = \pm\sqrt{\frac{[f^2]}{n}} = \pm\sqrt{\frac{510.20}{209}} = \pm\ 1\rlap{.}''56$$

- mean square error of angle by formula of Ferrero

$$m_a = \pm\sqrt{\frac{[f^2]}{3n}} = \pm\sqrt{\frac{510.20}{627}} = \pm\ 0\rlap{.}''90$$

In the net there are 10 triangles with error of closure larger than 3". The maximal error of closure 4"98 has the triangle 46 V. Prised - 45 Ovčar - 49 Tornik.

The net was adjusted as a whole by the method of Prof. Sviščev - method of successive approximation solving the conditional equations directly without setting up normal equations. In this adjustment there were solved 310 conditional equations (209 figural equations for triangles, 7 equations for fixed angles, 81 sine equations and 13 base equations). The mean square error of one direction from adjustment would be expressed:

$$\mu = \pm\sqrt{\frac{[v^2]}{k}} = \pm\sqrt{\frac{864.33}{310}} = \pm\ 1\rlap{.}''67$$

where v = correction of direction from the adjustment of net,

k = number of conditional equations; the mean correction is:

$$v_m = \pm\sqrt{\frac{[v^2]}{n}} = \pm\sqrt{\frac{864.33}{676}} = \pm\ 1\rlap{.}''13$$

maximal correction 3"582 has direction 95 Orahovački Hum - 94 Rumija. Six directions have larger corrections than 3" The net was attached in this adjustment to the K. und k. III Military Triangulation under the following imposed conditions:

- Sides: 1/261 Konjuh - 2/270 Džep Brdo - 3/271 V. Stolac - 47/273 Borovac - 72/276 Maglić - 73/277 Bjelasica - 74/283 Tisac remain Austrian.

- Angles: For the above mentioned stations the Austrian angles were used.

- Coordinates: Austrian coordinates were retained for the above mentioned stations.

- On stations: 20/496 Antina Livada and 26/501 Moldavica only the Austrian angles were retained because of previously mentioned discrepancies at station 27/502 Kukujova. Adjustment of the net was completed in 1927.

Stations attached to the first order net of Serbia, Macedonia and Montenegro. (See Inclosure 28):

- On the Bulgarian territory was observed station 163 Ruj (H). Because of errors of triangle closure up to 6".384 this station was not included in the adjustment of the net A.

- On the Romanian territory located first order stations 161 Pitulasu and 162 Bobuluj (G) were determined in 1934 by Yugoslav Cadastral Survey for the purpose of more convenient development of the Cadastral second order net. The accuracy of observations would be expressed by the mean square error of angle by formula of Ferrero

$$m_a = \pm 1''.18$$

The mean square error of direction computed from the corrections in the adjustment was ± 1".38, and the largest correction of direction is 2".35. [1][160]

(b) The first order net in northeastern part of Yugoslavia (B). It was known that the K. und k. III Military Triangulation north of the Danube and Sava Rivers was not sufficiently accurate. There also remained an empty area north of the net A, i.e., between the first order net in Serbia, Macedonia and Montenegro, and the Austrian first order chain, and also north of the Austrian first order chain to the Yugoslav-Hungarian and the Yugoslav-Romanian boundaries. In view of these deficiencies, the Commission of the State Survey decided to cover the entire area north of the first order net in Serbia, Macedonia and Montenegro with a closed net including stations of the Austrian first order chain which had to be resurveyed. The net was established by the Military Geographic Institute. The observations of the eastern part (Trigonometrical net in Vojvodina) were carried out in 1928. Meanwhile the western part was not completed prior to World War II and some directions were observed after the War. In the observations the theodolites Starke and Kammerer (and after 1937 also Wild III) were used. The accuracy of observations is expressed as follows:

The mean square error of triangle closure

$$m_\Delta = \pm\sqrt{\frac{[f^2]}{n}} = \pm\sqrt{\frac{419.01}{124}} = \pm 1''.84$$

The mean square error of angle by formula of Ferrero

$$m_a = \pm\sqrt{\frac{[f^2]}{3n}} = \pm \frac{419.01}{372} = \pm 1''.06$$

The maximal error of closure is - 4".924 in the triangle 481 Veudvar - 480 V. Bečkerek (Zrenjanin) - 357 Koševac. Errors of closure larger than 3" have 10 triangles. The smallest angle 16°03'15" is at the point 357 Koševac.

The length of the sides in the net are: minimal length 11.9 km, average length 28.8 km and maximal length 61.7 km.

The net consists of 82 stations of which 21 stations are given and 61 newly determined. Given stations are:

- In the northwest stations of K. und k. Military Triangulation: 254 Šibića Han 203 Kučerina, 247 Papuk, 248 Kapovac, 466 Ćvorkovo Brdo and 465 Trojnaš for which the coordinates were taken from the Ergebnisse der Triangulierungen.

- In the west stations of the 1937-40 first order net (the net in the western part of Yugoslavia C): 243 Kabajkovac, 257 Tisovac Stari and 369 Ranča.

- In the south stations of K. und k. Military Triangulation with coordinates taken from the Ergebnisse: 258 Vlašić 262 Tvrtkovac and 1/261 Konjuh and stations of the first order net in Serbia, Macedonia and Montenegro: 4 Gučevo, 6 Cer, 8 Podgorica, 9 Bukovik, 12 Avala 16 Udovice, 18 Leštar, 19/491 Dumača and 20/496 Antina Livada. The net is not uniform because it consists of 124 triangles with 6 diagonal ties and 2 quadrilaterals without diagonals.

The adjustment of this net carried out by Direction General of Cadaster and State Domains, started in 1934 and completed in 1951, represents piece work. Because the net was gradually esttablished, the first part to be adjusted was the eastern part which consisted of 44 stations, 68 triangles, 1 quadrilateral and 225 directions comprising the Trigonometrical net of Vojvodina. The least square adjustment of this net started with the western group and was carried out by the Krueger method; then the southern group was adjusted by the Boltz method; and finnally the central group (which partially overlaps the other two) was adjusted by the method of indirect observations. The mean correction of direction obtained from this heterogenous adjustment would be:

$$v_m = \pm\sqrt{\frac{[v^2]}{n}} = \pm \sqrt{\frac{257.43}{225}} = \pm 1''.07.$$

Maximal correction of direction is 2".615

The western part of the net consists of 39 stations (18 given), 52 triangles, 1 quadrilateral and 161 directions. The adjustment by the method of indirect observations started in 1940, was interrupted by World War II and not completed until 1951. The accuracy of this net after the adjustment would be expressed by the mean square error of direction computed from the adjustment by formula:

$$\mu = \pm\sqrt{\frac{[v^2]}{n-3k}} = \pm\sqrt{\frac{184.91}{161-3\cdot 39}} = \pm\ 2''.05$$

Meanwhile the mean correction of direction is of the same magnitude as in the eastern part of the net:

$$v_m = \pm\sqrt{\frac{[v^2]}{n}} = \pm\sqrt{\frac{184.91}{161}} = \pm\ 1''.07$$

Of 161 directions 12 directions have corrections larger than 3". It should be noted that these large corrections are not due to the poor observations (the error of direction computed from the errors of triangle closures amounts ± 0".75), but because this net was placed between two first order chains of K. und k. III Military Triangulation of which the northern chain with stations 465 Trojnaš and 466 Ćvorkovo Brdo has a shift of 3 m toward the southern chain with stations 258 Vlašić, 262 Tvrtkovac and 1/261 Konjuh.

In the area covered by first order net B the Vršac base line of the K. und k. III Military Triangulation is located. This base line with its extention net was not included in the adjustment of the net B. The logarithm of the exit side 19/491 Dumača - 497 Kudrički Vis taken from the Ergebnisse and compared with the logarithm of side obtained in this adjustment differs for 14 units of the eight place, or 0.009 m. [1] [160]

(c) <u>The first order net in the northwestern part of Yugoslavia</u> (C). The K. und k. III Military Triangulation in western Yugoslavia was composed of the chains and did not cover the central area of Bosnia, central area of Slovenia and the regions along Drava and Mura Rivers in Slovenia and Croatia. In order to fill these empty areas with first order stations and to establish a closed net work was started there in 1937 on the first order net in western Yugoslavia. The work was carried out according to the provisional instructions for the execution of triangulation published in 1937 by Military Geographic Institute. In this net the triangulators of Military Geographic Institute established only 11 stations including the completion of observation, another 82 were established and observed by 5 triangulators of the Direction General of Cadaster and State Domains under supervision of the Military Geographic Institute.

The observations were made by the theodolites Otto Fennel with diameter of horizontal circle 25cm, graduation interval of horizontal circle 5', graduation interval of micrometer drums 2", and magnification of telescope 45_x. The angles were observed by method of Schreiber with the weight $p = \frac{n.s}{2} = 12$, where s means number of directions and n number of positions.

In 1937-38, 34 stations which composed the fill net included into southern (Bosnian) loop of K. und k.III Military Triangulation were determined. The average side of this net has the length of 33.4 km, the minimal 16.6 km and the maximal 69.6 km. The smallest angle observed of 19° 55' is at station 191 Gola Plješevica. The mean square error of triangle closure in the net composed of 90 triangles would be:

$$m_\Delta = \pm\sqrt{\frac{[f^2]}{n}} = \pm\sqrt{\frac{152.55}{90}} = \pm 1\overset{''}{.}30$$

The mean square error of angle by formula of Ferrero

$$m_a = \pm\sqrt{\frac{[f^2]}{3n}} = \pm\sqrt{\frac{152.55}{27}} = \pm 0\overset{''}{.}75$$

The maximal error of closure 2"922 is in the triangle 355 Kamešnica - 306 Biokovo - 300 Mosor.

Since this net is a typical fill net which has to be included into Bosnian loop of K. und k. III Military Triangulation prior to its adjustment the accuracy of the Bosnian loop was tested. In the net there are 10 identical angles observed by Austrian and by Yugoslav triangulators. The differences between Austrian and Yugoslav angles run between 0"250 and 2"602, and 4 of them are below 1", 2 above 1" and 6 above 2". The mean square error of observed angle computed from disparities of 10 angles observed twice would be:

$$m_a = \pm\sqrt{\frac{[\Delta^2]}{2 \cdot n}} = \pm\sqrt{\frac{29.1}{20}} = \pm 1\overset{''}{.}21$$

Of special interest was the scale-test of the sides composing the triangles of the northern, southern, western and eastern chain of the Bosnian loop. For this purpose the centrally located side 242 Behramaginica - 310 Šiša Gora was computed from 4 sides (one side of each chain). The mean square error of the most probable value of the length of the side 32102.16 m determined as arithmetical mean from four computation was ± 0.27 m, i.e. 1/118.528. Considering these results of the test it was decided to adjust the newly observed first order net as a fill-net of the Bosnian loop of K. und k. III Military Triangulation.

Prior to the outset of this adjustment the observations were extended over the rest of the northwestern part of the country and completed in 1940. Within this extended net, composed of 64 triangles, 33 first order stations were determined. The accuracy of observations expressed by mean square error of triangle closure would be:

$$m_\Delta = \pm\sqrt{\frac{[f^2]}{n}} = \pm\sqrt{\frac{138.77}{64}} = \pm 1.''47$$

The mean square error of angle by formula of Ferrero is:

$$m_a = \pm\sqrt{\frac{[f^2]}{3n}} = \pm\sqrt{\frac{138.77}{192}} = \pm 0.''85$$

Three triangles have errors of closure larger than 3". The maximal error of closure + 3.''459 is in triangle 199 Čepeliš - 207 Gornja Humka - 200 Alje.

In western Yugoslavia are located the Austrian base lines of K. und k. III Military Triangulation at Maribor, Sinj, Dubica and Sarajevo. The markers of base end points and of base net stations were found except stations 296 Otok-Gradina (Sinj base net) 202 Vrištik (Dubica base net) and 269 Trebević (Sarajevo base net). Except for the Maribor base line Austrian base lines with their nets were not considered in this adjustment. The Maribor base net was reobserved in 1939, because of doubt that the stations 215 Žigertov Vrh and 214 Donačka Gora are identical with the first order stations 215 Bacher and 214 Donati of K. und k. III Military Triangulation. Since buildings erected on the base line prevented visibility between the end points it was impossible to carry out a new base line measurement or to repeat the observations of all angles in the base net. In the observations was included first order station 285 Grmada as newly determined. The observations were executed by method of Schreiber with the weight p = 24.

The mean square error of triangle closure is:

$$m_\Delta = \pm\sqrt{\frac{[f^2]}{n}} = \pm\sqrt{\frac{3.09}{10}} = \pm 0.56 \text{ (Austrian } 1.''52)$$

The mean square error of angle by formula of Ferrero is:

$$m_a = \pm\sqrt{\frac{[f^2]}{3n}} \quad \pm\sqrt{\frac{3.09}{30}} = \pm 0.32 \text{ (Austrian } 0.''87).$$

The base net was adjusted by the method of indirect observations. The length of the side 219 Bukovec - 216 Krčevina taken from the Ergebnisse served as given in the adjustment of base net. The coordinates of newly determined stations 215 Žigertov Vrh, 214 Donačka Gora and 385 Grmada were derived from the coordinates of stations 219 Bukovec and 216 Krčevina taken from the Ergebnisse der Triangulierungen.

The mean square error of correction of direction from the adjustment of base net is:

$$\mu = \pm\sqrt{\frac{[v^2]}{k}} = \pm\sqrt{\frac{3.76}{9}} = \pm 0''.65 \text{ (Austrian } \pm 1''.15).$$

It should be mentioned that the real (external) accuracy of the Austrian base lines located on Yugoslav territory is unknown (1/600,000 to 1/4,200.000 is the internal accuracy published for the five Austrian base lines in Yugoslavia.) The lengths of the base lines are too short except for the Maribor base line. All lengths are below 5 km with Dubica base line 2.9 km and Sinj base line 2.5 km. The number of Austrian base lines is not sufficient and distribution not adequate to meet the contemporary requirements for first order triangulation. Meanwhile the strength of figure of base line nets (factor R = 15 - 36) is better than that of 8 base line nets in the triangulation of Serbia, Macedonia and Montenegro.

The entire first order net in the western part of Yugoslavia (C) consists of 95 stations (91 first order stations and 4 stations of Maribor base net) 154 triangles with 444 directions. It was adjusted in 5 groups by the method of indirect observations. The adjustment was made by the Direction General of Cadaster and State Domains. In this adjustment 24 stations were given and 71 stations newly determined. The coordinates for the following 21 given stations were taken from Volume I of the Ergebnisse der Triangulierungen: 198 Priseka, 199 Čepeliš, 200 Alje, 203 Kučerina, 207 Gornja Humka, 208 Vis, 216 Krčevina, 219 Bukovec, 254 Šibića Han, 258 Vlašić, 262 Tvrtkovac, 279 Ločike, 280 Ćvrsnica, 281 Babina Gomila, 288 Visočica, 291 Vrčevo, 292 Velika Promina, 300 Mosor, 303 Velja Straža, 305 Sv. Nikola and 312 Sv. Ivan.

The coordinates for the 3 stations as follows were obtained from the adjustment of Maribor base net:

214 Donačka Gora, 215 Žigertov Vrh and 385 Grmada.

The accuracy of the adjusted net C would be expressed by the mean square error of adjusted direction:

$$\mu = \pm\sqrt{\frac{[v^2]}{n-3k}} = \pm\sqrt{\frac{284.2063}{444-3\cdot 66}} = \pm 1''.07$$

There is only one direction (306 Biokovo - 355 Kamešnica) with the correction larger than 2" (-2".330). Stations of this net 169 Blegaš and 381 Štefanje were adjusted as single points and later included in the net. [1][160]

(d) The first order net at the Coastland of Montenegro (D). The eastern section of Dalmatian chain of the K. und k. III Military Triangulation confined between the mountain range along the former Austria - Montenegro boundary and the Adriatic Sea consists of triangles with long sides and highly acute angles (15°, 10° and even 5°); consequently, although tied to the base line of Shkoder and connected to the Italian triangulation across the Adriatic Sea, it does not represent satisfactory work, especially by todays standards. The differences between the coordinates published in the Ergebnisse and coordinates of the adjusted first order net A (first order net in Serbia, Macedonia and Montenegro) at identical stations are as follows:

74/283	Tisac	(A-Y)	$\Delta N = 0.00$ m;	$\Delta E = 0.00$ m (given point)
92/324	Lovćen	(A-Y)	$\Delta N = -2.51$ m;	$\Delta E = +0.94$ m
94/326	Rumija	(A-Y)	$\Delta N = -3.40$ m;	$\Delta E = +0.01$ m

These disparities show that the differences between Austrian and Yugoslav coordinates are increasing from station 74/283 Tisac (Austrian coordinates used as given in the adjustment of the first order net A) toward the southeast. Nevertheless many markers of the first order stations of K. und k. III Military Triangulation were destroyed. On the other hand the Shkoder base line with its extension net, neither the old Austrian (1869) nor new Italian (1934) even was included into the net A of the Yugoslav first order net.

Shkoder (1934) 3060.407 m ± 1/2,480 000 (It is only 0.726 m shorter than the Austrian base line measured in 1869).

Under these circumstances in 1940, the Direction General of Cadaster and State Domains planned a project to reconstruct and reobserve the first order net in southern Dalmatia and the Coastland of Montenegro. This project, postponed by World War II, was completed in 1946 by a section of 6 triangulators (1 of Geographic Institute of Y.P.A. and 5 of Federal Geodetic Administration).

The net is composed of 32 stations of which 9 were given and 23 newly determined, 51 triangles with 156 directions (140 observed in 1946). Given stations are: 308 Sv. Djordje, 312 Sv.Ivan, 281 Babina Gomila, 282 Hrgud (Parić), and 73/277 Bjelasica of the K. und k. III Military Triangulation with the coordinates from the Ergebnisse der Triangulierungen; and 76 Golija, 77 Vojnik, 88 Maganik and 95 Orahovački Hum with the coordinates from the adjustment of first order net A. In the net only the following 5 stations are newly established:

230 Hum, 226 Neprobić, 228 Velja Trojica, 313 Veliki Grad and 316 Sv. Andrija. All other stations were established by K. und k. Military Geographic Institute, Yugoslav Military Geographic Institute and Italian Military Geographic Institute. The average length of the side is 26.5 km; the minimal 11.9 km (331 Jubani - 332 Taraboš); the maximal 56.8 km (308 Sv. Djordje na Lastovu - 313 Veliki Grad). The smallest angle 16°53' 19" is at station 308 Sv. Djordje. The net has 4 diagonal ties.

In the observations 4 Otto Fennel and 2 Starke and Kammerer theodolites were used. The angles were observed by Schreiber's method with the weight p = 12. (The mean error of angle observed in one position computed from the observations of stations observed by theodolite Fennel was ± 1".15, by theodolite Starke & Kammerer ± 1".44). The observations were carried out by an accuracy expressed by mean square error of the triangle closure:

$$m_\Delta = \pm\sqrt{\frac{[f^2]}{n}} = \pm\sqrt{\frac{107.99}{51}} = \pm 1''.46$$

The mean square error of angle by formula of Ferrero is

$$m_a = \pm\sqrt{\frac{[f^2]}{3n}} = \pm\sqrt{\frac{107.99}{153}} = \pm 0''.84$$

There is only triangle 332 Taraboš - 94/326 Rumija

- 328 Gruda with error of closure larger than 3" (+ 3".569).

The net D was adjusted by the method of conditional observations where 79 equations were solved (47 of triangle, 7 of given angles, 8 of given sides and 17 sine equations). The side 328 Gruda Griži - 331 Jubani with the length of 16,220.86 m computed from the base net of Shkoder (Scutari) base was included into adjustment as given.

The mean square error of direction computed from the corrections obtained from adjustment amounts:

$$\mu = \pm\sqrt{\frac{[v^2]}{k}} = \pm\sqrt{\frac{104.66}{79}} = \pm 1''.45,$$

and the mean correction would be:

$$v_m = \pm\sqrt{\frac{[v^2]}{n}} = \pm\sqrt{\frac{104.66}{140}} = \pm 0''.86$$

There are only 3 corrections larger than 2". The largest correction is + 2".579.

The differences between the coordinates obtained from this adjustment and coordinates published in the Ergebnisse at previously mentioned identical stations are:

74/288 Tisac (A-Y) $\Delta N = -0.03$ m; $\Delta E = -0.03$ m
92/324 Lovćen (A-Y) $\Delta N = -1.87$ m; $\Delta E = +0.96$ m
94/326 Rumija (A-Y) $\Delta N = -4.18$ m; $\Delta E = +0.28$ m

Considering these differences the replacement of old Austrian chain along the coast of Southern Dalmatia and Montenegro by the new net D was badly needed. Consequently, it should be noted, that the Dalmatia - Albanian chain of K. und k. III Military Triangulation represent a poor link in the European Adjustment. [54][160]

(e) The first order net in Slavonia (E): The net was observed in 1939 with the errors of triangle closures larger than 3", therefore it was reobserved in 1946 by a section of five triangulators (4 of the Geographic Institute of Y.P.A and 1 of the Federal Geodetic Administration). The net is composed of 21 triangles with 10 given and 9 newly-determined stations. Given stations are: 208 Vis, 207 Gornja Humka, 203 Kučerina, 247 Papuk, 248 Kapovac, and 466 Ćvorkovo Brdo with the coordinates from the Ergebnisse der Triangulierungen and 250 Lipovica, 363 Djakovo, 232 Sombor and 231 Stanišić with coordinates from the adjustment of the first order net B. Since it was impossible to establish the intervisibility among the first order stations 465 Trojnaš and 249 Osijek, Franciscan church of K. und k. III Military Triangulation and the stations 402 Donji Miholjac, 404 Valpovo and 397 Podgorje the stations Trojnaš and Osijek, Franciscan church were replaced by the new first order stations 259 Kamenjak and 246 Osijek, Cathedral. The lengths of the sides are: average 30.7 km, minimal 18.4 km and maximal 50.2 km. The smallest angle at station 363 Djakovo is 25° 03' 32".

The observations were carried out by method of Schreiber (p=12) with two theodolites of Otto Fennel (microscope reading 2") and one large Starke & Kammerer theodolite (microscope reading 1"). There were observed partially heliotropes and signals (pyramids). The accuracy of observations expressed by the mean square error of triangle closure is:

$$m_\Delta = \pm\sqrt{\frac{[f^2]}{n}} = \pm\sqrt{\frac{37.06}{21}} = \pm 1\overset{''}{.}33$$

and the mean square error of angle by formula of Ferrero

$$m_a = \pm\sqrt{\frac{[f^2]}{3n}} = \pm\sqrt{\frac{37.06}{63}} = \pm 0\overset{''}{.}77$$

The triangle 401 Gradina - 403 Brežić - 405 Dujanova Kosa has an error of closure larger than 3" (+3".498).

The adjustment was carried out by method of indirect observations where 7 stations were adjusted simultaneously and stations 246 Osijek, Cathedral, 259 Kamenjak separately. The largest correction - 2".131 from the adjustment has direction 391 Novoselsko Brdo - 208 Vis. The mean square error of direction is

$$\mu = \pm\sqrt{\frac{[v^2]}{3-3k}} = \pm\sqrt{\frac{57.47}{50-3\cdot 7}} = \pm 1''.41 \qquad [160]$$

(f) <u>The first order net in the newly-liberated regions</u> (F). This net covering the western part of Slovenia and the Croatian Coastland is composed of 29 first order stations with 33 triangles of the K. und k. III Military Triangulation. The length of the sides are: average 34.3 km, minimal 17.2 km, maximal 56.8 km. The smallest angle in the net is 14° 54' 18". It is at station 188 Osor in the triangle 188-187-186. From the Austrian observations computed mean square error of triangle closure is:

$$m_\Delta = \pm\sqrt{\frac{[f^2]}{n}} = \pm\sqrt{\frac{92.29}{33}} = \pm 1''.67$$

The mean square error of angle by formula of Ferrero is:

$$m_a = \pm\sqrt{\frac{[f^2]}{3n}} = \pm\sqrt{\frac{92.29}{99}} = \pm 0''.96$$

Two triangles have larger errors of closure than 3", i.e. triangle 175 Snežnik - 184 Tuhobić - 183 Učka + 3".090, and triangle 288 Visočica - 283/287 Stražica - 286 Šatorina + 3".505. Considering the above-mentioned errors it was decided to use the old Austrian observations in the adjustment of this net. The adjustment was completed in 1947, by the method of conditional observations. The net is attached to net C; hence in its adjustment the stations: 167 Grintovec, 168 Rašica, 172 Sv. Ana, 185 Cerk, 184 Tuhobić, 189 Velji Vrh, 190 Velebitska Plješevica, 286 Šatorina, 288 Visočica and 291 Vrčevo, were considered as given and the coordinates, the sides and angles belonging to these stations and obtained from the adjustment of the net C were held fixed. In the adjustment 58 conditional equations were solved (33 of triangles, 9 of given angles, 10 of given sides and 6 sine equations). Only 1 direction has a correction larger than 3" (-3".128). The mean square error of direction computed from the corrections obtained in the adjustment is:

$$\mu = \pm\sqrt{\frac{[v^2]}{k}} = \pm\sqrt{\frac{92.60}{58}} = \pm 1''.26 \qquad [160]$$

(g) The first order net of the Northern Adriatic (I). The information obtained in 1947, during the works on 2nd and 3rd order nets covering the peninsula of Istra, Croatian Coastland and Northern Dalmatia showed:

- that Italians in 1942 shifted the first order station 183 Učka (M. Maggiore 1942) 8.93 m south of Austrian first order station because of construction of a 6m high observation terrace ($d = 8.93$ m; $\alpha = 357^\circ\ 32'29''$). Austrian marker on first order station 188 Osor in 1942 was not found by Italians; hence the station 188 Osor (M. Ossero 1942) does not coincide with the K. und k. M.T. station.

- some doubt about the identity of the first order stations 189 Velji Vrh, 190 Velebitska Plješevica, 286 Šatorina and 288 Visočica with the same named stations of the K. und k. III Military Triangulation. (Only station 286 Šatorina exactly coincides with the Austrian center.)

In the works on 2nd order triangulation in Central Dalmatia (Environs of Split) in 1940 Austrian marks on the station 304 Hum na Visu were not found. (Italians, later established their first order station Hum 1942, found Austrian marker for $d = 5.39$ m and $\alpha = 303^\circ\ 21'$ northwest of their station.) Meanwhile on the station 302 Žirje a subsurface marker was found without any proof that it belongs to the first order station of the K. und k. III Military Triangulation. (It should be stated that Italians in 1942 established their first order station Žirje 1942 about 12 m west of the first order station 302 Žirje of the K. und k. III Military Triangulation. This Austrian primary station reportedly was reconstructed and its marker may have been moved. Nevertheless there was a first order station of the triangulation of Dalmatia Žirje II established in 1906 by Austrian Cadastral Survey, the marker for which was not found.) These confusing circumstances within the first order net at Adriatic Coast had to be cleared prior to the adjustment of second and lower order nets and consequently the station 183 Učka, 188 Osor, 189 Velji Vrh, 190 Velebitska Plješevica, 286 Šatorina, 288 Visočica, 302 Žirje and 304 Hum newly determined. Therefore the net I consisting of 27 stations (16 given) and 31 triangles was reobserved in 1948. Into the net which largely overlaps the net F the station 220 Goli was included. The average side in the net is 42.4 km, the shortest 19.6 km and the longest side 302 Žirje-304 Hum 79.2 km which is at the same time also the longest side in the entire Yugoslav Triangulation. The smallest angle $19^\circ\ 55'11''$ is in the triangle 190 - 191 - 285 at station 191 Gola Plješevica.

The observations were carried out in 1948 by a section composed of 4 triangulators of Federal Geodetic Administration. The angles were observed by method of Schreiber with the weight p = 12 utilizing the theodolites of Otto Fennel. There were partially observed heliotropes and signals (pyramids). The accuracy of observations would be expressed by the mean square error of triangle closure

$$m_{\Delta} = \pm\sqrt{\frac{[f^2]}{n}} = \pm\sqrt{\frac{58.33}{31}} = \pm 1\overset{''}{.}37$$

and mean square error of angle by formula of Ferrero

$$m_a = \pm\sqrt{\frac{[f^2]}{3n}} = \pm\sqrt{\frac{58.33}{93}} = \pm 0\overset{''}{.}79$$

The net was adjusted by the method of conditional observations where 65 equations were solved (31 of triangles, 14 of given angles, 14 of given sides and 6 sine equations). Given stations are: 187 Pula, 186 Sv. Mihovil, 182 Montaur, 181 Slavnik, 175 Snežnik with the coordinates from the adjustment of net F; 184 Tuhobić, 193 Bijela Lasica, 192 Hum, 191 Gola Plješevica, 289 Kremen, 290 Crnopac and 301 Prapatnica with the coordinates from the adjustment of net C; 292 V. Promina, 303 Velja Straža, 305 Sv. Nikola and 308 Sv. Djordje with the coordinates from the Ergebnisse der Triangulierungen. The mean square error of direction computed from the corrections obtained in the adjustment of the net is:

$$\mu = \pm\sqrt{\frac{[v^2]}{k}} = \pm\sqrt{\frac{98.57}{65}} = \pm 1\overset{''}{.}23$$

The largest correction - 2".308 has the direction 190 Velebitska Plješevica - 192 Hum.

Regarding the identity of present Yugoslav first order stations it should be stated that the station 183 Učka, 188 Osor and 304 Hum na Visu are identical with the Italian first order stations of in 1942 established Dalmatian chain. The rest of the stations of the Dalmatian chain included into net I are identical with the first order stations of K. und k. III Military Triangulation. Meanwhile station 302 Žirje is erected about 12 m east of Italian station Žirje 1942, and coincides with a subsurface marker found in 1940, which may have remained from the first order station of K. und k. III Military Triangulation. [105] [160]

(h) The first order net along the Italian boundary (J). Along with the works on delimitation between Yugoslavia and Italy in 1948, the Yugoslav first order net was tied with Italian first order net and the stations 179 Mangart, 202 Kanin and 221 Udine (Videm), St. Maria dell Castello Church included into Yugoslav first order net. First two stations are located on the boundary and station Udine in Italy. This connection forms the net J consisting of 7 stations (4 given) and 5 triangles. The observations were carried out on the stations 178, 221, and 202 by the Italian triangulators, on stations 179, 206/163, 170, and 171 by Yugoslav triangulators of Geographic Institute of Y.P.A. The mean square error of triangle closure is:

$$m_\Delta = \pm\sqrt{\frac{[f^2]}{n}} = \pm\sqrt{\frac{5.322}{5}} = \pm 1''.03,$$

and the mean square error of angle by formula of Ferrero is:

$$m_a = \pm\sqrt{\frac{[f^2]}{3n}} = \pm\sqrt{\frac{5.322}{15}} = \pm 0''.60.$$

The largest error of triangle closure is in the triangle

$$202 - 170 - 171 = -1''.835.$$

The net was adjusted by the method of conditional observations with 9 solved equations. The stations 206/163 Golica, 170 Rodica, 171 Mrzavec and 178 Aquilеia (Oglej) Cathedral with the coordinates obtained from the adjustment of net F are given.

The mean square error of correction computed from the corrections obtained in the adjustment is:

$$\mu = \pm\sqrt{\frac{[v^2]}{k}} = \pm\sqrt{\frac{11.12}{9}} = \pm 1''.11$$

The largest correction + 1''.613 has the direction 171 Mrzavec - 170 Rodica. [7][160]

(i) The first order station 253 Brezovo Polje (K). In 1950, the high signal on former first order station of K. und k. III Military Triangulation 253 Brezovo Polje was erected, and in 1951, the observations completed by triangulators of the Geozavod of Zagreb. There are 4 triangles with the largest error of triangle closure-2''.150. The mean square error of triangle closure is:

$$m_\Delta = \pm\sqrt{\frac{[f^2]}{n}} = \pm\sqrt{\frac{12.57}{4}} = \pm 1''.77,$$

and the mean square error of angle by formula of Ferrero is:

$$m_a = \pm\sqrt{\frac{[f^2]}{3n}} = \pm\sqrt{\frac{12.57}{12}} = \pm 1''.02.$$

The central system of four triangles was adjusted by method of conditional observations, where 9 equations were solved (4 of triangles, 3 of given angles, 1 of given side and 1 sine equation). The mean square error of direction computed from the corrections obtained in the adjustment is:

$$\mu = \pm\sqrt{\frac{[v^2]}{k}} = \pm\sqrt{\frac{79.01}{9}} = \pm 2''.96.$$

Three corrections are larger than 3". The largest correction is 4".687. These large corrections could be explained by the fact that four given points belonging to different groups of adjustment are heterogeneously positioned. Meanwhile the newly determined coordinates of the station 253 Brezovo Polje differ from the old Austrian coordinates for 0.06 m in northing and 0.10 m in easting. [160]

(j) Conclusions about the present Yugoslav first order net: The present Yugoslav first order net consists of 595 triangles and 2 quadrilaterals. Into the net are tied 341 first order stations of which 18 stations are on the territory of adjacent countries i.e. 3 in Italy, 5 in Albania, 2 in Greece, 1 in Bulgaria and 7 in Romania. To the number of first order stations 31 stations of base nets in Serbia, Macedonia and Montenegro and 20 stations of the 5 Austrian base nets should be added, making 392 stations altogether. Since the western part of Yugoslavia was covered by the first order net of K. und k. III Military Triangulation which largely was reobserved by Yugoslavs and readjusted as well as supplemented by the newly established partial nets, it would be of interest to see how many Austrian first order stations were included into the Yugoslav first order net, how many of them retained the coordinates published in the Ergebnisse der Triangulierungen and the relation between the coordinates of identical stations resulting from Austrian and from Yugoslav adjustment.

On the territory covered by the present Yugoslav first order net there were 175 first order stations (including 24 base net stations) of K. und k. III Military Triangulation of which 2 stations are located on Italian, 5 on Albanian and 5 on Romanian territory. Of these 175 stations 23 are not included into the Yugoslav first order net. There are 39 stations having the same name and approximate location as former Austrian stations but are not identical because Austrian markers were not found or certain other reasons required the replacement. In the present net 113 stations (19 base net stations) are identical with the stations of K. und k. III Military Triangulation and 45 (15 base net stations) of them still have the coordinates which were published in the Ergebnisse der Triangulierungen.

(See Chart of First Order Net of Yugoslav triangulation, Inclosure 27).

Considering the disparities between the Austrian and Yugoslav coordinates at identical stations the Yugoslav first order net has various shifts in respect to the first order net of K. und k. III Military Triangulation. The disparities at the identical stations of the central part of the net (Bosnia, Croatia and Dalmatia) are confined to less than 1 meter; meanwhile the disparities in the southern, northeastern and northwestern parts of the net increase up to 7 meters.

The shift in the southern part of the net caused by the inadequate shape of the Dalmatian chain which amounts up to $\Delta N_{(A-Y)} = -4.18$ m; $\Delta E_{(A-Y)} = +0.28$ m, was explained in the discussion of the first order net D. The northeastern part of the first order net, the "Trigonometrical net of Vojvodina, was in the adjustment placed between the net A (First order net of Serbia, Macedonia and Montenegro) and stations 465 Trojnaš and 466 Ćvorkovo Brdo of K. und k. III Military Triangulation, which beside the 8 stations of net A served in the adjustment as given stations. Since the coordinates of these westernmost two stations taken from the Ergebnisse were hold as fixed the disparities increase in the eastern direction and at the station 497 Kudrički Vis attain the maximal value $\Delta N_{(A-Y)} = +2.51$ m; $\Delta E_{A-Y)} = -6.74$ m. These disparities represent gradual displacement of the identical stations included into Austrian chain which was considered insufficiently accurate.

In Slovenia, Istra and Croatian Coastland the comparisons of Yugoslav and Austrian coordinates at identical stations of the northwestern part of net C, nets F, I and J show the disparities in the Easting increasing systematically from the Maribor base line toward West. At the westernmost common station 178 Aquileia (Oglej) the difference $\Delta E_{(A-Y)}$ reach its maximum and amounts to -5.28 m ($\Delta N = -1.71$ m). Such a systematical increasing of the difference could be caused by various scales of the two triangulations. Comparisons show that Austrian sides are longer than Yugoslav. The average relative difference obtained from the differences of 16 sides is 1/52.000 or 2 cm/km. The remeasurement of Maribor base line may show the reason for this difference in the length between Yugoslav and Austrian sides. (This is a very difficult task because houses were erected on the base line.) Nevertheless a question arises: Which sides are more accurate - Austrian or Yugoslav? Geographic Institute of Y.P.A. in 1950 measured the Radovljica base line. From this base line through the base net the first order side 206/163 Golica - 164 Košuta as exit side was computed. The length of the exit side compared with the lengths obtained from Yugoslav triangulation and K. und k. III Military Triangulation show the relations as follows:

K. und k. M.T. side 23,026.518 m + 357 mm = + 1/64,000
Exit side 23,026.161 m
Yugoslav triangulation side 23,025.609 m - 552 mm = - 1/41,713.

If the length of the side obtained in Yugoslav triangulation 23,025.609 would be corrected for the average relative difference 1/52,000 = 443 mm between the Yugoslav and Austrian sides, the corrected side 23,025.609 m + 0.443 m = 23,026.052 would differ from the exit side for - 109 mm or 1/211,250 part of the side. From this comparison it should be concluded that Austrian sides are closer to the exact scale than Yugoslav; but as had been said before, the remeasurement of the Maribor base line would test the correctness of such a conclusion.

Observations: The works on the Yugoslav first order net should be divided into two epochs:

- 1902-1936. The observations were carried out by the method of Struve (directional method with 12 positions), the instruments used were theodolites Kern and Starke and Kamerer. The accuracy of observations in this epoch would be expressed by mean square error of triangle closure:

$$m_\Delta = \pm\sqrt{\frac{[f^2]}{n}} = \pm\sqrt{\frac{929.21}{333}} = \pm 1''.67,$$

and mean square error of angle by formula of Ferrero

$$m_a = \pm\sqrt{\frac{[f^2]}{3n}} = \pm\sqrt{\frac{299.21}{999}} = \pm 0''.96.$$

- 1937-1948. In 1937, the provisional instructions for the execution of triangulation introduced the Schreiber's method (p = 12) in observations of the first order net as well a better method to determine the value of run correction. The old Kern and Starke and Kammerer theodolites were replaced by the theodolites of Otto Fennel. The accuracy of observations in this epoch considerably increased and would be expressed by the mean square error of triangle closure

$$m_\Delta = \pm\sqrt{\frac{[f^2]}{n}} = \pm\sqrt{\frac{500.02}{262}} = \pm\ 1.''38,$$

and mean square error of angle by formula of Ferrero

$$m_a = \pm\sqrt{\frac{[f^2]}{3n}} = \pm\sqrt{\frac{500.02}{786}} = \pm\ 0.''80\ .$$

Since in the Yugoslav triangulation mostly signals (pyramids) and less heliotropes at day light were observed it is evident that to the considerable mean square error of angle ± 0.''80, derived from the errors of triangle closures, largely contributed the phases (unequal illumination of targets). This statement is proved by the mean square error of adjusted angle computed from the data of station adjustment which is:

Derived from the differences of each position from the mean of all positions

$$m_a = \frac{m_0}{\sqrt{p}} = \pm\ \frac{1.''17}{\sqrt{12}} = \pm\ 0.''34,$$

derived from the corrections of observed angles

$$m'_a = \frac{m'_0}{\sqrt{p}} = \pm\ \frac{1.''45}{\sqrt{12}} = \pm\ 0.''42$$

The standards for the first order net established by the International Geodetic Association:

average error of triangle closure $\theta_\Delta = \frac{[|f|]}{n} = 1''$,

and only few errors of triangle closures may reach 3", are not exactly met by the Yugoslav first order net because more than 3% of triangles have errors of closure larger than 3" and because the average error of triangle closure, the mean square error of triangle closure and the mean square error of angle by formula of Ferrero, computed from the data of the entire net established in 1902-48, amount as follows:

$$\theta_\Delta = \frac{[|f|]}{n} = 1.''24$$

$$m_\Delta = \pm\sqrt{\frac{[f^2]}{n}} = \pm\sqrt{\frac{1429.23}{595}} = \pm\ 1''.55$$

$$m_a = \pm\sqrt{\frac{[f^2]}{3n}} = \pm\sqrt{\frac{1429.23}{1785}} = \pm\ 0''.89 \qquad [160]$$

The mean correction of one direction computed from the corrections applied to the directions in the adjustment of entire net would be:

$$v_m = \pm\sqrt{\frac{[v^2]}{n}} = \pm\sqrt{\frac{2072.40}{1916}} = \pm\ 1''.04$$

From this discussion about the Yugoslav first order net it is evident that:

- the net consists of triangles which considerably vary in size (east part of net B and net D with small triangles);

- the number and distribution of base lines (adopted Austrian base lines) in the western part of the net are not adequate;

- the inclusion of old Austrian observations and the imposed conditions, holding Austrian coordinates (sides and angles) fixed in the adjustment of partial nets, produced a certain strain in the net;

- the central part of the net consisting of 15 triangles with 15 stations never was reobserved or readjusted; hence it still represents a part of the first order net of K. und k. III Military triangulation with all data taken from the Ergebnisse der Triangulierungen.

Consequently the Yugoslav first order net, except for net A, does not represent a homogeneous triangulation, but rather a patchwork carried out in order to obtain as soon as possible the basic net for the development of the lower order triangulations badly needed in the execution of the cadastral survey as well as military topographical survey. These requirements are completely satisfied by the present first order net.

Considering the scientific value of the Yugoslav first order net and its inclusion into the Central European net as a valuable part thereof the following improvements are planned and some have already been carried out:

- the base lines at Osijek, Okučani, Velika Gorica, Radovljica, Mostar, Udbina, Livno and Titograd (Podgorica) were measured, base nets observed, and exit sides computed, (base line at Okučani and Livno replaced old Austrian base lines at Dubica and Sinj respectively).

Radovljica	(1950)	5921 m	(net of 4 stations)
Zagreb	(1951)	8330 m	(net of 3 stations)
Osijek	(1952)	9072 m	(net of 3 stations)
Okučani	(1952)	8282 m	(net of 4 stations)
Mostar	(1953)	5953 m	(net of 6 stations)
Titograd	(1954)	8136 m	(net of 3 stations)
Livno	(1955)	6264 m	(net of 4 stations)
Udbina	(1955)	7200 m	(net of 7 stations).[28] (See Enclosure 27)

At Belgrade in 1953, a comparative base line having a length of 960 m was established. The accuracy of measurements of base lines expressed by the mean relative error vary within limits 1/2,000 000 to 1/3,000 000. The measurements were carried out by Jäderin base apparatus with 6 wires.

The base extension nets were observed by method of Schreiber with the weight 24. In the observations of heliotropes the Wild T3 theodolites were used. The accuracy of observations expressed by mean square error of an angle computed by formula of Ferrero is

$$m_a = \pm\sqrt{\frac{[f^2]}{3n}} = \pm 0\overset{''}{.}15.$$

The ratio of exit sides in respect to the length of corresponding base lines vary from 1/2.6 to 1/4.5. The accuracy of derivation of exit sides through the extention nets expressed by the mean total relative error vary from 1/270 000 to 1/940 000. [28]

- the base lines in Istra and at Mura River (Slovenia) are projected (old Austrian base line at Maribor will be replaced by base line at Mura River;

- Austrian base lines at Vršac and Sarajevo will be remeasured and base nets reobserved;

- the base nets of base lines at Loznica, Paraćin, Negotin, Vranje, Prizren, Strumica, Prilep and Sjenica were reobserved and new values for exit sides computed. The base nets were observed by Schreiber's method with weight p = 24. The observations were carried out with an accuracy permiting an error of closure no larger than 1" (4"14 in old base nets).

The improvement obtained by the reobservation of the eight extention nets is evident from the comparisons of the mean square errors of closure and mean square errors of an angle resulting from the primary and recent observations as follows:

	Old observ.	New observ.
$m_\Delta = \pm\sqrt{\frac{[f^2]}{n}} =$	$\pm$ 1.29;	$\pm$ 0"64
$m_a = \pm\sqrt{\frac{[f^2]}{3n}} =$	$\pm$ 0"75;	$\pm$ 0"37

- the angles in the triangles with larger errors of closure than 3" will be reobserved. Up to the end of 1956 the observations were carried out in 11 triangles by using the Wild T3 theodolites and heliotropes. The accuracy of observations expressed by the mean square error of an angle computed by formula of Ferrero is:

$$m_a = +\sqrt{\frac{[f^2]}{3n}} = \pm 0''49 \qquad [29]$$

- in the two quadrilaterals the diagonal ties were observed and quadrilaterals transformed into central system of triangles with centeral point 476 Petrovaradin;

- all lost first order stations and lost stations of degree survey (arc of glacial meridian and arc of 45° parallel) have to be restored;

- some stations of the arc of glacial meridain and 45° parallel have to be reobserved, and the arc of 45° parallel tied with the Italian arc along 45° parallel.

- a sufficient number of well distributed Laplace stations has to be determined. Up to present time 38 Laplace stations and 34 astronomic stations having only latitude and azimuth (determined prior 1924) are included into the 1st order net.

After the completion of these projects the present geometrically adjusted first order net will be finally adjusted as an astro-geodetic net and oriented on a Yugoslav datum, for which the 1st order station 268 Bjelašnica is proposed because of its central location. Along with the astronomical observations extensive gravimetrical works are undertaken in order to obtain in the absolute orientation of the astro-geodetic net the best possible relationship between the local geoid and the spheroid as a reference surface. [131]

(k) Connections: The Yugoslav first order net was tied:

- In 1929, with first order net of Romania. Common stations are: 20/496 Antina Livada, 26/501 Moldavica, and 27/502 Kukujova

- In 1929, with first order net of Bulgaria. Common stations are: 57 Midšor, 163 Ruj, 114 Rujan.

- In 1930, with first order net of Greece. Common stations are: 127 Perister (Peristeri Serbie), 128 Kajmakčalan, 129 Kečikaja (Porta) and 130 Visoka Ćuka (Paleon Thriethnes).

- In 1946, with first order net of Albania. Common stations are: 328 Gruda-Griži, 331 Jubani, 332 Taraboš and 245 Cukali. (See discussion of net D.)

- In 1948-52, with first order net of Italy. Common stations are: 179 Mangart, 200 Kanin, 221 Udine (Videm) and 178 Aquileia (Oglej).

- In 1952, with first order net of Austria. Common station are: 179 Mangart, 206/163 Golica.

(2) Second, third and fourth order nets: By the Instructions for the National Survey, part I - Triangulation published in 1951, the Yugoslav triangulation consists of first order net, second order main and fill nets, third order main and fill nets and fourth order net. First, second and third order main net are higher order nets computed by consideration of curvature of the Earth, third order fill net and fourth order net are lower order nets in which computation curvature of the Earth is ignored. By the old instructions subdivision in second and third order nets did not exist.

The specifications characterizing the nets of Yugoslav triangulation are evident from the following table:

Net	Side	Observations	Max. error of △ closure	v maximal of directions from adjust.	$\frac{\Delta S}{S}$
1st order	S ≥ 20 km	Schreiber p = 12	3".0	1".5	1/100,000
2nd main	15-25 km	Struve 10 pst	7".0	4".0	1/ 60,000
2nd fill	9-18 km	8 pst	11".5	6".0	1/ 40,000
3rd main	5-13 km	6 pst	17".0	9".0	1/ 30,000
3rd fill	3-7 km	4 pst	23".0	13".0	1/ 20,000
4th order	1-4 km	3 pst	35".0	20".0	1/ 12,500

(a) Second order net: Since 1952, the second order net was established over all territory of Yugoslavia, the net consists of 2000 stations of which the coordinates were computed in Gauss - Krueger (Transverse Mercator) projection with 3° zones. Yugoslavia is covered by 5th (CM 15°), 6th (CM 18°) and 7th (CM 21° East of Greenwich) zones. The second order stations are located as follows.

487 stations in 5th Zone

581 stations in 6th Zone

932 stations in 7th Zone.

About 35% of stations were established by the triangulators of Military Geographic Institute and 65% by triangulators of the Cadastral Survey.

The average side is 15.2 km. The observations were carried out by the directional method of Struve in 10 and 8 positions. Observed were signals. In the observations were used these theodolites: Little Kern 10", Salmoiraghi 5", Otto Fennel 5" and 10" and after 1928 Wild T2 and Zeiss T2.

The accuracy of observations would be expressed by the mean square error of triangle closure and the mean square error of a direction computed from 133 triangles of the main net and 234 triangles of fill net located in the 5th Zone.

- In the second order main net the mean square errors are as follows:

$$m_\Delta = \pm\sqrt{\frac{[f^2]}{n}} = \pm\sqrt{\frac{269.85}{133}} = \pm 2''.70$$

$$m_d = + \frac{2.70}{\sqrt{6}} = \pm 1''.10$$

The largest error of closure is 6".90.

- In the second order fill net are the following mean square errors:

$$m_\Delta = \pm\sqrt{\frac{[f^2]}{n}} = \pm\sqrt{\frac{2232.26}{234}} = \pm 3''.10$$

$$m_d = \pm \frac{3''.10}{\sqrt{6}} = \pm 1''.27$$

The largest error of closure is 11".77.

The accuracy of the second order net determined from the records of the adjustment:

- The second order net established prior to 1951, (without subdivision on the main and fill net):

The mean square error of a direction computed from the corrections obtained in the adjustment of the coordinates of 447 stations is:

$$\mu = \pm\sqrt{\frac{[v^2]}{n-3k}} = \pm\sqrt{\frac{18214.82}{3836-3\cdot447}} = \pm 2''.70$$

The mean positional error of the coordinates of trig points computed from the values of semiaxes A and B of the mean ellipse of error of 147 stations would be expressed as follows:

The average values of semiaxes are

$$A_{av} = \frac{[|A|]}{147} = 0.11 \text{ m}; \quad B_{av} = \frac{[|B|]}{147} = 0.07 \text{ m};$$

hence the average positional error of coordinates would be

$$E_1 = \pm\sqrt{A_{av}^2 + B_{av}^2} = \pm\sqrt{0.11^2 + 0.07^2} = \pm\ 0.13$$

and the mean positional error is

$$E_2 = 1.25\ E_1 = \pm\ 0.162\ \text{m}.$$

Since the mean square error of a side would be expressed as

$$E_{s2} = E_2 \cdot \sqrt{2} = \pm\ 0.229\ \text{m}$$

the mean relative error of the average 2nd order side (15.2 km) is

$$\frac{\Delta S}{S} = 1/66{,}000\,.$$

Consequently the mean relative error of the side of the second order net established prior to 1951, completely satisfy the requirements prescribed by the 1951 triangulation instructions for the 2nd order main net. (See page 242)

- The second order main net established after 1951:

The mean square error of a direction computed from the corrections determined in the adjustment of the coordinates of 46 stations is:

$$\mu = \pm\sqrt{\frac{[v^2]}{n-3k}} = \pm\sqrt{\frac{724.71}{412-3\cdot 46}} = \pm\ 1''.36$$

The mean positional error of the coordinates computed from the semiaxes of the mean ellipse of error of 30 stations, the mean square error and the mean relative error of a side (average side 17.7 km) were computed in the same manner as in the second order net established prior 1951 and amount as follows:

$$E_2 = 1.25\ E_1 = 1.25\sqrt{0.07^2 + 0.05^2} = \pm\ 0.107\ \text{m}$$

$$E_{s2} = E_2 \sqrt{2} = \pm 0.151 \text{ m}$$

$$\frac{\Delta S}{S} = \frac{0.151 \text{ m}}{17,700 \text{ m}} = 1/117,000.$$

- The second order fill net established after 1951:

The mean square error of a direction computed from the corrections obtained in the adjustment of coordinates of 58 stations of the fill net is

$$\mu = \pm\sqrt{\frac{[v^2]}{n-3k}} = \pm\sqrt{\frac{1777.88}{743-3\cdot58}} = \pm 1''77 \qquad [160]$$

The mean positional error of the coordinates computed from the semiaxes of the mean ellipse of error of 46 stations, the mean square error and the mean relative error of a side (average side 12.8 km) are as follows:

$$E_2 = 1.25\, E_1 = 1.25\sqrt{0.06^2 + 0.04^2} = \pm 0.090 \text{ m}$$

$$E_{s2} = E_2 \sqrt{2} = \pm 0.127 \text{ m}$$

$$\frac{\Delta S}{S} = \frac{0.127 \text{ m}}{12,800 \text{ m}} = 1/100,000.$$

(b) Third and fourth order nets which will comprise about 140,000 trig points still are in the stage of development. From 1921-1940, the triangulation covering Serbia and Macedonia, including the fourth order net, with 61,585 3rd and 4th trig points determined was completed. After World War II large areas of Croatia (12,225 3rd and 4th order trig points determined till 1953), Bosnia and Herzegovina, Montenegro and Slovenia were covered by third and fourth order nets; consequently at the present time more than 100,000 third and fourth order trig points were determined. Hence, it should be stated that in a few years Yugoslavia will be completely covered with triangulation including a fourth order net. The density of the triangulation in Serbia and Macedonia is 1 trig point to 1.6 km^2, in other regions with fourth order net established 1 trig point to 2 km^2.

In order to estimate the degree of accuracy of coordinates of the third and fourth order nets there were computed the semiaxes A and B of the mean ellipse for:

298 trig points of the third order net established prior to 1951,
504 trig points of the third order main net,
469 trig points of the third order fill net and
2896 trig points of the fourth order net.

The mean positional error of coordinates of the third order net established prior to 1951 was computed by formula

$$E_2 = 1.25\ E_1 = 1.25\sqrt{0.052^2 + 0.034^2} = \pm\ 0.079\ m;$$

The mean positional errors of coordinates of the third and fourth order nets established after 1951 were computed by formula

$$E_2 = \pm\sqrt{A^2 + B^2}$$

where $A = \pm\sqrt{\frac{[A^2]}{n}}$ and $B = \pm\sqrt{\frac{[B^2]}{n}}$, and

amounts:

$E_2 = \pm\ 0.078$ m for the third order main net;

$E_2 = \pm\ 0.066$ m for the third order fill net; and

$E_2 = \pm\ 0.052$ m for the fourth order net. [128]

Consequently, the mean square error and the mean relative error of the sides will be as follows:

3rd order net	$E_{s2} = \pm\ 0.112$ m;	$\frac{\Delta S}{S} = 1/58,000$
3rd order main net	$= \pm\ 0.110$ m,	$= 1/64,000$
3rd order fill net	$= \pm\ 0.093$ m,	$= 1/48,000$
4th order net	$= \pm\ 0.074$ m,	$= 1/24,000$

(c) Conclusion about the accuracy of the 2nd, 3rd and 4th order nets: The data expressing the accuracy of the 2nd-4th order nets are evident from the following table:

Triangulation Nets	S_{av}	μ	E_2	$E_2\sqrt{2}$	$\frac{\Delta S}{S}$
2nd order net prior to 1951	15200 m	± 2"70	± 0.162 m	± 0.229 m	1/ 66,000
3rd order net prior to 1951	6500	± 5.50	± 0.079	± 0.112	1/ 59,000
2nd order main net	17700	± 1.63	± 0.107	± 0.151	1/117,000
2nd order fill net	12800	± 1.77	± 0.090	± 0.127	1/100,000
3rd order main net	7000	± 5.1	± 0.078	± 0.110	1/ 64,000
3rd order fill net	4500	± 5.7	± 0.066	± 0.093	1/ 48,000
4th order net	1800	± 8.7	± 0.052	± 0.074	1/ 24,000

The real accuracy test of a triangulation can not be carried out by this indirect method of deriving the mean positional error of the coordinates of trig points and mean relative error of sides from the data of adjustment of the nets. The mean relative accidental errors of the length of sides determined from the coordinates are merely a proof that the accuracy does not considerable decrease due to the passage through the nets from 1st order sides to 4th order sides, and that the trig points in respect to their mutual position are determined with an sufficient accuracy. The real accuracy of the sides should be tested by direct measurement of the lengths by invar tapes or by the inclusion of precise traverses. In this case also systematical error would be considered.

Such tests by which the real accuracy of Yugoslav triangulation would be determined were not carried out, but each city survey actually could be considered as a manner of such test. Since in the cadastral survey of cities: Belgrade, Niš, Skoplje, Novi Sad, Banja Luka and Veliki Bečkerek (Zrenjanin) based upon the national trigonometrical net there did not emerge any discrepancies not within permissible limits according to instructions, the triangulation should be considered accurate enough also for the city - survey of which the plans are compiled at 1:1000 and even 1:500 scale.

(3) <u>The Italian triangulation on the territory of present Yugoslavia.</u> This triangulation consists of:

(a) First order net of Venezia Giulia (Litoral) observed in 1930-31, and of 2nd, 3rd and 4th order nets observed in 1930-31, and supplemented in 1938-39, which are in sympathy with the first order net of 1930-31.

(b) Dalmatian first order chain observed in 1942, into which was included in the same year reobserved first order net of Venezia Giulia. On the Dalmatian chain are based 2nd, 3rd and 4th order nets of the Krk Island consisting of 51 trig points of which 17 are identical with the trig points of Yugoslav triangulation. The coordinates of the Krk triangulation were in 1944 transformed by the Germans into the system of the Yugoslav first order net. [105] [106]

After World War II the Yugoslavs in 1947-48 reobserved the stations of the Dalmatian chain and by the adjustment of first order nets F, I, J included into Yugoslav first order net as previously discussed. The following stations of Dalmatian chain are included into Yugoslav second order net: Veli Vrh na Kornautu (Metlina), Stankovac 1942, Vela Straža na Dugom Otoku, Jurišinka 1942, Gradina Novigradska, Sv. Vid na Pagu, Pogled and Crvena Glavica (Tignarossa). [46]

(4) The Artillery Survey in Yugoslavia:

(a) The Inspectorate General of the Yugoslav Artillery in order to carry out the topographical preparation of the boundary regions in 1935-38 executed a survey consisting of fourth order triangulation and traverses. The survey extends over the territory along former Italian boundary covered by 1:100,000 sheets 10-Bled, 25-Vrhnika, 26-Cerknica and 41-Sušak. In this survey there were determined:

339 Artillery points (permanent objects such as churches, chapels, shrines, smokestacks and other orientation points) by means of intersection;

955 Artillery points marked by concrete pillars, by means of intersection and partly by traverses;

1026 Artillery points - kilometer stones along the roads and railroads, mostly by traverses.

1505 Picture points, by intersection, traverses, and in the vicinity of trig and traverse stations by polar method.

The observations and measurements were carried out by artillery officers who completed the course for artillery topographers at Military Geographic Institute. Since the survey was executed under technical supervision of Military Geographic Institute, chiefs of sections were officers of the Geodetic Service. Manner of measurements:

- Belfries, smokestacks, shrines, corners of houses and other buildings from existing trig stations of Military Geographic Institute (unadjusted triangulation locally established from trig stations of the K. und k. III Military Triangulation), were intersected. Intersections were taken from at least three stations.

- Artillery points marked in the field by concrete pillars were determined as above mentioned orientation points.

- Artillery points in the forest areas marked by the same type of pillars as in the field, mostly were determined as traverse stations of closed and adjusted transit traverses. Distances were taped by steel tape. On the same way were determined kilometer stones.

- Elevations were determined by trigonometric leveling and given with accuracy of 0.1 m.

The observations were carried out by the directional method of Struve in three positions. The instruments used were: Theodolites (transits) Kern-Aarau 15", Zeiss T IV 6" and Wild T 1 6". Accuracy fourth order triangulation and traverses.

All records of Artillery Survey are published in form of trig lists which include Gauss-Krueger 3° Zones rectangular coordinates (Scale factor 0.9999) and grid azimuths. The trig lists are compiled according to the 1:25,000 sheets of the Yugoslav topographic map. In the enclosed 1:25,000 sheets the artillery points are plotted in red and picture points in blue colour.

The coordinates differ from the values in sympathy with the present Yugoslav first order net up to $\Delta N = \pm 1.70$ m and ΔE from - 2.50 m to - 5.00 m.

(b) <u>German Artillery triangulation along the Adriatic Coast</u>. In the 1944, Survey units of the German Army established 706 Artillery points (AP) and 188 Picture points (PP) along the Yugoslav Coast of the Adriatic Sea; of them 233 Artillery points and 87 Picture points in the region of the Montenegrin Coastland for the purpose of defense of the Naval base at Boka

Kotorska. These German Artillery and Picture points were locally determined from existing Yugoslav triangulation. Hence this German artillery survey represents simply a densification or, in some cases, a restoration of the Yugoslav lower order net. The northwestern part (sheets: 92, 93, 94, 109, 110, 111, 112, 124, 125, 126, 127 of Yugoslav 1:100,000 scale map) of the artillery triangulation is developed from existing Yugoslav Cadastral triangulation, therefore it is in sympathy with the adjusted first order net. Meanwhile the southeastern part of the artillery triangulation extending over the sheets 127, 136 and 137 of Yugoslav 1:100,000 map, based upon unadjusted 2nd and 3rd order nets of Yugoslav Military Geographic Institute, therefore the coordinates of artillery points if compared with the values adjusted to the present Yugoslav first order net would have disparities up to $\Delta N = -1.50$ m; $\Delta E = -2.00$ m. the accuracy of German Artillery Triangulation in this area corresponds to 4th order net.

In order to provide certain areas not covered by the 2nd, 3rd and 4th order nets of the Yugoslav M.G.I. or Cadaster with a sufficient number of Artillery points the Survey units of the German Army incorporated into the system of the Yugoslav first order net:

- the K. und k. Military triangulation of Bosnia and Herzegovina consisting of 2260 trig points having Soldner spheroidal coordinates with the origins at center of each 1:75,000 sheet of the special map; (See page 26-28) and

- the K. und k. Military triangulation of the Dalmatian Coast carried out in 1906. This triangulation consists of 368 trig points, among them 168 2nd and 3rd order stations and 200 intersected 4th order trig points. This Coastal net was determined from 10 first order stations of the K. und k. III Military triangulation oriented at Hermannskogel. For the 168 stations GP's referring to Hermannskogel were computed and for all 378 trig points (including 10 first order stations) the Soldner spheroidal coordinates with origin, first order station 291 Vrčevo with:

$$\phi = 44^\circ\ 01'\ 56''.6741$$

$$\lambda = 33^\circ\ 03'\ 36.3442 \text{ East of Ferro}$$

$$\alpha = 55^\circ\ 21'\ 13.684 \text{ to 290 Crnopac}$$ [103]

were computed and listed in the M.G.I. Protocol No. 346 A (manuscript). Positional accuracy of coordinates:

2nd and 3rd order stations ± 0.10 m
4th order station ± 0.30 m

The net covers sheets 74, 75, 91, 92 and 93 of the 1:100,000 topographical map of Yugoslavia. The computed Yugo Reed. G.K.s were included into the German trig lists of the mentioned sheets.

Since the K. und k. Military triangulation of the Dalmatian Coast was carried out for the purpose of the 1907-1910 Coastal survey from which the Austro-Hungarian nautical charts were compiled, despite that the hydrographic survey and nautical charts are not purpose of this study, the following statements concerning the positioning of the Austro-Hungarian nautical charts should be made.

The position of graticule of the Austro-Hungarian nautical charts published in 1860-1910 refer to:

Vienna, St. Stephen's Tower, with

$\phi = 48^\circ\ 12'\ 32''.7$

$\lambda = 16^\circ\ 22'\ 31''.2$ East of Greenwich
($34^\circ\ 02'\ 17''.7$ East of Ferro).

$\alpha = 345^\circ\ 55'\ 22''.0$ to Leopoldsberg.

(The difference Ferro-Greenwich = $17^\circ 39' 46''.50$ is derived from the determination of Paris = $2^\circ\ 20' 13''.50$ published in the Nautical Almanac 1901 and 1907.) Meanwhile the St. Stephen's Tover as datum point called "Marinenormale" after its inclusion in 1910 in the K. und k. III M.T. oriented at Hermannskogel obtained the following coordinates:

$\phi = 48^\circ\ 12'\ 31''.54$

$\lambda = 16^\circ\ 22'\ 40''.82$ East of Greenwich
($34^\circ\ 02'\ 27''.32$ East of Ferro.)

This geographic position in respect to the old position differ for:

$\Delta\phi = -\ 1''.16$
$\Delta\lambda = +\ 9.62$

In order to retain the old graticule the geographic coordinates referring to the Hermannskogel were provided with corrections

$\Delta\phi = +\ 1''.16$
$\Delta\lambda = -\ 9.62.$

Consequently the coordinates of Hermannskogel and Vrčevo referring to "Marinenormale" are as follows:

103 Hermannskogel

$\phi = 48^\circ\ 16'\ 16''.45$

$\lambda = 16^\circ\ 17'\ 44.94$ East of Greenwich

291 Vrčevo:

$\phi = 44^\circ\ 01'\ 57.834$

$\lambda = 15^\circ\ 23'\ 40.224$ East of Greenwich.

Since all computations of the 1906 coastal triangulation were carried out in the Hermannskogel system and the coordinates of trig points provided with the above mentioned blanket corrections the net merely was placed but not oriented, on "Marinenormale". Due to the various orientation of the triangulations used in the coastal surveys and in the positioning of nautical charts and because the old costal survey (started 1860) was based upon unadjusted and not uniformly oriented triangulation the intended uniformity of graticule of the old edition with the graticule of the new edition (1910 and later), based upon the adjusted and uniformly oriented K. und k. III Military triangulation, was not obtained. On the overlappings of the old and new charts the graticule does not concide, the scaled coordinates and the directions differ.

The graticule of natutical charts is constructed in Mercator projection therefore G.Ps and Soldner spheroidal coordinates were converted into Mercator coordinates with origin at intersection of 43° parallel and 16° East of Greenwich meridain.

(5) The following old systems of cadastral triangulations cover the territory Yugoslavia:

(a) Austrian Cadastral systems:

- Krim (Krimberg) covering provinces Carinthia, Carniola, Littoral (After 1918 system Krim was extended over all Slovenia and coordinates of system Schöckl for Lower Styria and stereographic coordinates of system Budapest for Prekmurje transformed into plane rectangular coordinates of system Krim.)

- Schöckl near Graz covering province Styria;

- Vienna, St. Stephen's Tower, covering province Dalmatia. The coordinates of trig points of the Austrian Cadastral systems are plane-rectangular coordinates computed without consideration of curvature of the Earth. (See Inclosure 1).

(b) Hungarian Cadastral systems:

- Stereographic system Budapest, Gellérthegy covering provinces Baranja, Bačka, Banat, Srem, Medžumurje and Prekmurje. Stereographic plane rectangular coordinates;

- Stereographic system Kloštar Ivanić covering Croatia and Slavonia. Stereographic plane rectangular coordinates. Original coordinates used in the cadastral survey of this system (carried out graphically by plane table method) were not stereographic but plane rectangular coordinates computed without consideration of curvature of the Earth; [92]

- Oblique cylindric system (3 oblique cylinders), southern horizontal zone with origin in intersection of Gellérthegy meridian with $45^\circ\ 34'\ 36''.5869$ parallel, covering province Vojvodina (Baranja, Bačka and Banat). Plane rectangular coordinates.

(c) Bosnian Cadastral system. Center of each 1:75,000 sheet ($15'_\phi \times 30'_\lambda$), positioned on geographic positions referring to Vienna University datum, serve as origin for Soldner spheroidal rectangular coordinates used in the cadastral survey of Bosnia and Hercegovina. (See Inclosure 1)

(d) Serbian Cadastral systems:

- Jautina 1st order trig station:

$$\phi = 44^\circ\ 22'\ 40''.2684\ (2448)$$
$$\lambda = 19\quad 48'\ 36.2090\ (1719)\ \text{East of Greenwich}$$

covering districts Mačva and Tamnava.

- Gospodarska Dubrava 1st order trig station:

$$\phi = 44^\circ\ 31'\ 32''.8641\ (8104)$$
$$\lambda = 21\quad 13'\ 38.9331\ (8334)\ \text{East of Greenwich}$$

covering districts Požarevac, Podunavski, Ramski and Golubac. Values in parenthesis refer to the adjusted Yugoslav first order net.

Soldner spheroidal rectangular coordinates were computed in the period from 1923-27; after 1927, they were transformed into plane rectangular coordinates of the newly adopted Gauss- Krueger projection with 3° zones.

In the Yugoslav topographical mapping the coordinates of the above mentioned cadastral systems never were used. Meanwhile, since the new cadastral survey of the former Austro-Hungarian provinces is not yet nearly completed, the coordinates of Austrian, Hungarian and Bosnian cadastral systems still are used along with the old cadastral maps.

(6) The Catalogues of Yugoslav triangulation:

(a) Prior to World War II the geographic and unreduced Gauss-Krueger coordinates, observed directions, azimuths and grid azimuths for the first order stations were published in the Catalogue of first order triangulation (Manuscript). The Geographic coordinates and elevations of first order stations as well as 2nd and 3rd order stations established by Military Geographic Institute and the reduced Gauss-Krueger coordinates (scale factor 0.9999 and false easting applied) of all trig points - military and cadastral - within each 1:100,000 sheet in form of trig lists (Spisak) were published.

(b) After World War II the Catalogues of Yugoslav triangulation are compiled accordingly to 1:25,000 sheets of the Yugoslav map. There are two types of catalogues:

- Abbreviated catalogue (Skraćeni Katalog); a trig list published for each 1:25,000 sheet which includes number, order, reduced Gauss-Krueger coordinates and elevations of trig points plotted in the attached sheet of 1:25,000 map.

- Complete catalogue (Pun Katalog) published for each 1:25,000 sheet includes number, order and name of stations, unreduced Gauss-Krueger coordinates (for higher order stations only), reduced Gauss-Krueger coordinates, grid azimuths, observed directions, oriented directions, corrections from adjustment, and elevations, as well as descriptions, and sketches. To each catalogue a corresponding sheet of 1:25,000 map with the trig points plotted is attached. [52]

d. Elevations.

The vertical control of Yugoslavia still refers to the leveling datum Trieste, Molo Sartorio of which the elevation of starting benchmark within one year (1875) of observations of tidal gauge was defined to be:

$$+\ 3.3520 \text{ meters}$$

above the mean sea level of the Adriatic Sea.

(1) The precise leveling net of the Austro-Hungarian Empire refers to the leveling datum Trieste, Molo Sartorio. The part of this net, consisting of 19 loops with total length of 7401.7 km, established in 1873-98 by Military Geographic Institute of Vienna covers the former Austro-Hungarian provinces of Yugoslavia (6300 km on Yugoslav territory). The accuracy of Austrian precise leveling in Yugoslavia would be expressed by:

The mean square accidental error = ± 5.1 mm/km, and

The probable accidental error = ± 3.4 mm/km,

meanwhile the largest mean square accidental error in the loop LXVII is ± 12.2 mm/km. The Austrian precise leveling in Yugoslavia at the present time has only a historical meaning because it was entirely resurveyed. (See Inclosure 29). Nevertheless, considering the magnitude of the probable accidental error - larger than 3 mm/km - it did not meet the standards of precise leveling established in 1867 by the International Geodetic Association.

(2) The leveling of high precision in Yugoslavia;

(a) Epoch 1905 - 1911. Works on the leveling of high precision started in Serbia in 1905. Since the Serbian leveling net was attached to the Austrian leveling it is of interest to know what magnitude should be expected in the mean square error of the elevation of Austrian benchmark at the Sava bridge between Zemun and Belgrade, which is the starting elevation for the Serbian leveling net. The length of the leveling line connecting the benchmark at Sava bridge with the starting benchmark of leveling datum Trieste, Molo Sartorio is 760.7 km, hence the mean square error would be:

$$M = \pm 5.1\sqrt{760.7} = 141 \text{ mm} = \pm 0.14 \text{ m}.$$

In this epoch 1242 km leveling lines of high precision were established. In the measurements large Kern leveling instrument was used. The accuracy achieved would be expressed by:

The mean square error ± 0.94 mm/km and

probable error ± 0.62 mm/km

(b) Epoch 1920-1941. In the epoch between the two World Wars there were established these leveling lines of high precision:

5176 km by the Military Geographic Institute, and

486 km by the Direction General of the Cadaster

and State Domains including 4649 benchmarks. In the measurements the Zeiss leveling instruments with invar rods were used. The accuracy achieved by Military Geographic Institute was:

probable accidental error $\eta_r = \pm 0.50$ mm/km (± 0.63 mm/km)

probable systematical error $\sigma_r = \pm 0.10$ mm/km (± 0.05 mm/km)

(Values in parenthesis were achieved by Direction General of Cadaster and State Domains).

The leveling lines of the epochs 1905-11 and 1920-41 are closed into 15 loops. The probable systematical error of loop closure is:

$$\sigma_R = \pm 0.12 \text{ mm/km.} \qquad [160]$$

In some leveling lines established in these two epochs during World War II 70% of all benchmarks were destroyed, hence these lines have to be releveled.

In this epoch the mareographs (tidal gauges) at Bakar (1929) and Split (1930) were established.

(c) Epoch 1946-1952. Under direction of the Geographic Institute of Y.P.A and by the collaboration of Federal Geodetic Administration and Geodetic Administrations of Republics the Austrian leveling lines were resurveyed and 5048 km leveling lines of high precision established; including the new connection with the starting benchmark at Trieste, Molo Sartorio. In the measurements Wild NIII leveling instruments having optical micrometers and invar rods have been used. The sections of level lines between two benchmarks with a length about 1 km the same day are observed in both directions by the application of the method of observing from the center with a maximal length of the sight permitted 50 m. The maximal permitted difference between the forward and backward observations of a section is:

$$\Delta \text{ mm} = 6\eta\sqrt{R} \text{ km;}$$

and of a level line:

$$\Delta \text{ mm} = 6\tau\sqrt{L} \text{ km, where } L>60 \text{ km.}$$

Inclosure 29

Inclosure 29

In steep terrains where sights are shorter than 15 m the maximal permitted difference is $8\eta\sqrt{R}$ km or $8\tau\sqrt{L}$ km. The accuracy for a part of the leveling net consisting of 15 loops (5015 km) established after the World War II, would be expressed as follows:

probable accidental error $\eta = \pm 0.50$ mm/km

probable systematical error $\zeta = \pm 0.82$ mm/km

probable total error $\tau = \sqrt{\eta^2 + \zeta^2} = \pm 0.96$ mm/km [161]

The Yugoslav leveling net of high precision is near its completion. In 1953, it consisted of 52 loops with 11,952 km of leveling lines not yet adjusted. Within the period 1953-1956 another 1137 km were established. Prior to the final adjustment of the leveling of high precision the following works had to be completed:

- Leveling lines with high percentage of destroyed benchmarks have to be releveled.

- A system of basic benchmarks established and connected with the Yugoslav mareographs along the Adriatic Coast, and

- A leveling datum defined.

(d) Connections. The leveling net of high precision was tied with the leveling nets of adjacent countries as follows:

- 1929, with Bulgarian net at

Bregovo $\Delta h = 0.73$ m

Dragoman $\Delta h = 0.53$ m

Zlatarevo $\Delta h = 0.54$ m

From these differences it is evident that the mean sea level of the Black Sea defined in the leveling datum Varna is 0.60 m above the mean sea level of the Adriatic as defined in the leveling datum Trieste.

- 1929-32, with the leveling net of Greece at Gevgelija and Kremenica (Kenali). The connections show that the Sea level of the Aegean Sea as determined by observations of the tidal gauge at Harbour of Thessaloniki is 0.18 m above the mean sea level of Adriatics defined in leveling datum Trieste.

- 1953, with the leveling net of Italy at Gorizia (Gorica) and Fusine-Laghi (Fužine).

(3) Precise and Technical leveling nets.

The subdivision of the Yugoslav leveling net and the specifications prescribed by the instructions are evident from the following table:

Order of leveling nets	Observations	Probable accid. error η_r	Probable syst. error σ_r
Leveling of high precision	both directions	± 1.0 mm/km	± 0.2 mm/km
Precise leveling	both directions	± 2.0 mm/km	± 0.4 mm/km
Tech. leveling of higher accuracy	one direction	± 5.0 mm/km	——
Tech. leveling	one direction	± 8.0 mm/km	——

In the leveling of high precision and precise leveling benchmarks should be placed at 0.7-1 km intervals along the leveling line. In technical leveling, if it is carried out in the country along dirt roads, forest and field roads, benchmarks should be placed approximately 1 km apart. The standards prescribed for the accuracy are in accordance with the standards established by the International Geodetic Association.

(a) Precise leveling. The precise leveling lines are included into loops of the leveling of high precision. Prior to World War II there were established 3123 km of precise leveling lines with an accuracy expressed by:

The probable accidental error $\eta_r = \pm 1.18$ mm/km, and

probable systematical error $\sigma_r = \pm 0.34$ mm/km.

After World War II from 1945-53, there were established 6775 km of precise leveling lines with:-

probable accidental error $\eta = \pm 0.75$ mm/km,

probable systematical error $\zeta = \pm 1.30$ mm/km, and

probable total error $\tau = \pm\sqrt{\eta^2 + \zeta^2} = \pm 1.50$ mm/km. [161]

Hence by the end of 1952, Yugoslavia had 9898 km of precise leveling lines.

(b) Technical leveling of higher accuracy. Technical leveling lines are included into the net of leveling of high precision and precise leveling. Prior to World War II 11,923 km and after the World War II 5749 km, i.e. until the end of 1952 a total of 17,672 km technical leveling lines of higher accuracy were established with an accuracy expressed by probable accidental ± 5.5 mm/km and ± 3.4 mm/km respectively.

(c) Technical leveling is carried out by the Geodetic Administrations of the Republics. In the Republic of Croatia by the end of 1952, there were established 1177 km of technical leveling lines. No records are available for other Republics.

The responsibility for approximately 50,000 km spirit leveling lines carried out up to the end of 1953, is shared among the surveying agencies as follows:

- Leveling of high precision Geographic Institute of Y.P.A.

- Precise leveling and Technical leveling of higher accuracy Federal Geodetic Administration.

- Technical leveling Geodetic Administrations of the Republics.

(4) <u>Trigonometrical leveling</u>. The elevations of trig points are determined by means of trigonometrical leveling. The starting points are trig stations included in the spirit leveling net. The distances between the trig stations with the elevations determined by means of spirit leveling should not exceed 12 km. The trig stations are tied by vertical traverses (sides 0.5 - 3 km) with reciprocally observed vertical angles (zenith distances); the traverses are run between two trig stations, or closed on the starting trig station having the elevations determined by spirit leveling. The elevations of trig points (belfries, smokestacks tree signals etc.) are determined as the arithmetic mean from three forward observations. The vertical angles are measured in three positions. The accuracy of the elevations determined by means of trigonometrical leveling would be expressed by the mean square error computed from the data of 4376 elevations by formula

$$E_2 = \pm\sqrt{\frac{[Pd^2]}{2n}} = \pm\ 0.0473 \text{ m} = \pm\ 4.7 \text{ cm},$$

where $p = \dfrac{1}{S^2}$ and n = number of Δh. [21]

Since the trig points determined by Cadastral survey prior to World War II do not have elevations the Cadastral triangulation after World War II is in process of determination of elevations by means of trigonometrical leveling based upon the elevations determined by spirit leveling.

(5) The question of leveling datum for Yugoslav vertical control.

(a) Leveling datum Trieste, Molo Sartorio defined in 1875: The leveling datum Trieste as defined in 1875 within one year of tidal observations does not refer to the true mean sea level of the Adriatic Sea. In 1875, there was a particularly low state of water and the value determined from the observations of the sea level oscillations represents a level for 0.0899 m (9 cm) lower than the mean sea level defined later from the tidal observations covering a period of 8 years (1875, 1876, 1879, 1901, 1902, 1903 and 1904). The elevation of the starting benchmark No. 1 defined from these observations is

3.2621 m ± 0.99 cm.

There same benchmark in 1875 was defined as

3.3520 m above the "mean sea" level, i.e. for

0.0899 m (approx. 9 cm) too high.

Consequently the elevations of the Austro-Hungarian as well as the Yugoslav leveling include this starting error, i.e. they are 9 cm too high. In 1904 Gen. Dr. Robert v. Sterneck supported this statement by the differences obtained in comparison of the elevations of precise leveling with the elevations derived from the observations of mareographs at Pula ($\Delta h = +6.92$ cm) and Dubrovnik ($\Delta h = +9.65$ cm). [169]

(b) The mareograph (automatic tidal gauge) at Bakar: In 1929 the Geophysical Institute of Zagreb installed a mareograph in the building of Harbour Master at Bakar which, with three short interruptions, recorded the oscillations of the sea level of the Adriatic Sea until April 1941. The elevation of the benchmark which is placed in the front wall of the building of the Harbour Master and defined from the observations of the mareograph during seven years (1930, 1931 1932, 1933, 1935, 1937, 1938) is

2.6838 m ± 0.5 cm.

The elevation of the same benchmark determined by means of precise leveling referring to the leveling datum Trieste, Molo Sartorio is

2.7731 m,

i.e., 0.0893 m (approx. 9 cm) too high in respect to the mean sea level defined from the recordings of the mareograph at Bakar.[78] Consequently the result obtained from the recordings of the mareograph at Bakar during the seven years is the same as that derived by Dr. Sterneck from the recordings of the mareograph at Trieste during the 8 years, in an epoch of 30 years prior to observations at Bakar, i.e. the mean sea level of the Adriatic Sea is 9 cm higher than that determined in 1875 at Trieste and adopted as the leveling datum to which the elevations of the successor states of the former Austro-Hungarian Empire still refer.

Evidently, in the final adjustment of the Yugoslav leveling of high precision, inaccuracies such as the leveling datum defined 9 cm too low and the mean error of attachment of the Serbian leveling at the Sava bridge ± 14 cm cannot be tolerated therefore it is projected:

- to establish the normal benchmark in the geologically stable area near the center of the country and a system of the basic benchmarks in geologically stable areas of various parts of the country.

- to define the elevation of the normal benchmark above the mean sea level of Adriatic Sea as found from the recordings of the mareograph at Bakar. [167]

The main reason that this project has not been realized is the fact of too short a period of recording of the oscillations of sea level at the mareograph at Bakar, as well as at the mareographs in Split, and at Dubrovnik which did not work during World War II. In order to establish a reliable leveling datum consistent recordings of a mareograph covering a period of at least 18 years are needed. Only during such a long period, would oscillations of a complete cycle caused by the attraction of the Sun and Moon and by gravity as well as by irregular meterological influences be recorded. Consequently the coincidence of the Adriatic Sea defined from the eight years of recordings of the mareograph at Trieste with the mean sea level defined at Bakar from the recordings of the mareograph during seven years should be considered incidental. Since the yearly means of the state of the water recorded at Bakar, Trieste, Venezia and Porto Corsini are in sympathy, and since the average deviations of the monthly means in respect to the mean of a period are approximately equal, it is concluded that the determination of the mean sea level at Bakar is free of systematical errors. Hence, the mean sea level as defined at Bakar and strongly supported by the result of Dr. Sterneck published in 1904, should be regarded at the present time as the most probable fictitious mean level of the Adriatic Sea.

2. Topographical Survey:

During the Wars for Liberation and Independence of Serbia (1876-1878) the 1:300,000 map of the K. und k. Military Geographic Institute in the Serbian Army was used. The sheets of this, at that time the most reliable map covering the Balkans, were positioned upon very sparse fixed points most of which were determined astronomically and compiled from sketches, itineraries, and various intelligence sources which did not base upon any regular survey; hence during the operations many deficiencies were discovered in this map. Due to the unreliability of the Austrian 1:300,000 map there was inaugurated the first topographical survey of Serbia and the Geographic Division at the Serbian General-Staff (Geografsko Odelenje Glavnog Djeneraštaba) was created in December 14, 1878. Consequently this date should be considered as marking the outset of the Yugoslav topographical activities.

a. First Topographical Survey of the Kingdom of Serbia (1879-92).

This survey bases upon a graphical (plane table) triangulation in southeast developed from the 1877-79 Russian triangulation (Datum Minaret of Mosque at Sistovo; ellipsoid of Walbeck.) which extended along the Bulgarian and Turkish boundaries, and from the K. und k. Military Triangulation (Datum Vienna University, Bessel ellipsoid) covering the Austro-Hungarian territories located west and north of Serbia. There are no records to indicate how accurately this graphical tie between the two differently oriented triangulations was established.

The survey in the field was carried out at 1:50,000 scale. The plane table sheets were rectangulars with dimensions 0.50 m_N x 0.55 m_E, covering a surface of 687.5 km; consequently the sheets are not cut along the meridians and parallels. The graticule constructed in the sheets, i.e. meridians with 15' interval and parallels with 7'30"interval, was computed on the ellipsoid of Bessel. The meridian of Paris was used as starting meridian. The geographic coordinates of existing trig points were transformed to rectangular coordinates with the origin in the intersection of 19° 30' meridian (East of Paris) with 43° 30' parallel and trig points together with intersections of the graticule plotted into sheets. The parallel as X axis was considered positive to East and the meridian as Y axis positive to North. The rectangular plane 300 km_N x 330 km_E (approximately 3° in latitude and 4° in longitude) covering the entire Serbia was divided into 12 zones and 12 columns consisting of rectangular sheets with the sheet-lines parallel to the coordinate axes (parallel 43°30' and meridian 19°30' East of Paris). The center of this rectangular plane has the coordinates

$$X = -62{,}200 \text{ m and}$$
$$Y = +18{,}400 \text{ m.}$$

[166]

by which the position of the sheet lines in respect to the graticule is expressed. Evidently the distortion along the periphery of this large plane was too great for the scale of the map and exceeded by 10 times the graphical error of plotting.

The survey covering 48,995 km^2 extended over 96 sheets (including incomplete sheets along the boundaries). It was carried out semi-instrumentally by plane table, sight alidade, compass, and aneroid. The detail points were determined by intersection, pacing and estimation. The drawing of planimetry on an average was based upon 5 detail points per one square kilometer. The elevations were measured only barometricaly and compared with the readings of barometer located at the Military Academy in Belgrade which elevation, determined by spirit leveling, was 91.6 m above the mean sea level of the Adriatic Sea (Trieste, Molo Sartorio). There were determined 700-800 elevations on each plane table sheet, i.e. about 1 per 1 km^2. The relief in the field was expressed merely by form lines. The contours with an interval of 50 m (auxiliary 25 m and 12.5m) were drawn in the office. The manuscripts were completed in the field in pencil and inked in the office. The standard symbols used were similar to the Austro-Hungarian.

The average norms achieved by one topographer per day were:

In planes 8 km^2;

In hillyland 10 km^2; and

In mountains above 500 m altitude 13 km^2.

These norms exceed by 6-10 times the norms achieved in the topographical survey of the eastern part of Yugoslavia (Serbia, Macedonia and Montenegro) at 1:50,000 scale carried out in 1920-28.

The first topographical survey of Serbia was utilized in the compilation of the following maps:

(1) <u>1:75,000 Topographical map of Serbia.</u> The colour separations drawn on the blue lines of the topographical manuscripts were photographically reduced to 1:75,000 scale. Altogether there were photolithographically reproduced 96 sheets with the dimensions

$$0.3333\ m_N \times 0.3667\ m_E$$

The reproduction was made in five colours, i.e. cultural features and nomenclature in black, main roads in red, drainage in blue, woodland in green and relief expressed by 50 m contours in brown colour. It should be noted that the sheets of 1:75,000 topographical map of Serbia represented merely a reduced reproduction of plane table sheets.

(2) 1:200,000 General map of the Kingdom of Serbia. The general map consists of 9 rectangular sheets (I-IX) with the dimensions 0.50 m_N x 0.55 m_E. Each sheet is composed of 16 sheets of the 1:75,000 map contents of which were photographically reduced and generalized. The map was in 1893 photolithographically reproduced in four colours, i.e. cultural features and nomeclature in black, drainage in blue, woodland in green and the relief in gray shading. Because of insufficient generalization the legibility was poor.

(3) 1:250,000 General map of the Kingdom of Serbia. The second edition of general map in 1894 was published at 1:250,000 scale. The manner of compilation was the same as that of the first edition. Since the contents were more properly generalised the legibility was improved in respect to the first edition. The map was photolithographically reproduced in four colours with the relief expressed in brown hachuring.

(4) 1:150,000 Topographical map of Serbia and Macedonia (War Map). It was hastily compiled in 1912, from the topographical survey carried out in 1906-11 at 1:25,000 and 1:50,000 scale, revised 1:75,000 topographical map of Serbia, Austrian 1:200,000 general map and from numerous sketches, itineraries and other intelligence data particularly for the regions of Macedonia. This map was reproduced in five colours in the same manner as 1:200,000 general map, except the relief was expressed by brown 100 m contour lines.

(5) 1:200,000 General map of the Yugoslav countries. The compilation of this map, composed of 66 polyhedric graticule sheets 1° in latitude and longitude with starting meridian that of Paris, was begun in 1914, and was completed in 1917 at Thessaloniki (Greece). The sheets covering Serbia and Macedonia were compiled from the 1:75,000 and 1:150,000 topographical maps; for the rest of the sheets compilation was based upon the Austro-Hungarian 1:200,000 general map with an inclusion of all native and foreign cartographic material available at that time. The map was photolithographically reproduced in 4 colours with the relief expressed by brown 100 m contour lines. Since only 9 sheets of the new 1:200,000 general map of Yugoslavia from the sheets of 1:100,000 topographical map of Yugoslavia were compiled and published prior to World War II, some of the sheets of this World War I edition in the epoch between the two World Wars were still used.

The first topographical survey of Serbia, i.e. the cartographic material of 1:75,000 topographical map was also included in the compilations of the 1:75,000, 1:200,000 and 1:750,000 maps of the K. und k. Military Geographic Institute of Vienna. Nevertheless upon this survey were based the school and synoptical maps of Serbia and Yugoslavia published before and immediately after World War I by Dr. Jovan Cvijić and his collaborators Gregor and Lazić.

Regarding the Yugoslav military maps compiled after World War I the first topographical survey of Serbia and the 1:75,000, instrumental survey are of historical interest only. The cartographic material resulting from this survey never was used in the compilation of the contemporary military maps of Yugoslavia.

b. <u>First precise topographical survey of Serbia (1906-1919)</u>.

After the completion of the first triangulation of Serbia (1900-1906) the "precise topographical survey of Serbia" was started. (See pages 217-218). This survey was carried out by the method of plane table tachymetry. Since the instructions prescribed for this survey did not change substantially until photogrammetry at a large scale was introduced in the topographical survey of Yugoslavia the plane table tachymetrical method as it was applied in the survey of Serbia and later of Yugoslavia will be briefly explained.

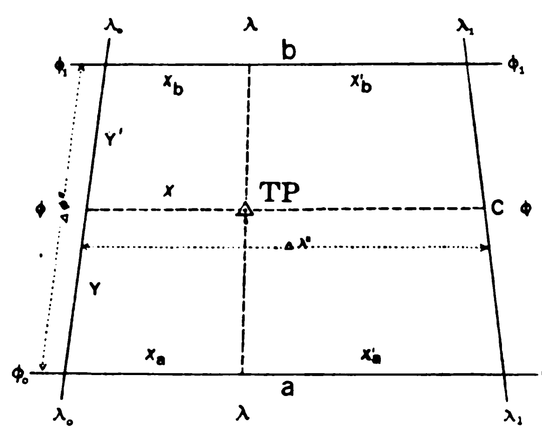
(1) Equipment of topographical parties:
Plane table, tripod with leveling head, telescopic alidade (Kippregel) with stadia cross wires having ratio 1:100, vertical plate with reading 30", compass and two stadia rods. After 1920 also an artillery range finder of Zeiss or Goerz with base 0.80 and 1 m respectively. Various equipment were used as R.A Rost, Starke and Kammerer, Kern, Teleoptik, and Zeiss.

(2) The plane table sheets consisted of drawing paper mounted on a sheet of cloth, after 1930 on aluminum plate. The sheet lines were constructed in polyhedric projection computed by the same formula as the Austro-Hungarian plane table sheets. (See pages 31 and 50). Into sheets framed by sheet lines were plotted trig points with geographics converted to linear values where it is considered that every trig point represents the intersection of its meridian and parallel for which the corresponding sections of the sheet lines have to be computed by formulae:

$$X_a = \frac{(\lambda - \lambda_0)''}{\Delta \lambda''} \cdot a$$

$$X_b = \frac{(\lambda - \lambda_0)''}{\Delta \lambda'} \cdot b$$

$$Y = \frac{(\phi - \phi_0)''}{\Delta \phi''} \cdot c$$



For the control the supplementary section of the sheet lines x'_a, x'_b and y' should be computed by inclusion in the formulae the differences $(\lambda_1 - \lambda)''$ and $(\phi_1 - \phi)''$. The plane table sheets in average were provided by five trig points of which at least three should be stations. Until 1928 the sheet lines were constructed and the trig points plotted by means of beam compasses and transversal plotting scale which hardly would assure an accuracy greater than ± 0.2 mm. Since 1928 the large coordinatograph of Coradi was utilized in the plotting of trig points and sheet corners.

(3) On base of given trig points topographers in the field developed plane table triangulation with a density of station from station about two kilometers apart. ($6'_\phi$ x $10'_\lambda$ sheet about 50 stations; $3'\ 45''_\phi$ x $7'\ 30''_\lambda$ sheet about 30 stations). The graphical points were determined only by checked intersections, resections were not permitted in graphical triangulation. The extensive forest areas should be provided by a number of graphical points (tree signals) sufficient for development of plane table traverses.

The elevations of graphical points were determined by means of trigonometrical leveling. The vertical angles were observed in both positions of telescope. The stations with reciprocal observations were tied into vertical traverses placed between two trig points or closed on starting trig point of which elevations were determined by precise leveling or by trigonometrical leveling based on stations with elevations determined by means of precise leveling. The sum of vertical differences of the stations included into a vertical traverse should not differ by more than ± 0.50 m from the difference between the elevations of given trig points. The vertical traverses were adjusted by means of distribution of error to the determined elevations proportionally with the length of the sides. The elevations of graphical points which were not occupied were determined as arithmetic mean of elevations obtained from the forward observations from at least three trig or graphical stations. In such manner the elevations of graphical points were determined by a mean error ± 0.20 m.

In the large forest areas along the main roads, railroads, fire break lines the plane table traverses between the trig and graphical points were run. The orientation of plane table was by back sights and foresights, the distances measured by stadia, the elevations computed from observed vertical angles and distances by means of slide rule or in the plain determined by means of spirit leveling. The traverses after closing, were adjusted horizontally and vertically. The stations were marked by wooden posts. These traverses served as a skeleton for the detail survey in the forest regions.

(4) The detail survey in the open areas was carried out by the polar method. The distances were measured by stadia, elevations determined by measurement of vertical angles in the plain by means of spirit leveling. There was no pacing and no barometric elevations. In the forest regions the compass traverses in the detail survey were used; the traverses should be no longer than 3 km and always should be closed. The plotting and drafting of planimetry based:

at 1:25,000 scale upon 80-200 detail points,
at 1:50,000 scale upon 20-50 detail points per 1 square kilometer.

The cadastral survey was not utilized in the topographical survey because in Serbia, Macedonia and Montenegro at that time did not exist, and later in Yugoslavia in the regions inherited from the Austro-Hungarian Empire the cadastral survey was obsolete.

The relief was immediately expressed in the field by contour lines based upon the following number of measured elevations:

at 1:25,000 scale 20-100 elevations per 1 km^2;
at 1:50,000 scale 5-30 elevations per 1 km^2.

In the first epoch of survey (1906-1919) the contour interval was 5 m and 10 m at 1:25,000 and 1:50,000 scale respectively. Since 1920 in the topographical survey at 1:25,000 scale the contour interval of 10 m with auxiliary contours at 5, 2.5, and 1.25 m; and in the topographical survey at 1:50,000 scale the contour interval of 20 m with auxiliary contours at 10 and 5 m were used.

All survey, including plane table triangulation, traverses and survey of detail, was completed on the same plane table sheet. The manuscripts were drawn in pencil in the field and inked on rainy days and holy days during the field season. For each plane table sheet along with the survey the following enclosures were made:

- manual of observed vertical angles, computed and adjusted elevations,

- manual of elevations determined in plane table and compass traverses,

- oversheet tracing with the net of plane table triangulation,

- oversheet tracing showing the vertical traverses and elevations of graphical points,

- oversheet tracing including spot elevations,

- oversheet tracing showing magnetic declination on trig and graphical stations,

- oversheet tracing with woodland and other vegetations,

- overshit tracing with nomenclature,

- oversheet tracing showing progress and inspections.

(5) The topographical survey ordinarily was executed in the summer period of six months (May 1 - October 31). The topographers were officers of geodetic service ranking from lieutenats to majors and after 1920, also civilian employees-former officers of Russian Corps of Military Topographers. Six topographical parties formed a section headed by a colonel or lt. colonel. Three to five sections composed a branch headed by a colonel.

Since the first epoch of the precise topographical survey (1906-1919) was interrupted by the Balkan War and World War I there were completed only the following surveys in which 13 topographers participated:

- at 1:25,000 scale with contour interval of 5 m:

  Environs of Belgrade
  Environs of Niš
  Environs of Pirot (1911) 1350 km^2,
  Environs of Skoplje (1918)

- at 1:50,000 scale with contour interval of 10 m:

  Environs of Valjevo
  Environs of Knjaževac
  Environs of Zaječar

- at various scales 1:5000, 1:25,000 and

1:50,000 the topographical surveys for artillery purposes were executed during the operations on the Front of Thessaloniki (1916-18) in World War I. In these surveys for the first time in the history of mapping activities aerial photography of the territory occupied by enemies (Germans, Austro-Hungarians and Bulgarians) was utilized in the mapping by means of graphical construction. The survey executed on the Front of Thessaloniki was based on a locally oriented triangulation. [23]

From all these surveys only the topographical survey of the Environs of Pirot carried out in 1911 at 1:25,000 scale and covering a surface of 1350 km^2 is included into 1:100,000 topographical map of Yugoslavia.

c. Topographical survey of Serbia, Macedonia and Montenegro (1920-1928) at 1:50,000 scale:

After World War I the fresh memory on the difficulties in conducting military operations without adequate maps created urgent requirement for a uniform topographical map which would cover entire territory of the newly created Yugoslavia, at that time officially called the Kingdom of the Serbs, Croats and Slovenes (SHS). To this requirements made by the military authorities joined also by civilian agencies which badly needed an accurate large scale topographical map in the planning of technical reconstruction and improvement of the country. Such a map could be produced only from manuscripts of a topographical survey based upon a uniform horizontal and vertical control.

Since the newly liberated western part of the country was covered by the third topographical survey of the Austro-Hungarian Empire (6500 km^2 in West Slovenia by IV Topographical survey) it was decided to start in 1920 with the topographical survey of Serbia, Macedonia and Montenegro of which entire territory of Macedonia and large parts of Serbia and Montenegro never were covered by an instrumental topographical survey. (In Serbia only the Environs of Belgrade, Niš, Pirot, Valjevo, Knjaževac and Zaječar were covered by precise topographical survey as mentioned in previous chapter. In Montenegro Russians in 1879-81, developed a locally oriented triangulation consisting of 70 first, second and third order points and covered by a topographical survey at 1:42,000 scale, based upon this triangulation, the territory within limits of that time boundaries of Montenegro. Records of this triangulation as well as topographical manuscripts remained secret in the archive of Russian general staff.)[165] The Austrians in 1916-1918, in the so called War-Survey (Kriegsvermessung) extend the triangulation of first, second and third order (1300 Tp[s]) over occupied territory of Serbia, Montenegro and Albania which includes measurements of base lines at Novi Pazar and Kosovska Mitrovica. This triangulation was not completed. In the War-Survey the precise leveling line Višegrad-Užice-Čačak-Kraljevo-Kosovska Mitrovica was also included. The elevations of trig points were determined by means of trigonometrical leveling based upon the mentioned leveling line and Austrian leveling lines along the boundaries of Serbia and Montenegro. The topographical survey at 1:50,000 scale based on preliminary coordinates and elevations of the "War Triangulation" covered considerable areas of Serbia, Montenegro and Albania with the Eastern part of Montenegro surveyed by application of terrestrial stereo-photogrammetry. The reproduction of the 1:75,000 sheets of special map, in colours with relief expressed by 20 m contours, composed from reduced topographical manuscripts was not completed because of disintegration of the Austro-Hungarian Empire. The largest part of this good cartographical material was lost.[82] Some topographical manuscripts, mostly covering the regions of Southern Montenegro and Albania were captured by the Serbian Army and some obtained by the division of material and inventory of the K. und k. Military Geographic Institutes among the successor states. The Military Geographic Institute of Yugoslavia included none of these captured manuscripts in its topographical survey at 1:50,000 scale and in the 1:100,000 topographical map with the exception of some parts in the area of the Montenegrin Littoral previously checked in the field.

The topographical survey started in July 1920, without sufficient planning and preparations. The field work allthough representing a precise topographical survey, was seriously handicapped by a lack of uniform and adjusted control. The result was distorted 1:100,000 topographical map.

The polyhedric plane table sheets used in the survey should be uniform with dimensions $6'_{\phi} \times 10'_{\lambda}$, meanwhile many of them are irregulars combined of two, one and half, or only parts of the sheets.

(1) In 1920 and 1921, the topographical survey was executed in the regions along the Bulgarian boundary on the territory of pre-Balkan War Serbia (1913) where there existed the adjusted Serbian first order net (1900-1906) computed on Bessel ellipsoid. (See Inclosure 30). Also in 1922, three topographical sections were in work in the same region and extended the survey westward to 19° 20' meridian east of Paris. The plane table sheets of this survey are positioned on geographic coordinates of the adjusted Serbian triangulation (1900-1906) computed on Bessel ellipsoid. The differences between the coordinates of Serbian triangulation and the coordinates of the Yugoslav adjusted first order net, (and to it adjusted second, third and fourth order nets), are in this region within limits of ± 3 m and therefore negligible in mapping at 1:50,000 scale. (It should be noted, that the triangulation of Serbia in 1925-1928 was reobserved, densified and lost stations were restored by the Military Geographic Institute of Yugoslavia. Within this restoration many stations were established merely in the vicinity of the lost old stations and hence do not coincide with those plotted on the plane table sheets surveyed in 1920-1922, and on the maps compiled from these sheets. The coordinates available are those of 1925-1928 triangulation.

Consequently, in any scaling comparison and selection of the control for the positioning of the 1920-22 surveyed sheets 88 part, 89 part, 90 part, 104 part, 105, 106, 119 part, 120, 121, 133 part, 134, 135, 143 part this fact should be considered and only indentical stations used.)

Since 1920, the International Boundary Commissions started the delimitation on Yugoslav-Bulgarian and Yugoslav-Albanian boundaries which were completed in 1922. The boundary regions were covered by the chains of triangulation on base of which the positions of boundary pillars were determined as well as a topographical survey at 1:25,000 scale of 2 km wide strip along the boundary. These records were later reduced and incorporated into 1:50,000 plane table sheets. Along the new Bulgarian boundary the territory of the annexed districts Caribrod, Bosiljgrad, Carevo Selo, Berovo and Strumica was in 1920-21 covered by first, second and third order nets extended from the Serbian triangulation. In 1920 and 1921 the observations of the first order net in Macedonia were completed; except base lines and base nets at Strumica, Prilep and Prizren which were measured in 1922, the net was attached to the first order net of Serbia and preliminary geographic coordinates computed. Along the Albanian boundary the International Boundary Commission carried out the boundary triangulation which was west of the meridian 20° 15' East of Greenwich extended from the first order trig stations of the K. und k. III Military triangulation located in the environs of Shkoder (Scutari). East of the 20° 15' meridian the boundary triangulation was based upon first order stations of the Yugoslav first order net with the preliminary coordinates computed in 1921-1922. The triangulations carried out up to the end of 1923 by Military Geographic Institute of Yugoslavia and the triangulation along Albanian boundary carried out by the International Boundary Commission were computed on Clarke 1880 ellipsoid. Topographical survey followed the triangulation carried out in the previous year; hence the plane table sheets covering the entire territory of Macedonia, districts Caribrod and Bosiljgrad and almost the entire region Kosovo-Metohija of Serbia are positioned upon the trig points of the unadjusted triangulation carried out by the Military Geographic Institute of Yugoslavia into which the eastern part of Albanian boundary triangulation was incorporated. In the plotting of trig points the linear values of the preliminary geographic coordinates computed on Clarke 1880 ellipsoid were used.

The Yugoslav first order net (Group A, First order net of Serbia, Macedonia and Montenegro) was in 1927 adjusted and its geographic coordinates and unreduced Gauss-Krueger coordinates computed on Bessel ellipsoid. About ten years later that topographical survey in Macedonia, Kosovo-Metohija Region, and districts Caribrod and Bosiljgrad was carried out, those M.G.I. second and third order stations which were used in the development of the cadastral second, third and fourth order nets (1928-1940) were adjusted to the Yugoslav first order net and for them, along with cadastral trig points, computed and published Yugo-Reduced Gauss-Krueger coordinates. 312 M.G.I. trig points were not included in the cadastral adjustment and still have Clarke 1880 preliminary geographics and from them erroneously computed Yugo-Reduced GK's by use of Bessel's tables.

Since the intersection of 21° meridian and 45° parallel as a point of coincidency of the two ellipsoids was considered, the disparities between Clarke and Bessel geographic coordinates within the mentioned area limited by first order stations 57 Midžor, 128 Kajmakčalan, 82 Krstača and 116 Kadijica would run as follows:

$$\begin{aligned}\Delta\phi_{(C-B)} &= +\ 0\overset{''}{.}5686\ (\Delta\,\text{Midžor})\ \text{to}\ +\ 1\overset{''}{.}3814\ (\Delta\,\text{Kajmakčalan})\\ &= +\ 17.54\ \text{m}\qquad\qquad\qquad \text{to}\ +\ 42.61\ \text{m}\end{aligned}$$

$$\begin{aligned}\Delta\lambda(C-B) &= +\ 0\overset{''}{.}5145\ (\Delta\,\text{Krstača})\ \text{to}\ -\ 1\overset{''}{.}1509\ (\Delta\,\text{Kadijica})\\ &= +\ 11.66\ \text{m}\qquad\qquad\qquad \text{to}\ -\ 26.57\ \text{m}\end{aligned}$$ [53]

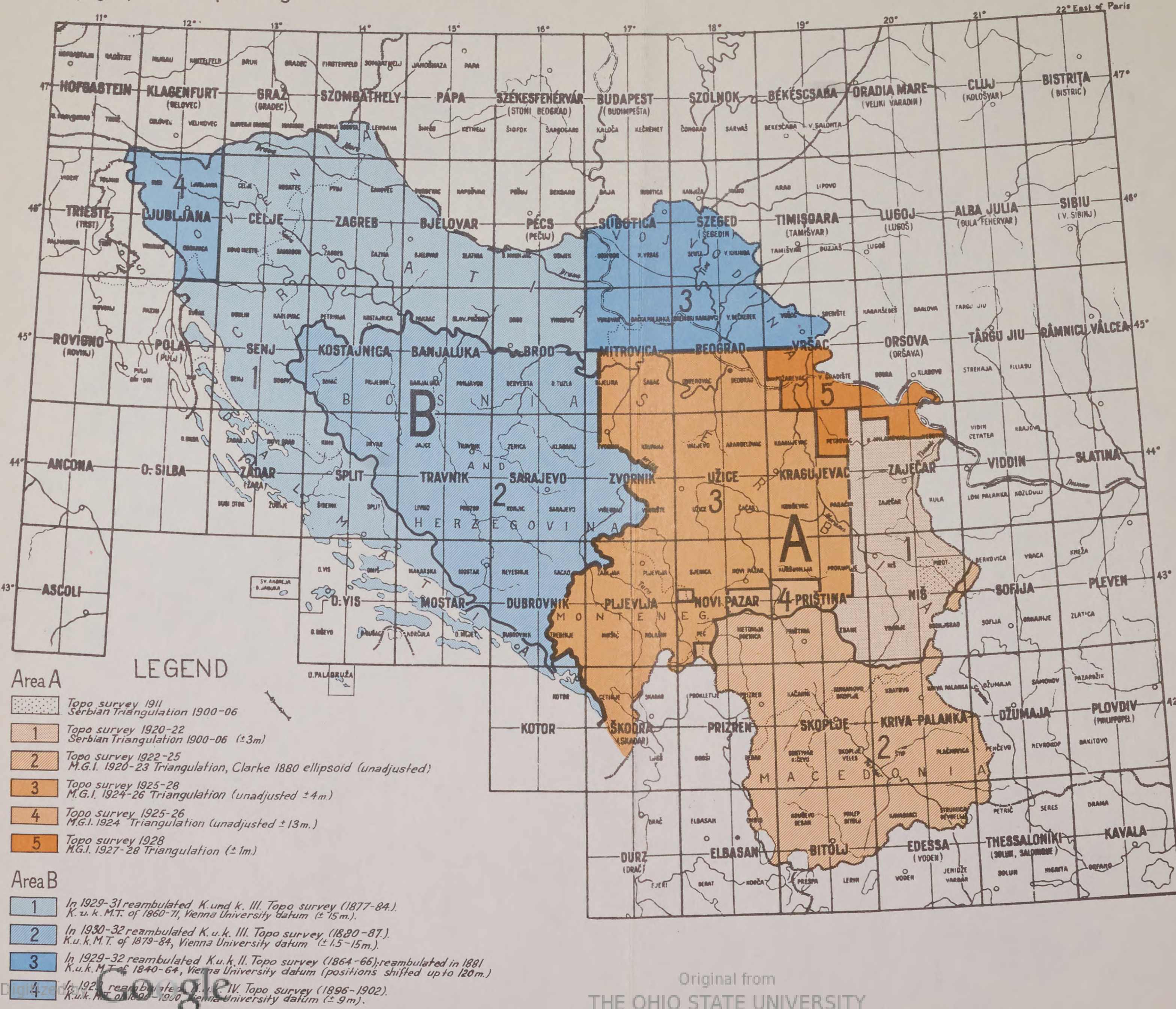
These ellipsoidal disparities are distorted by the differences between the coordinates of the unadjusted and adjusted net which along the Bulgarian boundary barely exceed 1 m; in the eastern half of area the differences are less than 5 m and therefore negligible in the 1:50,000 mapping; meanwhile in the northwestern part of the area (1:100,000 sheets 130,131, 140 and 141) the differences reach up to $\Delta\phi = +\ 11$ m and $\Delta\lambda = -\ 5$ m. In a narrow strip along the Albanian boundary (sheet G-III) these differences, because of inclusion of the boundary triangulation executed by the International Boundary Commission (1920-22), are even larger and amount up to + 20 m in $\Delta\phi$ (northing). Consequently in the area of 1:100,000 sheet Ohrid-G III the plotted positions of trig points in plane table sheets which refer to Clarke 1880 ellipsoid would have to differ in (northing) up to + 58 m from the final coordinates of identical points located in the sheets of 1:50,000 and 1:100,000 maps which refer to Bessel ellipsoid.

The triangulation carried out by the Military Geographic Institute of Yugoslavia in 1924, and later in Montenegro and Serbia is computed on the Bessel ellipsoid and the disparities between adjusted and preliminary coordinates which were used in the topographical survey are negligible for the 1:50,000 mapping. There is one exception in the area covered by parts of sheets 117, 118, 130, 131, 132 and 133 where these disparities are larger than 5 m and in northing reach up to + 10 m and in easting up to - 8 m.

The M.G.I. triangulation carried out in 1927, and in 1928, in Northeastern Serbia is within limits of ± 1 m in sympathy with the adjusted Yugoslav first order net.

Inclosure 30

Topographical map of Yugoslavia at 1:100,000 scale



The plane table sheets are positioned upon preliminary geographic coordinates of M.G.I. trig points. Since the cadastral control in Serbia, Macedonia and Montenegro in the time of topographical survey did not exist it was not used in the mapping. Consequently the cadastral trig points are not symbolized in the sheets of topographical maps at 1:50,000 and 1:100,000 scale covering the territory of Serbia, Macedonia and Montenegro except those which are identical with M.G.I. trig points.

(2) The survey was carried out in the manner explained in the previous chapter. It should be mentioned that optical range-finders of Zeiss and Goerz, used for the first time in topographical survey, were extremely useful in the mountainous and rocky regions.
In this survey no cadastral records were utilized and no photogrammetry was applied. The topographical survey at 1:50,000 scale covers an area of 108,730 km^2.

The average norm achieved in six months by one topographer is 275 km^2. In respect to the various types of relief the average norm was achieved as follows:

High mountains	313 km^2
Mountains	320 km^2
Mountains and hills	270 km^2
Hills and developed plain	284 km^2
Karst with high mountains	259 km^2.

Since in the topographical survey at 1:50,000 scale carried out by the method of plane table tachymetry the surface of 270 km^2 of a regularly shaped and averagely developed (populated) area is considered as a norm achieved in six months by an experienced topographer, the norms achieved in this survey are higher particularly in the region of Karst. (The norm achieved in the Karst should be 2/3 of normal norm i.e. 180 km^2.)

The disadvantages of this survey would be summarized as follows:

- Lack of uniformity in size of plane table sheets cut in graticule with starting meridian of Paris; meanwhile the longitudes of trig points refer to meridian of Greenwich.

- The survey is based upon unadjusted triangulation.

- The preliminary coordinates used in the positioning of plane table sheets are computed on two different ellipsoids.

- Some of the plane table sheets covering the area along the line which divides the triangulation computed on Bessel and Clarke 1880 ellipsoids are provided with trig points of which some refer to Bessel and other to Clarke ellipsoid. If trig points of both types were combined in the plane table triangulation it was impossible to develop an exact graphical triangulation and the positions of graphical points and consequently of detail points are distorted up to 1 mm.

- The plane table triangulation was based upon a scanty number of trig points, many plane table sheets were provided only with three trig points.

d. The reambulation (instrumental field revision) of the Austrian 1:25,000 plane table sections covering the western part of Yugoslavia (1929-1933).

The western part of Yugoslavia with a surface of 141,647 km^2 was covered by:

- The plane table sections of the Third topographical survey carried out in 1876 - 1887, and covering 134,647 km^2 of which 36,500 km^2 along the Serbian and Montenegro boundary were in 1907-13 reambulated; and

- The plane table sections of the Fourth topographical survey carried out in 1896 - 1902 and covering 6500 km^2 of western Slovenia.

The original manuscripts with appropriate enclosures of these 1:25,000 topographical surveys of the former Austro-Hungarian Empire by the division of material and inventory of the K. und k. Military Geographic Institute among the successor states in 1921 passed into Yugoslav possession.

In order as soon as possible to cover the entire Yugoslav territory by a topographical map at 1:100,000 scale it was decided in 1928, to reambulate the Austro-Hungarian plane table sections and to use them together with the 1:50,000 plane table sheets of the newly surveyed Serbia, Macedonia and Montenegro in the compilation of the 1:100,000 topographical map of Yugoslavia.

For purposes of the field revision the 1:25,000 Austro-Hungarian manuscripts were photographically reduced to 1:50,000 scale and on drawing paper the blue lines reproduced. The blue lines were mounted on the aluminum plates and fixed upon the plane tables.

The field revision was carried out by the method of plane table tachymetry using the same equipment as in the topographical survey. A brief explanation of how this field revision was carried out would be as follows:

(1) Topographer made a reconnaissance of assigned area and within this reconnaissance his assistants erect temporary signals upon all trig stations for which markers were found.

(2) From the stations determined by resection than gradually all the open area was checked. In the measurement of the distances mostly rangefinders were used. The stadia rods were used where new roads, railroads, canals and new settlements have to be included; such parts actually were newly surveyed. The areas covered by extensive forests were checked by comparing the manuscript with the situation in nature where same less important features such as trails, paths and small clearings by estimation were included. New roads, railroads and the details along them always were included by means of closed and checked compass traverses. Larger clearings and newly settled areas where the forest was cut down were re-surveyed.

(3) The relief in open areas was corrected along with the checking of spot elevations if disagreements occured. In the forest areas the relief was corrected around the newly surveyed roads and clearings. Since in the Austro-Hungarian topographical survey there was lack of details in the expression of the relief by contours drawn in the office experienced topographers observing the relief in nature corrected the contours and included many particularities which produce a more natural expression of the relief.

(4) Along with the topographical revision the correct native nomenclature was collected as well as a new classification of roads was made. (Nomenclature on Austro-Hungarin maps covering Slovenia was largely germanized and those covering Littoral and Dalmatia italianized.)

(5) The corrections were in the field included into blue lines in pencil. The manuscripts were in rainy days during the field season completed in ink in the same manner as the newly surveyed 1:50,000 plane table sheets. For each manuscript along with the revision the following inclosures were made:

- manual of observed vertical angles and computed elevations,
- oversheet tracing including spot elevations,
- oversheet tracing showing woodland and other vegetations,

- oversheet tracing including nomenclature, and

- oversheet tracing showing progress and inspections.

Since the 3.810 km^2 of former Austro-Hungarian territory up to 45° parallel was included into topographical survey of Serbia, Macedonia and Montenegro the rest of 137.837 km^2 was reambulated within five years (1929-33). The average norm achieved by one topographer in six months is 477 km^2. In respect to the various types of relief the average norm was obtained as follows:

Plain	710 km^2
Hills	490 km^2
Mountains	460 km^2
Highmountains	440 km^2
Karst	430 km^2

The reambulation was carried out under most strenuous conditions where the topographers worked in the field up to 15 hours a day. Considering that the Austro-Hungarian plane table sheets were up to 60 years old, the norms achieved are too high, particularly in the large populated hills and in the regions of Karst. Comparison of the 1:100,000 (1:50,000) sheets with the 1:25,000 sheet surveyed five years later show that in the reambulation there remained places on which topographer's boots had never stepped. The areas assigned by requirement to be unconditionally completed within the summer season of six months were too large. In respect to the relief and development of areas should be between 270-550 km, or an average norm 400 km^2.

e. <u>The topographical map of Yugoslavia at 1:100,000 scale.</u>

(1) <u>General information</u>: The 1:100,000 topographical map has to cover the entire territory of Yugoslavia and the boundary regions of adjacent countries. The first sheet - Zaječar - was published in 1924. Up to 1941 there were published altogether 179 sheets covering an area of 400,000 km^2.

The Military Geographic Institute of Yugoslavia in order to facilitate the utilization of the Austro-Hungarian cartographic material in the compilation of 1:100,000 map of Yugoslavia intended to obtain a continuity of the Yugoslav cartographic works with that of the K. und k. Military Geographic Institute of Vienna. For this purpose it had adopted:

- Ellipsoid of Bessel as reference ellipsoid (1924).

- Polyhedric projection with the meridian of Paris (20° East of Ferro) as starting meridian and the same sheet-cut of basic 1:200,000 sheet as Austro-Hungarian (two 1:75,000 sheet = one 1:100,000 sheet).

- Datum Hermannskogel on which the triangulation of Serbia, Macedonia and Montenegro (first order net A) by the attachment to the K. und k. Military triangulation is oriented.

- Vertical datum Trieste, Molo Sartorio to which the Yugoslav vertical control refers.

By the adoption of the Austro-Hungarian geodetic foundation and considering the standards of the IV Topographical survey of the Austro-Hungarian Empire, 16-30 detail points plus cadastral planimetry and 4-22 elevations measured per 1 km^2 (Yugoslav 1:50,000 topographical survey bases upon 20-50 detail points without cadastral planimetry and 5-30 elevations determined per 1 km^2) it was assumed that the cartographic material for the 1:100,000 topographical map of Yugoslavia obtained from 1:50,000 topographical survey of Serbia, Macedonia and Montenegro and from at 1:50,000 scale reambulated Austro-Hungarian plane table sections, originally surveyed at 1:25,000 scale, would be geodetically uniform and topographically equivalent.

In 1924, the Committee for the State Survey, of which the chairman was chief of the Military Geographic Institute and vice chairman the director general of the Cadaster and State Domains, was still of the opinion that the topographical survey and maps of the Austro-Hungarian Empire as well as Austrian cadastral survey (!) are based upon the K. und k. Military triangulation with Hermannskogel Datum. [160] Page 70.

In 1931, chief of the Military Geographic Institute Gen. Bošković wrote that Serbian first order net and precise leveling were attached to the Austro-Hungarian first order net and precise leveling that permits a junction and continuity of Yugoslav cartographic works with that of the K. und k. Military Geographic Institute of Vienna.

Sometime in 1930-32, in the cartographic division of M.G.I. a list, which includes geographic coordinates of the first order stations published in the Ergebnisse der Triangulierungen, geographic coordinates of the same stations computed from the observations of M.G.I as far as were observed, and scaled positions of these stations from the 1:25,000 and 1:75,000 Austro-Hungarian sheets, was made. (File No. 658.0488, previously mentioned in the discussion of composition of the Austro-Hungarian 1:75,000 sheets pp. 75-78).

By the letter of May 2, 1934 chief of M.G.I. of Yugoslavia asked the Austrian Federal Office for Standards and Survey (Bundesamt für Eich und Vermessungswesen), as the successor of the M.G.I. of Vienna, about the reason for the differences between the coordinates of trig stations published in the Ergebnisse and the scalled positions plotted in the Austro-Hungarian 1:25,000 and 1:75,000 maps.

On May 21, 1934, the president of the Austrian Office for Standards and Survey answered that the plane table sheets of the III and IV. Topographical survey as the sheets of 1:75,000 maps covering Yugoslavia are based on the triangulation which refers to Vienna University datum. Since the datum point for the first order net of the K. und k. III Military Triangulation Hermannskogel in the system of Vienna University (Positions Rechnungen, M.G.I. Protocol A) has geographic coordinates which vary by

$$\Delta\phi = +\ 1''20; \qquad \Delta\lambda = -\ 5''70$$

and because of a very small azimuthal difference in orientation between the Hermannskogel and Vienna University systems (III M.T. and II M.T.) the sheet lines of the 1:25,000 and 1:75,000 sheets in respect to the Hemannskogel system are shifted to the south and east. From the comparisons of the geographic coordinates of first order stations published in the Ergebnisse with those of the Positions Rechnungen for instance the 1:75,000 sheets 5759 and 5860 would have a shift to the south and east for $\Delta\phi = 2''2$ and $\Delta\lambda = 6''0$ respectively. (The letter is enclosed to the Vol. I of the Ergebnisse, File No. B-661. 3300 V.I, c.2).

This explanation makes it evident that there is no geodetical uniformity (identical positioning) of the Austro-Hungarian and Yugoslav (Serbian) cartographic material. The Yugoslav plane table sheets and the already published 1:100,000 sheets of the topographical map of Yugoslavia (compiled from the plane table sheets) covering Serbia, Macedonia and Montenegro belong to the Hermannskogel system; meanwhile the Austro-Hungarian plane table sections covering the western part of Yugoslavia belong to Vienna University system. (The plane table sections covering the province of Vojvodina - Srem, Bačka and Banat, in order to establish a gradual passage between the Vienna University and Arad, St. Anna systems, have adjusted positions of sheet lines.) Since the reambulation started in 1929 the large part of the 1:100,000 sheets compiled from reambulated plane table sections in 1934 also were published. These sheets of the 1:100,000 topographical map of Yugoslavia;

composed from reambulated Austro-Hungarian plane table sections without any change in position (recasting) retained Austro-Hungarian sheet lines, i.e. remain in the Vienna University system. The sheets 50, 51, 52, 53, 54 and 55 published in 1934-35 remain also unchanged in position, but the topographical features along the southern sheet lines (45° parallel) were cartographically tied (fudged) with the corresponding features on the sheets 66, 67, 68, 69, 70, and 71 published prior to 1930. The combined sheets 66, 83, 84, 99, 100, 113, 114, 127, 136 and 137 were composed in such a manner that each part - newly surveyed (A) and reambulated (B) remained in its original position. The positional disparities of the topographical features along the line of junction (former Austro-Hungarian boundary with Serbia and Montenegro), caused by two different datums, Hermannskogel and Vienna University, were cartographically fudged together. Because 48 sheets of 1:100,000 topographical map compiled from the reambulated Austro-Hungarian plane table sections in 1934 already were published the Military Geographic Institute of Yugoslavia did not recast the sheets positioned in Vienna University system to Hemannskogel system but exercised the above explained forced junction of the features within the combined sheets. By this erroneous decision the geodetic continuity of the Yugoslav 1:100,000 map was sacrified and with it also the possibility to provide this map with a uniform grid. (The construction of any uniform grid over all 1:100,000 sheets of the topographical map of Yugoslavia in addition to recasting of the sheets covering the area B primarily requires the recomposition of the combined sheets.)

The failure to obtain continuity in the Yugoslav mapping is due to poor research and analysis, if any, of the Austro-Hungarian cartographic material which should precede the decision to include the Austro-Hungarian plane table sheets into new 1:100,000 topographical map of Yugoslavia. It is true that the Positions Rechnungen M.G.I. Protocol A and B never were published. These protocols in manuscript remained in the archives of the Office for Standards and Survey in Vienna. Nevertheless at that time there was no Yugoslav triangulation in the western part of the country; but there were the Ergebnisse der Triangulierungen Volume I and II including entire first order net of the K. und k. M.T. and Volume IV including 2nd and 3rd order net of K. und k. M.T. in western Slovenia, which were in possession of the Military Geographic Institute of Yugoslavia. Moreover, in the introduction to the Volume IV of the Ergebnisse, published in 1906, it is stated that the 1:75,000 special map is not in sympathy with the final positions of trig points and in order to bring it into sympathy with the coordinates published in the Volume IV, covering the 1:200,000 sheets Trieste and Ljubljana, the sheet lines have to be shifted for about 1" toward north and 4"5 toward west. Having this statement, the coordinates of the K. und k. M.T. published in the Ergebnisse der Triangulierungen Vol. I, II and IV should be compared with the scaled positions of the corresponding trig points plotted in the Austro-Hungarian 1:25,000 and 1:75,000 sheets and consequently the sheet lines of the reambulated Austro-Hungarian plane table sections, along with their inclusion into Yugoslav 1:100,000 topographical map, brought in sympathy with the existend K. und k. Military Triangulation oriented on Hermannskogel datum.

Furthermore to the failure of continuity it was added the erroneous evaluation of the Austro-Hungarian cartographic material covering the western part of Yugoslavia of which 95% belong to the less accurate III Topographical survey. In the regions where cadastral planimetry was utilized this survey in respect to the planimetry should be considered equivalent or even superior to the 1:50,000 topographical survey of Serbia Macedonia and Montenegro; meanwhile the expression of the relief by contours based upon 1-6 elevations per 1 km^2 and drawn in the office is remarkably less exact then in the 1:50,000 topographical survey of Serbia, Macedonia and Montenegro. Therefore it should be concluded that the 1:100,000 topographical map of Yugoslavia is not homogeneous either in respect to the positioning of the sheets or to the cartographic material included. Despite many varieties in the cartographic material there are two distinctive areas, area A of 1:50,000 topographical survey of Serbia, Macedonia and Montenegro and area B covered by the reambulated Austro-Hungarian plane table sections. (See Inclosure 30)

(2) <u>Construction, composition and reproduction:</u> The $30'_\phi \times 30'_\lambda$ polyhedric sheets considered as plane trapezoids framed by meridians and parallels constructed as straight lines corresponding to the natural lengths of 30' meridians and parallel arcs refer to ellipsoid of Bessel. In this replacing of each spheroidal trapezoid by a corresponding plane trapezoid the curvature of 30' meridian arc can be ignored, meanwhile the curvature of the 30' parallel arc expressed by the rise between the chord and the arc at the center of Yugoslavia (44°) amounts to 30.69 m, i.e., 0.3 mm at 1:100,000 scale. In respect to the paper deformation of printed sheets the curvature of the 30' parallel arc in the construction of sheet lines was ignored. The sheet lines were constructed at the same 1:50,000 scale used in the composing and drawing of colour separations. The original sheets were not provided with any grid, but the 15' meridian and parallel are drawn and divide each sheet into four parts.

Since the cartographic manuscript was not compiled, the blue lines of the topographical manuscript - plane table sheets at original 1:50,000 scale - were printed on drafting paper and the publishing manuscript - colour separations - were drawn in black ink. The composition of four colour separations for each sheet:

- graticule with marginal information, cultural features, nomenclature and elevations

- relief

- drainage

- woodland

was made on large cardboards (after 1930 on aluminum plates). Identical sheet lines were constructed on four cardboards. Into sheet lines of the first cardboard the inked blue lines of plane table sheets showing the cultural features, nomenclature and elevations were fitted. In area A the 1:100,000 sheet ordinarily is composed of 15 plane table sheets ($6'_{\phi}$ x $10'_{\lambda}$); in area B of 8 plane table sheets ($7!5_{\phi}$ x $15'_{\lambda}$). Since the topographers were assigned with areas larger than 1 plane table sheet there were in the new topographical survey many plane table sheets of irregular size and in the reambulation there were patches of divided plane table sheets which make the composition more difficult. The identity of placing of inked blue lines of plane table sheets and patches in all four colour separation sheets was obtained by at least three identical fitting marks selected on each plane table sheet or patch of which positions, after the completed composition and pasting of the basic color separation sheet including cultural features were, by means of beam-compasses, plotted into sheet lines of the other three color separations. The patches were then placed in position by fine needles and pasted.

The basic color separation sheet including the graticule and cultural features should be composed by means of trig points plotted into the sheet lines. In order to assure accurate positioning within the catographic or publishing manuscript (basic color separation sheet) it is necessary to have at least 3 well-distributed trig points for each plane table sheet or patch. The basic deficiency of the 1:100,000 topographical map of Yugoslavia is a result of disregarding this necessity. Generally the sheets were composed merely by fitting of the plane table sheets into the graticule of the $30'_{\phi}$ x $30'_{\lambda}$ sheet. The disparities found by comparisons of scaled positions with the coordinates are systematical for trig points plotted in the same plane table sheet but differ distinctly from disparities found in adjacent plane table sheets. This all proves that composition of the basic color separation sheet was not done in accordance with the plotted trig points but rather by fitting of the blue lines without exact size into graticule there were exercised compromising shifts which caused distortion of the positional relation among the patches as well as of the patches in respect to horizontal control. Consequently these shifts within each sheet produced a certain inconsistency in the positioning of the details which largely affects the horizontal (positional) accuracy of the map. In order to evaluate the reliability of the map, as well as to find out how the map could be improved i.e. brought into sympathy with the presently adjusted and uniformly oriented control, for each area there should be established:

- the disparity between the adjusted control and unadjusted control used in the topographical survey.

- the size and direction of the shifts made in the composing of the sheets; and

- particularly for the southern part of area A the difference caused by the inclusion of the plane table sheets positioned on the Clarke 1880 control, as well as in area B the difference caused by the inclusion of the plane table sheets positioned upon the control referring to various datums.

Since the horizontal control in the plane table sheets by means of the beam compasses was plotted with a maximal error of ± 0.2 mm (by coordinatograph ± 0.1 mm), the large differences in excess of ± 0.2 mm stated by the comparison of the coordinates of the adjusted control with the positions scaled from the map are merely due to the above mentioned shifts and disparities.

(a) Area A (Serbia, Macedonia and Montenegro).

- Sheets compiled from the topographical survey carried out in 1920-22(1): The plane table sheets surveyed in 1920-22 are based upon the trig points of the Serbian triangulation established in 1900-1906, which coordinates would differ from the coordinates of the adjusted Yugoslav first order net within limits of ± 3 m. The coordinates of Servian triangulation are not available. The coordinates available are those of the net, which was reobserved and densified in 1925-28, with a large percentage of restored stations established merely in the vicinity of the lost old stations. Comparing the coordinates of 172 trig points belonging to this resurveyed net with the scaled positions from the map there were obtained:

average error E_1 = ± 40.98 m, and

probable error E = ± 34.14 m.

= ± 0.34 mm/1:100,000.

Since from these 1:100,000 sheets the positions of trig points can be determined within the probable error E = ± 30 m (0.3 mm) the orientation points and clearly visible detail points (sharply shaped points of planimetry) would be determined within a probable error of 45 m (0.45 mm), which considerably exceeds the probable error of ± 0.3 mm obtained in the analysis of the maps of various European countries compiled from the topographical survey carried out in the period between the two World Wars. Of course there would be some excuse for such a large probable error in the identity (as merely assumed) of the 1925-28 stations, for which the coordinates are available, with the stations of the Serbian triangulation used in the mapping with no coordinates available. It is true that many of the stations reestablished in 1925-28 do not coincide exactly with the corresponding stations of the 1900-06 Serbian triangulation; therefore the comparisons and probable error derived from them are to a certain degree affected by the inexact identity of the points to which coordinates and scaled positions refer, but the larger part of the disparity is due to the poor composition of the 1:100,000 sheets. It should be mentioned that the area of 1350 km^2 of the sheet 121 Pirot was compiled from the plane table sheets surveyed in 1911 at 1:25,000 scale. In drafting and composing of color separations the blue lines reduced to 1:50,000 scale were used.

- Sheets compiled from the topographical survey carried out in 1922-25, in Macedonia, Kosovo-Metohija region and districts Caribrod and Bosiljgrad(2): These sheets were compiled from the plane table sheets positioned upon the preliminary geographic coordinates of the triangulation carried out by the M.G.I. of Yugoslavia into which the eastern part of Albanian boundary triangulation was incorporated. In the plotting of the trig points into plane table sheets the linear values of the preliminary geographic coordinates computed on Clarke 1880 ellipsoid were used as explained in chapter V-2c (pp 271-273). Meanwhile the 1:100,000 sheets of the topographical map of Yugoslavia should refer to the ellipsoid of Bessel. The plane table sheets with dimensions $6'_\phi \times 10'_\lambda$ computed on Clarke ellipsoid are larger by 1 m in northing and by 2.20 m in easting in respect to the size of the sheet lines referring to the Bessel ellipsoid. These differences are meaningless in graphical construction at 1:50,000 scale. Since a $30'_\phi \times 30'_\lambda$ sheet at the center of the area concerned if computed on Bessel ellipsoid would be smaller by 5.20 m in northing and 6.60 m in easting at the scale 1:50,000, in which the sheet lines were constructed and the map was compiled, this would amount to about 0.1 mm and is practically meaningless also in the construction of sheet lines; hence it would be absolutely impossible on the basis of scaling records to determine if the sheets of 1:100,000 topographical map of Yugoslavia compilation of which was started in 1923, and were published in 1925-27, in respect to the size of the sheet lines refer either to the Clarke 1880 or to Bessel ellipsoid. On the other hand the accumulation of the differences of the size of the sheets expressed in the ellipsoidal disparities between the coordinates referring to the Clarke 1880 and Bessel ellipsoids can be stated by the comparison of the scaled positions from the map with the coordinates of the control. Comparing the scaled positions of the 378 stations with their respective coordinates there were obtained the following values of the average differences in N and E and average as well as probable errors:

Clarke 1880 GPs - scaled positions

$N_{av} = \pm\ 9.28$ m

$E_{av} = \pm\ 18.61$ m

$E_1 = \pm\sqrt{N_{av}^2 + E_{av}^2} = \pm\ 20.80$ m

$E = 5/6\ E_1 = \pm\ 17.33$ m $= \pm\ 0.17$ mm/1:100,000

Bessel Yugo Red. GKs - scaled positions

$N_{av} = -\ 41.78$ m

$E_{av} = \pm\ 27.01$ m

$E_1 = \pm\sqrt{N_{av}^2 + E_{av}^2} = \pm\ 49.75$ m

$E = 5/6\ E_1 = \pm\ 41.44$ m $= \pm\ 0.41$ mm/1:100,000

These figures provide a sufficiant proof that the 1:100,000 sheets in this region, irrespective of which ellipsoid the size of the sheet lines are referred to, are positioned upon the GPs referring to Clarke 1880 ellipsoid.

Since after 1930, the 1:100,000 sheets were reproduced without any changes at the scale of compilation 1:50,000 the so called 1:50,000 topographical map of Yugoslavia would be more properly called an "enlarged edition of the 1:100,000 map." Except for the scale the sheets are identical, and the 1:50,000 sheets are provided with a 2 km (4 cm) Gauss-Krueger grid. The grid was constructed on basic color separations for 1:100,000 sheets and is plotted in sympathy with the sheet corner values for 1:100,000 sheets computed in terms of Yugo-reduced GKs (3^o zones, Bessel ellipsoid). The accuracy of plotting would be expressed by the mean square error $\pm$ 11.5 m = $\pm$ 0.23 mm/1:50,000. The 1:100,000 sheets at the scale of compilation were in the process of reproduction along the 15' graticule decomposed into four 1:50,000 sheets and printed as an emergency map for the artillery. There was need for this brief explanation about the identity of the 1:50,000 sheets with 1:100,000 sheets because in the evaluation of the 1:100,000 sheets, in order to facilitate the scaling, the Yugo-Red. GKs of the adjusted control were compared with the positions in terms of Yugo-Red. GK grid scaled from 1:50,000 sheets. These comparisons of scaled positions - Yugo-Red. GKs show systematical disparities with a shift of the plotted positions to the north and symetrically toward the 21° meridian. (See Inclosures 31 and 32). Since the point of the coincidence of the ellipsoids (ϕ 45°, λ 21°) is north of the center of the area concerned the latitudes in terms of Clarke 1880 ellipsoid are larger then that which refer to the Bessel ellipsoid; meanwhile the longitudes referring to Clarke 1880 ellipsoid are shorter in the area east of the 21° meridian and longer in the area west of the 21° meridian in respect to the longitudes computed on the ellipsoid of Bessel. This relation between the coordinates referring to the two ellipsoids agrees (insofar as it is not distorted by the poor composition of sheets and somewhat by the fact that disparities are found from the comparison of the scaled positions of unadjusted control with the coordinates of adjusted control) with the relation between the scaled positions (Clarke 1880 GPs) and corresponding Yugo-Red GKs. This fact provides further proof that the 1:100,000 sheets covering the regions of Macedonia and Kosovo-Metohija are positioned upon the GPs which refer to the Clarke 1880 ellipsoid.

The previously discussed comparisons justify the following conclusions:

- That the 1:100,000 sheets were composed by means of fitting the blue lines of the 1:50,000 topographical manuscripts (plane table sheets) into graticule of the $30'_\phi \times 30'_\lambda$ sheets constructed at 1:50,000 scale. The blue lines positioned upon the unadjusted control which refers to Clarke 1880 ellipsoid were included into the graticule without any recasting; therefore both the 1:100,000 and 1:50,000 sheets are positioned upon the unadjusted control referring to Clarke 1880 ellipsoid and the geographic values of sheet corners are in terms of Clarke 1880 GPs.

- That the sheet corner values published for the 1:100,000 sheet in terms of Yugo-Red. GKs refer to the ellipsoid of Bessel, hence are inconsistent with the respective geographic values. (See enclosed ellipsoidal differences which should be applied to the sheet corner values referring to the Clarke 1880 ellipsoid in order that they be in sympathy with those expressed in terms of Yugo-Red. GKs; Inclosure 33).

- That the 2 km (4 cm) Gauss-Krueger grid, with which the 1:50,000 sheets are provided, was plotted in sympathy with the sheet corner values of 1:100,000 sheets computed in terms of Yugo-Red. GKs which refer to the Bessel ellipsoid; therefore this grid is also inconsistent with the geographic sheet corner values and with the plotted control.

- That the sheets 121. 130, 132, 133, 135 and 143 are composed of the blue lines of topographical manuscripts based upon the horizontal controls which refer to the ellipsoids of Bessel and Clarke 1880. Since the sheets are consistent in size and the fitting of the two types of blue lines into graticule required some compromising shifts, the combined sheets in respect to one or other ellipsoid are not exact in position, their geographic sheet corner values represent compromising values between the exact sheet corner values in terms of Clarke 1880 and Bessel ellipsoids. This displacement in respect to the exact sheet corner values in terms of one or the other ellipsoid which amounts to ± 12-18 m (0.2-0.4 mm/1:50,000) was ignored and the details along the sheet lines of the adjacent sheets cartographically tied. For the same reason displaced details along the junction of blue lines within the sheets were in the same manner cartographically tied. Since the error in the construction of sheet lines is ± 0.2 mm/1:50,000 (± 0.1 mm/1:100,000), and the error in the composing of sheets is even larger, the displacement of ± 0.1-0.2 mm in position of the sheets as well as the internal displacement of the details of the same size at the 1:100,000 sheets could be tolerated.

Considering that the probable error by which the trig points on the map could be determined amounts to;

$$E = \pm 41.44 \text{ m} = \pm 0.41 \text{ mm}/1{:}100{,}000$$

the orientation points determined by plane table triangulation and clearly visible detail points (sharply shaped points of the planimetry) would be scaled by a probable error:

$$E = \pm\sqrt{0.41^2 + 0.3^2} = \pm 0.51 \text{ mm}/1{:}100{,}000 = 51 \text{ m}$$

This error in respect to the probable error obtained from the analysis of the European maps compiled from the topographical surveys carried out between two World Wars is nearly of double magnitude.

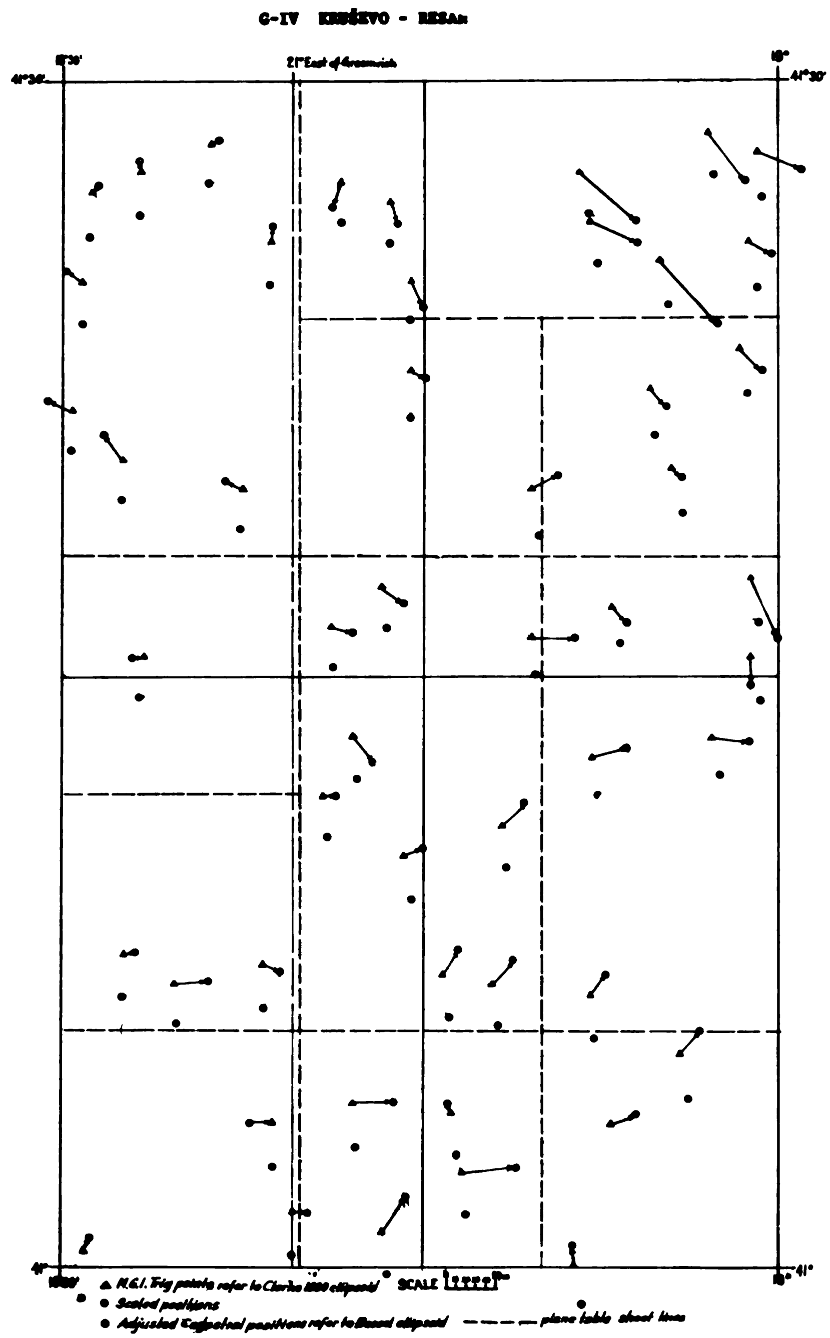
In case the 1:100,000 sheets would be recasted from Clarke 1880 to Bessel ellipsoid (applied the enclosed corrections) the probable error by which the trig points could be determined from the map would drop to:

$$E = \pm 17.33 \text{ m} = \pm 0.17 \text{ mm}/1{:}100{,}000;$$

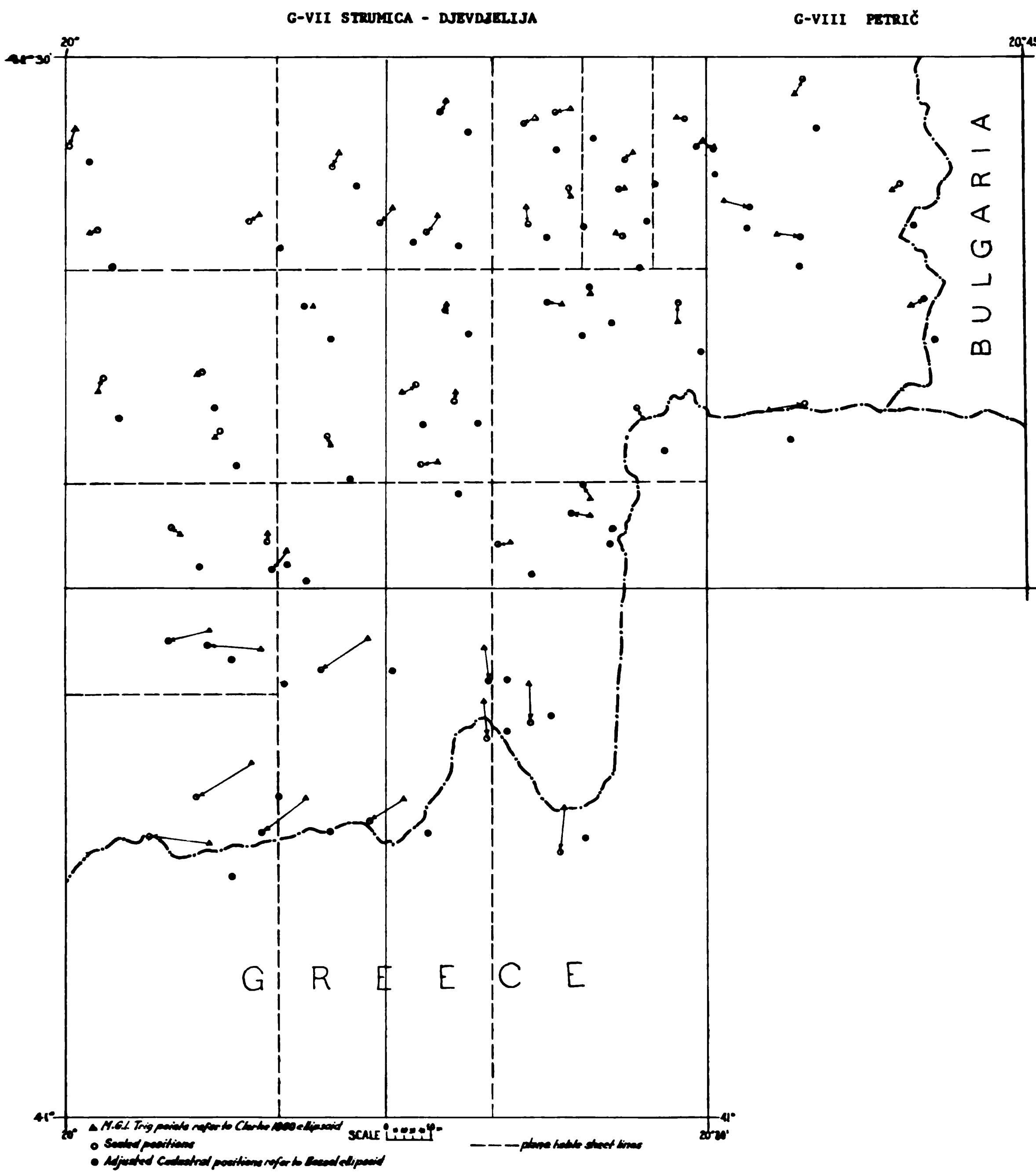
hence the probable error of the orientation points and clearly visible detail points would be:

$$E = \pm 34 \text{ m} = \pm 0.34 \text{ mm}/1{:}100{,}000$$

Inclosure 31



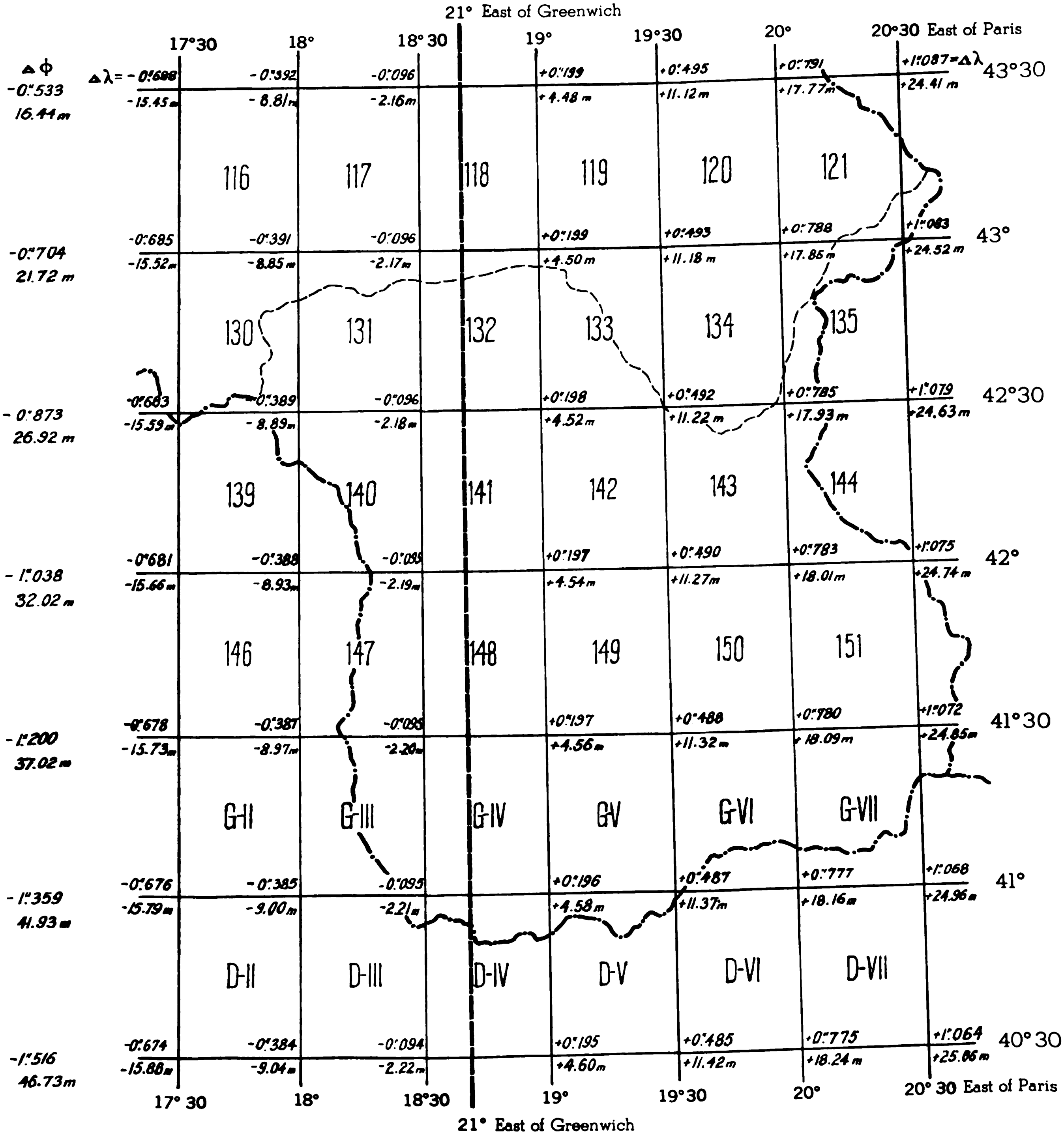
Inclosure 32



Inclosure 33

CORRECTIONS

which should be applied to the Clarke 1880 sheet corner values in the recasting of the 1: 100,000 sheets to the Bessel ellipsoid.



which is close to the above mentioned European standard.

It should be noted that the recasting at 1:100,000 scale with cutting and adding of 0.2-0.4 mm strips is technically a tedious cartographic process which would be less complicated at 1:50,000 scale. Since the sheets generally were composed merely by fitting of the blue lines into graticule, the internal inconsistency in the position of the details in many sheets is considerable, particularly in the combined sheets and in the sheets along the Albanian boundary, (See the Inclosures 34 and 35) the recasting would be acceptable only for 1:100,000 sheets. In order to bring the 1:50,000 sheets into sympathy with the adjusted triangulation the sheets within which the internal shifts of the details exceed the allowed tolerance of graphical accuracy have to be panelled, decomposed and positioned by the control.

- The 1:100,000 sheets composed of the plane table sheets surveyed in 1925-1928(3): These sheets are positioned upon the M.G.I. triangulation with the preliminary coordinates which refer to the Bessel ellipsoid. In the largest area surveyed topographically in 1925-28 the positions of trig points used in topographical survey differ up to ± 4 m from the positions determined by final coordinates. Comparing the final coordinates of 516 trig points with the scaled positions the following probable error of the determination of the positions of trig points from the map was obtained:

$$E = \pm 24.87 \text{ m} = \pm 0.25 \text{ mm}/1{:}100{,}000.$$

Hence, the probable error by which the orientation points and clearly visible detail points from the map could be determined would be

$$E = \pm 39 \text{ m} = \pm 0.39 \text{ mm}/1{:}100{,}000$$

- The sheets composed from the plane table sheets surveyed in 1924-26(4): In a narrow strip extending over the area covered by southern parts of the 1:100,000 sheets 116, 117, 118 and northern parts of the sheets 131, 132, and 133 the plane table sheets are based upon the unadjusted control with a maximal displacement of 13 m. From the comparison of the final coordinates of 33 stations located in the quads 116/3, 117/3, 117/4, 118/3 and 118/4 with the respective scaled positions the following probable error of the determination of the positions of trig points from the map was obtained:

$$E = \pm 25.88 \text{ m} = \pm 0.26 \text{ mm}/1{:}100{,}000;$$

hence also from these quads the positions of the orientation points and clearly visible detail points could be determined with a probable error smaller than 0.4 mm.

Meanwhile the combined sheets and quads composed from the plane table sheets based upon the control referring to Bessel and to Clarke 1880 ellipsoid in respect to the exact positioning and internal consistency should be considered as the most deficient among the sheets compiled from the 1:50,000 topographical survey of Serbia, Macedonia and Montenegro. The probable error of the positions of trig points from these sheets grows up to:

$$E = \pm 60 \text{ m} = \pm 0.6 \text{ mm}/1{:}100{,}000;$$

hence the positions of the orientation points and clearly visible detail points could be determined with a probable error of 0.7 mm. (See Inclosure 30).

- The sheets covering the region along the Danube river in Eastern Serbia(5): These sheets, composed from the plane table sheets surveyed in 1928 and based upon the triangulation carried out in 1927 of which coordinates were computed by use of final coordinates of the adjusted first order net as starting points, are the best sheets compiled of the 1:50,000 topographical survey of Serbia, Macedonia and Montenegro. The displacement of the positions of trig points used in the survey from the finally adjusted positions is within 1m. From the comparison of the coordinates of 72 trig points with the respective scaled positions a probable error

$$E = \pm 20.23 \text{ m} = \pm 0.2 \text{ mm}/1{:}100{,}000$$

was obtained. Since from these sheets the positions of trig points could be determined with a probable error 0.2 mm the positions of the orientation and clearly visible detail points would be determined with a probable error.

$$E = \pm 36 \text{ m} = \pm 0.36 \text{ mm}/1{:}100{,}000.$$

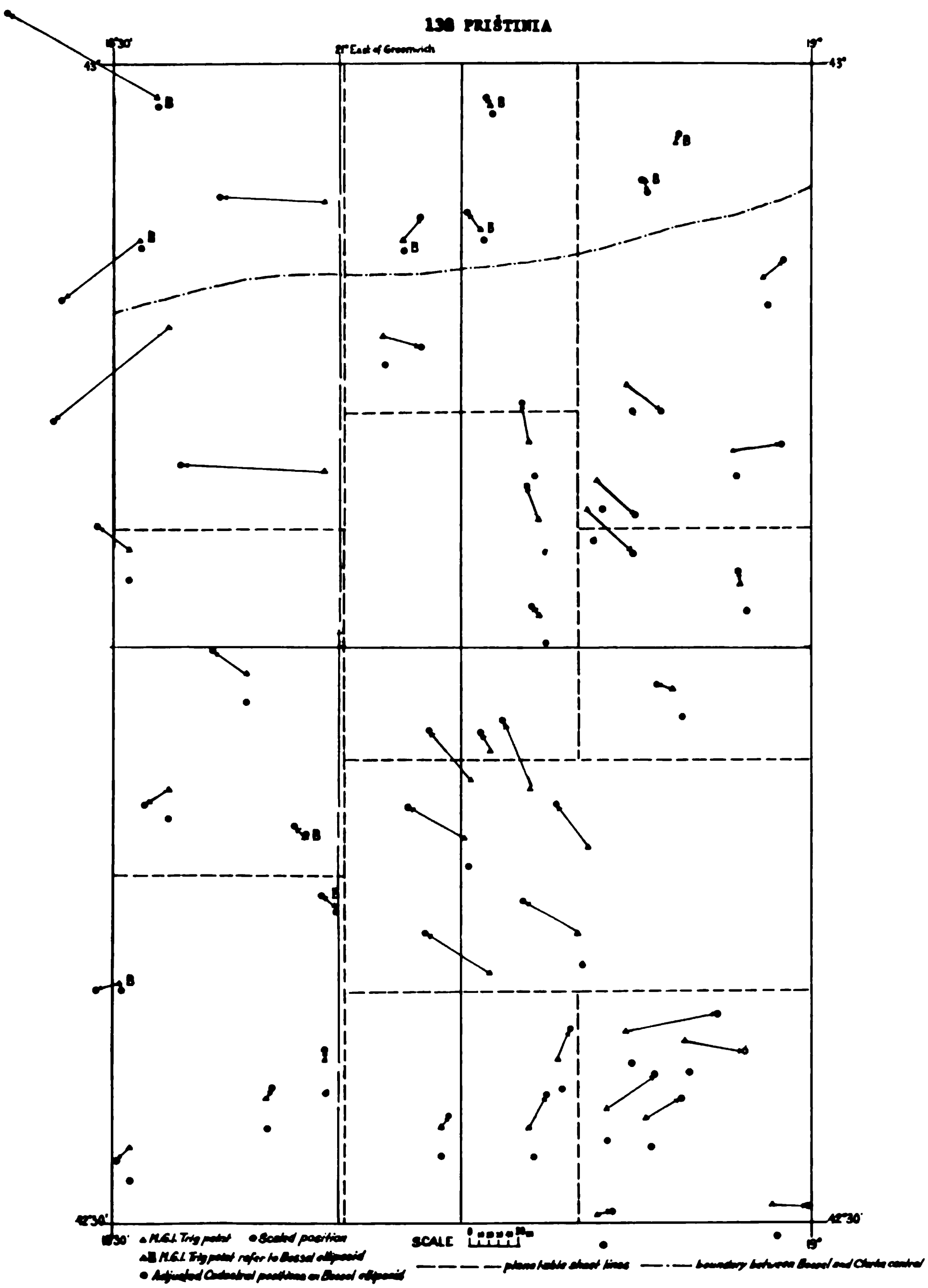
Hence, according to the Gaussian law of the distribution of accidental errors only 65% of planimetric features would be located within 0.5 mm (0.02 inch) of their true geographical position at the reproduction scale 1:100,000, and 94% within 1 mm (0.04 inch).

- Conclusions about the positional accuracy and internal consistency of the 1:100,000 sheets compiled from the topographical survey of Serbia, Macedonia and Montenegro:

Inclosure 34

Sheet with combined Bessel and Clarke 1880 Control

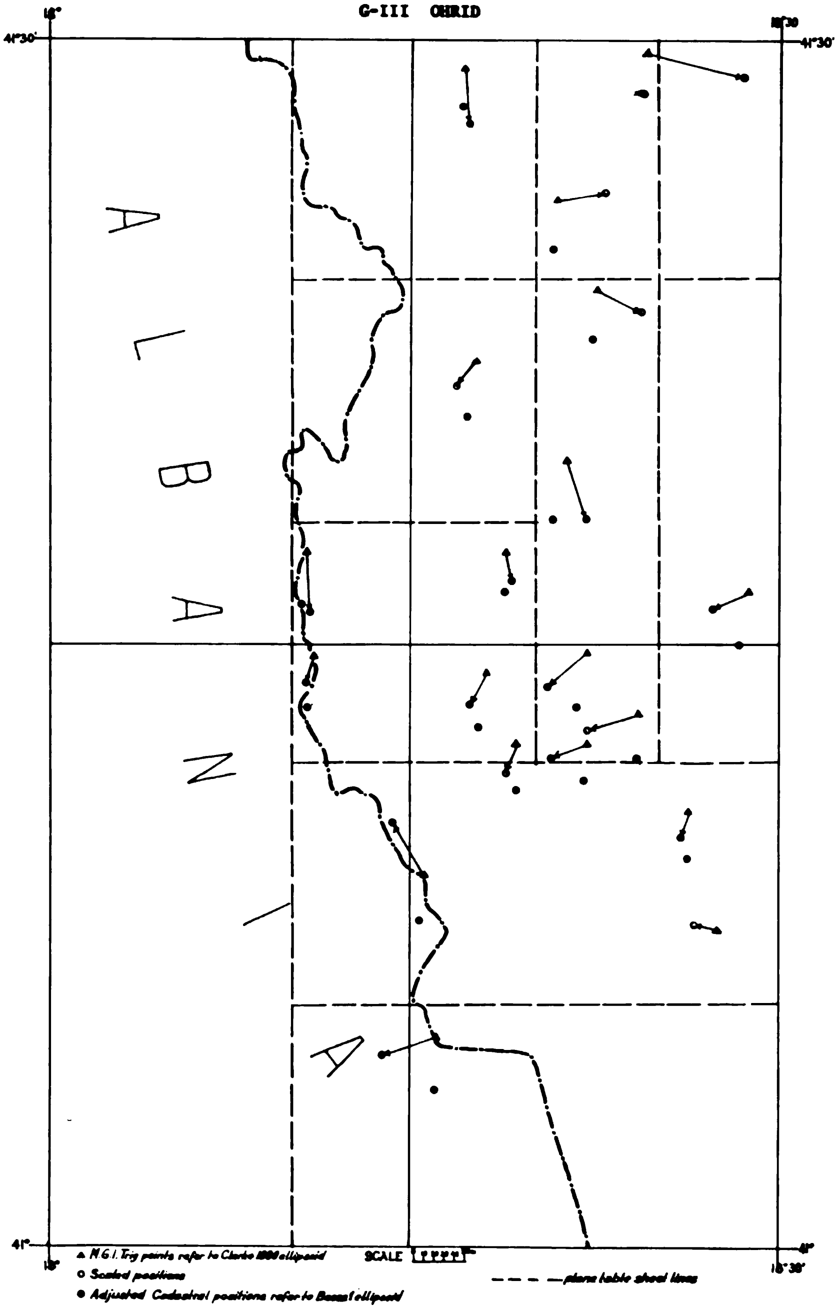
138 PRIŠTINIA



Inclosure 35

Sheet on Albanian Boundary

G-III OHRID



Comparing the final coordinates of 806 trig points with the scaled positions of the sheets in area A compiled from the plane table sheets positioned upon the control referring to the Bessel ellipsoid the following probable error was obtained:

$$E = \pm 24.52 \text{ m} = \pm 0.25 \text{ mm}/1{:}100{,}000,$$

and from the comparisons of 1216 trig points covering the entire area A (Bessel and Clarke 1880)

$$E = \pm 30.74 \text{ m} = \pm 0.3 \text{ mm}/1{:}100{,}000.$$

Consequently the orientation points and clearly visible detail points from the sheets positioned upon the Bessel control can be determined with a probable error

$$E = \pm 39 \text{ m} = \pm 0.39 \text{ mm}/1{:}100{,}000$$

i.e. 58% of the planimetric features are located within 0.5 mm (0.02 inch) and 92% within 1mm (0.04 inch).

Considering all sheets compiled from the topographical survey of Serbia, Macedonia and Montenegro (area A) the corresponding accuracy would be expressed as follows:

$$E = \pm 43 \text{ m} = \pm 0.43 \text{ mm}/1{:}100{,}000$$

i.e. 56% of planimetric features located within 0.5 mm (0.02 inch) and 88% within 1mm (0.04 inch).

The sheets positioned upon the M.G.I triangulation carried out in 1924-28, with the preliminary positions referring to the Bessel ellipsoid in respect to the final GPs have the maximal displacements

$$\Delta S = \pm\sqrt{x_{max}^2 + y_{max}^2} = \pm 1\text{m}, \pm 4\text{m}, \pm 13 \text{ m}.$$

The probable errors obtained from the comparisons of final coordinates with scaled positions of the sheets referring to the Bessel ellipsoid are:

$$E = \pm 20.23 \text{ m}, 24.87 \text{ m}, 25.88 \text{ m respectively.}$$

Considering these figures it is easy to conclude that the magnitude of the probable error is affected not so much by the displacements of the preliminary positions from final positions of trig points as by the internal inconsistency resulting from the poor composition of the sheets. The probable error due to the poor construction and composition of the sheets would be about ± 0.2 mm/1:100,000 and maximal error about ± 0.9 mm/1:100,000. Since the map was constructed and compiled at 1:50,000 scale the probable error at scale of the construction is ± 0.4 mm and maximal error ± 1.8 mm. It should be assumed that the sheet lines and graticule were constructed and the trig points plotted with an accuracy expressed by a maximal error ± 0.2 mm. Because the positions were scaled by means of the Yugo-Red. GK grid, which on basic color separation sheets 5-8 years after the compilation was constructed, the plotting accuracy of the grid is not identical with the plotting accuracy of the sheet lines data and the control, and has to be determined from the comparisons of plotting data with scaled positions of the grid (scaled from 1:50,000 sheets; manuscripts are not available). From these comparisons the following mean square error expressing the plotting accuracy of the grid was obtained:

$$E_2 = \pm 11.5 \text{ m} = \pm 0.23 \text{ mm}/1{:}50{,}000.$$

The maximal error obtained from the comparisons is:

$E_3 = \pm 26$ m $= \pm 0.5$ mm/1:50,000. (theoretically would be $E_3 = 3E_2 = 34.5$ m.)

Consequently the scaled positions contain within the limits of 26 m an error due to the insufficient accuracy of the grid. Subtracting this maximal error ± 0.5 mm and the maximal shift of the positions $\Delta S = \pm 0.3$ mm due to the differences between the preliminary and final coordinates from the maximal error made in the construction and composition of the sheets which amounts ± 1.8 mm we find that the shifts due to the poor composition of the sheets, producing internal inconsistency, would reach up to 1mm/1:50,000. Within the 1:100,000 sheets composed of the plane table sheets positioned upon the control referring to Clarke 1880 ellipsoid the shifts of the same sixe (up to 1mm/1:50,000) are stated if the ellipsoidal differences are subtracted from the total displacement obtained in the comparisons of the final coordinates with scaled positions. Meanwhile the sheets composed of the plane table sheets based upon the old Serbian triangulation (1900-06) have internal shifts larger by ± 0.3 mm/1:50,000. This increase of the shifts is due to inexact identity of the scaled positions with the positions of 1926-28 trig points for which coordinates are available. In case the coordinates of Serbian triangulation are available and compared, the internal inconsistency of these sheets would be of the same magnitude as in the rest of the sheets in area A positioned upon the 1924-28 M.G.I. triangulation referring to the Bessel ellipsoid.

In the enclosed diagram are shown the arithmetic means of the differences between the final Yugo-Red. GKs - scaled positions for the sheets in area A composed of the plane table sheets positioned upon the triangulation referring to the Bessel ellipsoid. (See Inclosure 36).

(b) Area B (former Austro-Hungarian territory consisting of Yugoslav provinces: Slovenia, Croatia, Bosnia and Herzegovina and Vojvodina). (See Inclosure 30).

The sheets of the 1:100,000 topographical map of Yugoslavia in area B are composed from reduced and reambulated plane table sections at 1:50,000 scale of the III and IV Topographical surveys of the Austro-Hungarian Empire. As a preface to the explanation of the manner of composing and compilation of these sheets only a few remarks about the triangulation used in their survey need to be made here, since a detailed study of these topographical surveys is included in chapters B III and IV, pp. 8-54.

- The plane table sections of the III Topographical survey in Slovenia, Croatia and Dalmatia (1) are positioned upon the unadjusted K. und k. Military triangulation carried out in 1860-71 with the geographic coordinates referring to Vienna University datum. Since there was no adjustment of the loops the coordinates of the some stations computed from various chains differ. Consequently this triangulation can not be considered homogeneous despite the fact that coordinates refer to one datum. The maximal disparity at station Oser amounts to:

$$\Delta N = 1.28 \text{ m}$$

$$\Delta E = 28.19 \text{ m}$$

$$\Delta S = \sqrt{N^2 + E^2} = 31.16 \text{ m}$$

Since the mean values were used in the plotting of trig points the maximal displacement of the positions of trig points and sheet corners in this area should be considered ± 15 m.

The topographical survey was carried out in 1877-84. Only the plane table sections within the 1:100,000 sheets 41,57 and some plane table sheets within the 1:100,000 sheets 75, 76 were reambulated by K. und k. M.G.I. in 1908 and 1914 respectively.

- The "uniform graticule system" of the Austro-Hungarian sheet lines in Bosnia and Herzegovina (2) is based upon the so-called "main net", i.e. first and second order stations of the K. und k. Military Triangulation carried out in 1879-84, for which the geographic positions referring to the Vienna University datum prior to the adjustment of Bosnian first order chain were computed. Since the plane table sections are positioned upon geographic positions of the Vienna University system computed from preliminary adjusted regional nets, in which computation the GPs of various trig stations of surrounding K. und k. M.T. chains were used as starting coordinates, the sheet corners are not in sympathy with the adjusted K. und k. M.T. first order net or with the Yugoslav first order net and in addition to the datum disparity have dispalcements from 1.5 m - 15 m.

From the comparison of the coordinates of Bosnian M.T. (transformed to Yugo-Red. GKs) with the final coordinates of Yugoslav triangulation at 112 identical stations third order station Obla Glava shows the largest displacement;

$$\Delta N = 14.51 \text{ m}$$

$$\Delta E = 14.98 \text{ m}$$

$$\Delta S = 20.86 \text{ m.}$$

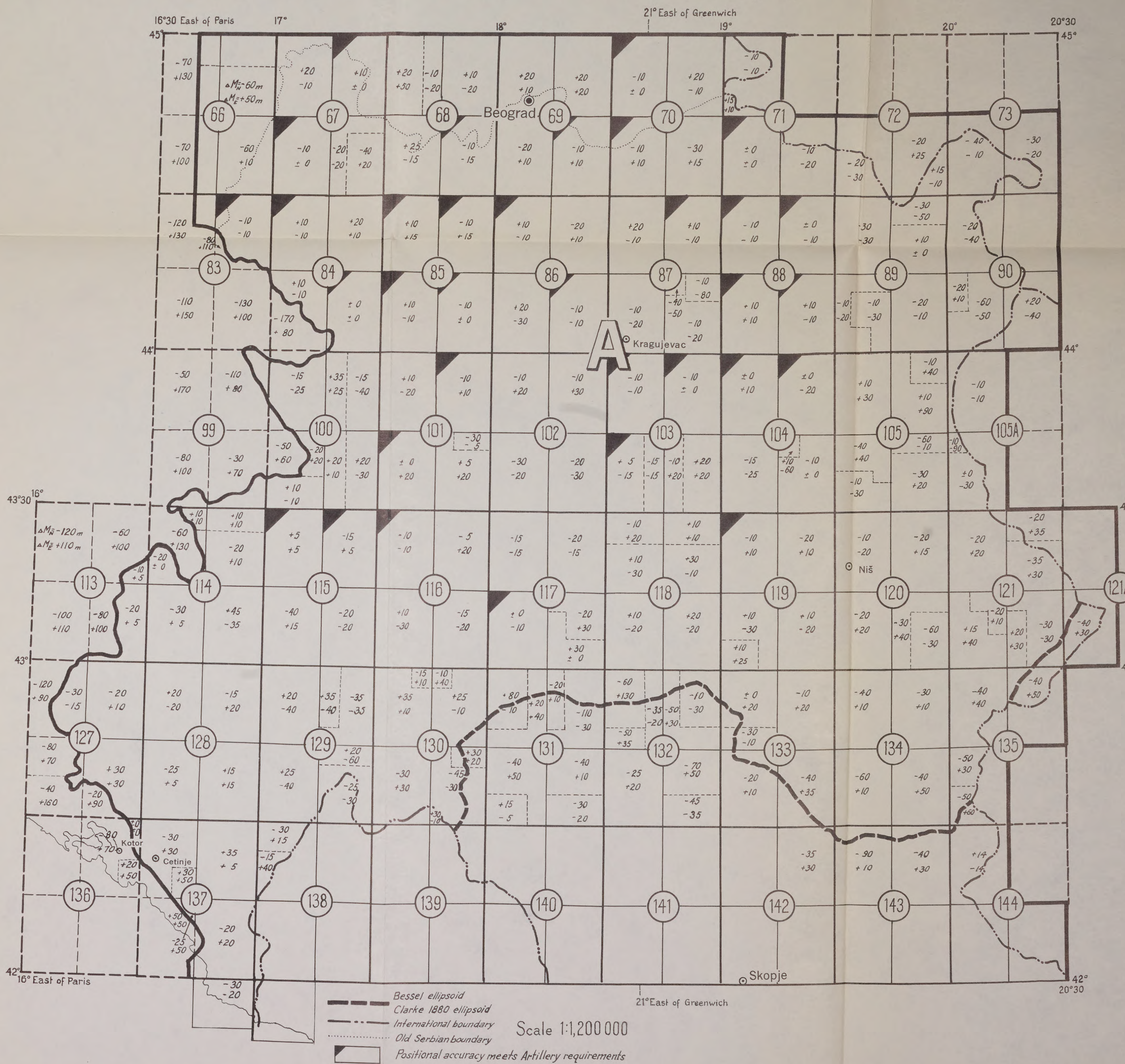
The topographical survey of Bosnia and Herzegovina was carried out in 1880-87. In 1907-13 the plane table sections along Serbian and Montenegrin boundaries east of the 16° meridian were reambulated by K. und k. M.G.I.

- The plane table sections covering Vojvodina east of 16° 30 meridian and north of 45° parallel (3): Since in this area at the time of the III Topographical survey no cadastral survey had been made the rectangular sheets of the II Topographical survey were used as a base for the topographical survey. For this purpose the rectangular sheets constructed in Cassini projection and surveyed in 1864-66 at 1:28,800 scale were enlarged to 1:25,000 scale and recasted into polyhedric plane table sections. In 1881 these plane table sections were reambulated and redrafted according to the standards of the III Topographical survey (See chapter B III-1c (3) pp. 17-25). Because east of this area the triangulation is oriented on St. Anna datum in order to eliminate the overlapping strips among the sheets of Vienna University system and St. Anna system caused by the datum difference ($\Delta\phi = + 2''.92; \Delta\lambda = + 4''.25$) the sheet lines were shifted toward the southwest; i.e. the plotted positions represent the GPs of Vienna University system enlarged with certain corrections which were added erratically. (See Inclosure 37). Due to the erratic shifts the desired junction along the 40° 30' meridian east of Ferro was not achieved. The scaled positions from the plane table

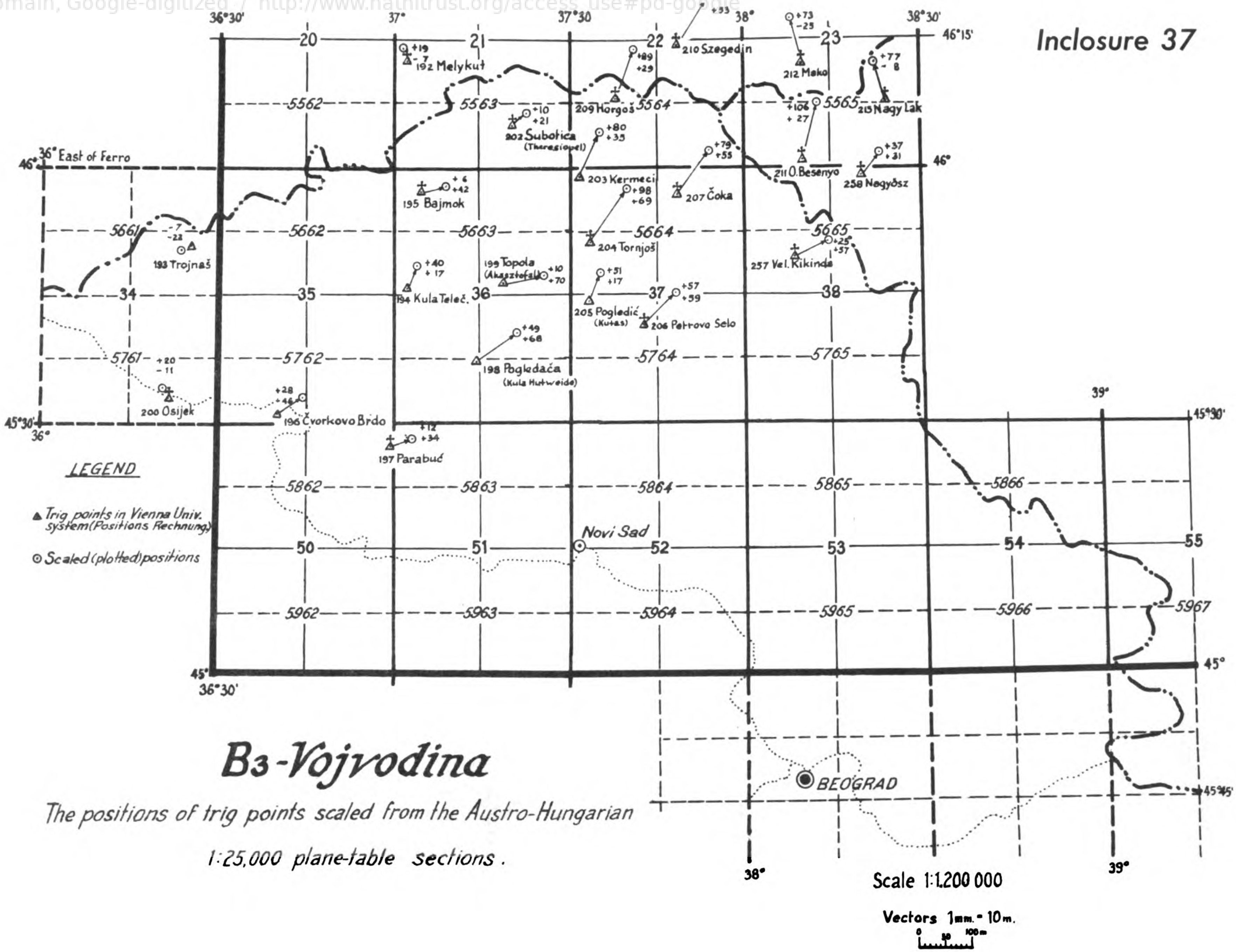
Inclosure 36

Topographical map of Yugoslavia at 1:100,000 (50,000) scale

The arithmetical means of the differences between the final Yugo-Red. GK[s] - scaled positions: $\Delta M_N = -$ m, $\Delta M_E = +$ m



Inclosure 37



B3-Vojvodina

The positions of trig points scaled from the Austro-Hungarian 1:25,000 plane-table sections.

sections covering the Vojvodina differ from the GPs of Vienna University system up to:

$$\Delta N = + 98 \text{ m}$$

$$\Delta E = + 70 \text{ m}$$

Station 204 (337 Yug. I.O. net) Tornjoš shows the largest displacement.

$$\Delta S = \sqrt{\Delta N^2 + \Delta E^2} = \sqrt{98^2 + 69^2} = + 120 \text{ m} = 4.8 \text{ mm}/1:25,000.$$

In 1913, the plane table sections covering the area south of 45° 30' parallel were reambulated by K. und k. M.G.I. In view of the inaccuracy in positioning and the failure to utilize the cadastral planimetry in their survey it is easy to see why the plane table sheets covering the area of Vojvodina are the most defective in the whole K. und k. topographical survey covering Yugoslavia.

- The plane table sections of the IV Topographical survey covering West Slovenia (4): The plane table sections of the IV Topographical survey in West Slovenia are based upon the third order net of the K. und k. M.T. established in 1896-1900. The observations started from cadastral stations at which markers were found. In the computing of preliminary GPs the combined observations of the 1896-1900 survey and old cadastral were used. In some cases the coordinates were computed in the field and immediately utilized by topographers. These preliminary coordinates by means of which the trig points were plotted into plane table sheets refer to Vienna University datum and were never published. Each plane table sheet within the Yugoslav 1:100,000 sheets 11 Ljubljana and 26 Cerknica was provided with about 10 trig points. Other plane table sheets in the area surveyed were provided with merely 3 trig points.

In 1900-1904, after the utilization in the topographical survey this triangulation was tied to the uniformly adjusted first order net oriented on Hermannskogel datum by means of a sparse second order net. It was then adjusted and recomputed and the coordinates were published in Volume IV of "Die Ergebnisse der Triangulierungen". The preliminary coordinates of the trig points used in the topographical survey are not known; therefore it is impossible to determine the displacement of the preliminary positions in respect to the final positions by means of comparisons. Since the GPs of Positions Rechnungen referring to Vienna University datum were used as starting values in the computing of the preliminary coordinates, the GPs of 15 stations covering the area of the IV Topographical survey in West Slovenia were compared with the final geographic coordinates of the K. und k. M.T. first order net referring to Hermannskogel datum. From those comparisions in addition to the datum shift at the center of the area $\phi\ 46^\circ, \lambda\ 32^\circ$ which amounts to:

$$\Delta N = 42.41 \text{ m}$$

$$\Delta E = 113.40 \text{ m}$$

between the preliminary and final coordinates there was found a maximal displacement:

$$\Delta S = \pm 8.56 \text{ m.}$$

In this area due to the change of the scale the coordinates of the Yugoslav first order net in respect to the coordinates of K. und k. M.T. first order net have systematical differences of + 2 to + 5 m in Easting increasing toward the West. (See chapter D V-1c - (1J) pp. 235-236).

The composing of the 1:100,000 sheets from the reambulated plane table sections was done in the manner previously explained on pages 280-282. Each 1:100,000 sheet is composed at 1:50,000 scale of 8 plane table sections with dimensions $7'5_\phi \times 15'_\lambda$. Since the Military Geographic Institute of Yugoslavia did not possess the data of the triangulation used in the III and IV Topographical survey of the Austro-Hungarian Empire, i.e. the "Positions Rechnungen", the blue lines of the reambulated plane table sections were positioned into sheet lines of the 1:100,000 sheets by means of graticule without any change in position (recasting). Hence, the part B of the Yugoslav 1:100,000 topographical map retained Austro-Hungarian sheet lines, i.e. remains in the Vienna University system. In order to make the 1:100,000 map appear to be continous the positional disparities of the topographical features along the line of junction of part B with part A (45° parallel and former Austro-Hungarian boundary with Serbia and Montenegro), caused by two various datums, were cartographically fudged together. (See pp. 276-280). From the previous discussion it is known that the composing of the map sheets by means of graticule, where the blue lines of the plane table sheets or patches were not positioned by fitting to the plotted control but merely by matching the graticule, due to inexact size of the patches would produce an internal inconsistency up to 1mm. Furthermore, from the discussion of the incorporation of the cadastral planimetry into the uniform graticule system (See chapter B III-2b, pp. 32-34) it is known that the features of the pantographed cadastral planimetry in some plane table sections have displacements up to 3 and more milimeters. Consequently the internal inconsistency within the 1:100,000 sheets of part B is considerably larger than that within the sheets of part A and in some sheets would exceed 100 m = 2 mm/1:50,000. The maximal internal inconsistency appears to be in sheet 34/4 with the features of the northeastern plane table sheet shifted toward north-east by 350 m = 7 mm/1:50,000 in respect to the position of the features within rest of the sheet. Hence it should be stated that the displacements due to the inaccurate incoropration of the cadastral planimetry into original Austro-Hungarian topographical manuscripts, largely contributed to the magnitude of internal inconsistency within 1:100,000 sheets of part B. Meanwhile that portion of the internal inconsistency caused in the positioning of plane table sheets by means of Yugoslav M.G.I. matching of graticule remains also in part B within 1mm/1:50,000. This statement is supported by the fact that the smallest internal inconsistency appears in the 1:100,000 sheets covering Bosnia and Herzegovina where the cadastral survey in this province based upon the K. und k. M.T. and executed in the polyhedric projection (uniform graticule system) is completely identical in position with the topographical survey and consequently there were no positional problems in the utilization of the cadastral planimetry in the topographical survey. (See chapter B III-1c (4), pp. 26-28).

The Yugo-reduced GK's were compared with the scaled positions of more than 4000 trig points located in area B and in the inclosed diagrams are shown the arithmetic means of the differences between the final Yugo-Red. GKs and scaled positions for the sheets composed of the reambulated Austro-Hungarian plane table sections belonging to the Vienna University system. In the first diagram are shown the differences as obtained directly from the comparison, i.e. containing the difference between the Hermannskogel and Vienna University datums; second diagram includes the differences after the elimination of the datum shift by means of Dr. Ledersteger's corrections applied to the sheet corner values in order to make them in sympathy with the Hermannskogel datum. (See Inclosures 38 and 39).

In order to answer the question: Within what accuracy in area B from the 1:100,000 sheets of the topographical map of Yugoslavia could be determined the positions of trig points, orientation and sharply-shaped detail points; from the comparisons of Yugo-Red GK's with scaled positions the probable error of of determination of trig points, after the datum difference was eliminated from the disparities obtained in the comparisons, for the following mapping areas was computed:

Bosnia and Herzegovina (2) E = ± 26.29 m = ± 0.26 mm/1:100,000
Dalmatia (1) E = ± 28.19 m = ± 0.28 mm/1:100,000
West Slovenia (4) E = ± 39.02 m = ± 0.39 mm/1:100,000
Croatia and East Slovenia (1) E = ± 40.20 m = ± 0.40 mm/1:100,000
Vojvodina (3) E = ± 65.12 m = ± 0.65 mm/1:100,000

Consequently, the positions of the orientation and sharply-shaped detail points from the sheets of parts B would be determined with a probable error as follows:

Bosnia and Herzegovina (2) E = ± 40 m = ± 0.40 mm/1:100,000
Dalmatia (1) E = ± 41 m = ± 0.41 mm/1:100,000
West Slovenia (4) E = ± 49 m = ± 0.49 mm/1:100,000
Croatia and East Slovenia (1) E = ± 50 m = ± 0.50 mm/1:100,000
Vojvodina (3) E = ± 72 m = ± 0.72 mm/1:100,000

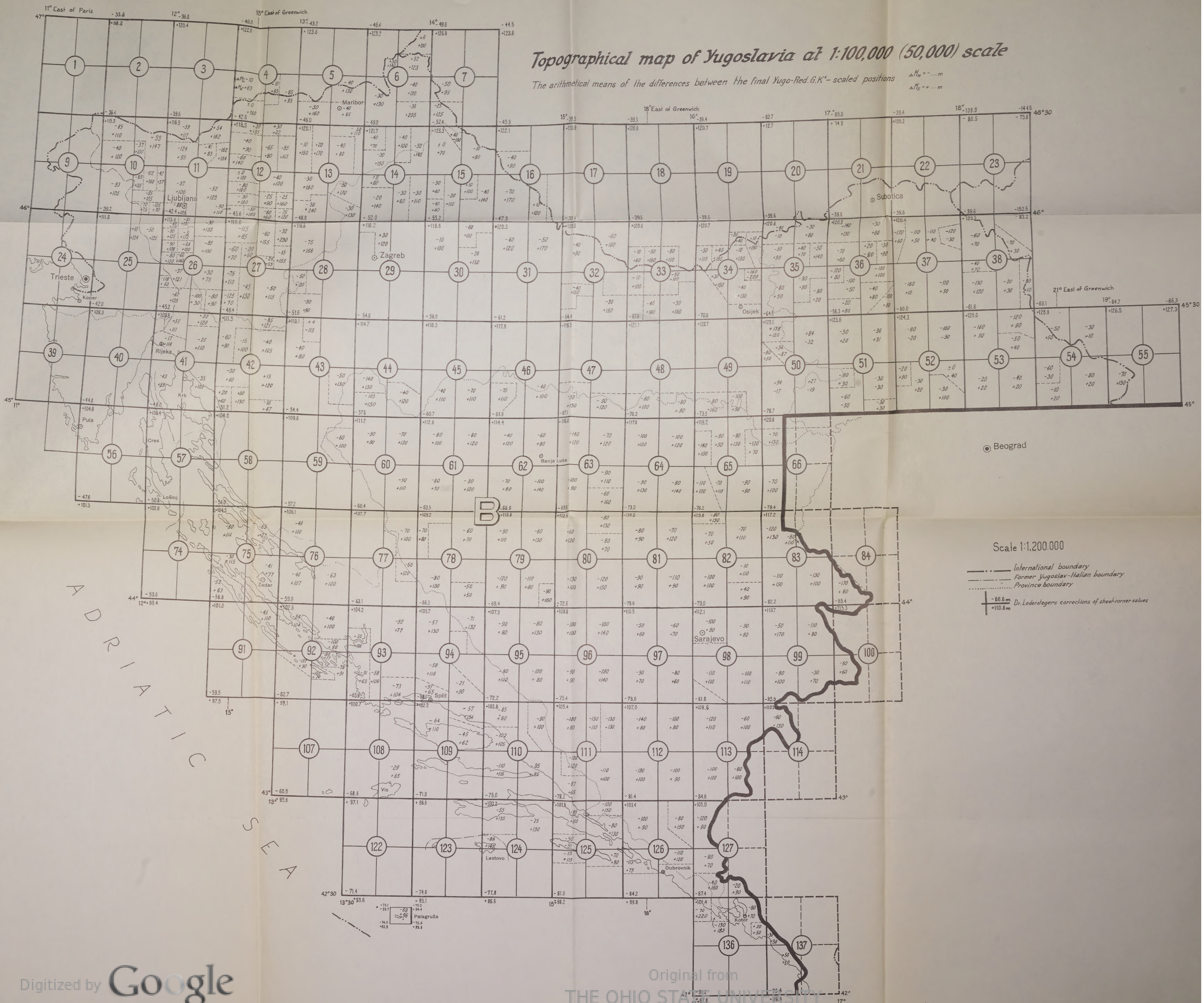
(c) Horizontal (positional) accuracy: Table showing the probable and mean square errors by which the positions could be determined from the sheets of the topographical map of Yugoslavia at 1:100,000 scale as well as positional evaluation of planimetry of the sheets covering various areas of Yugoslavia. (See Inclosure 30):

1:100,000 TOPOGRAPHICAL MAP OF YUGOSLAVIA

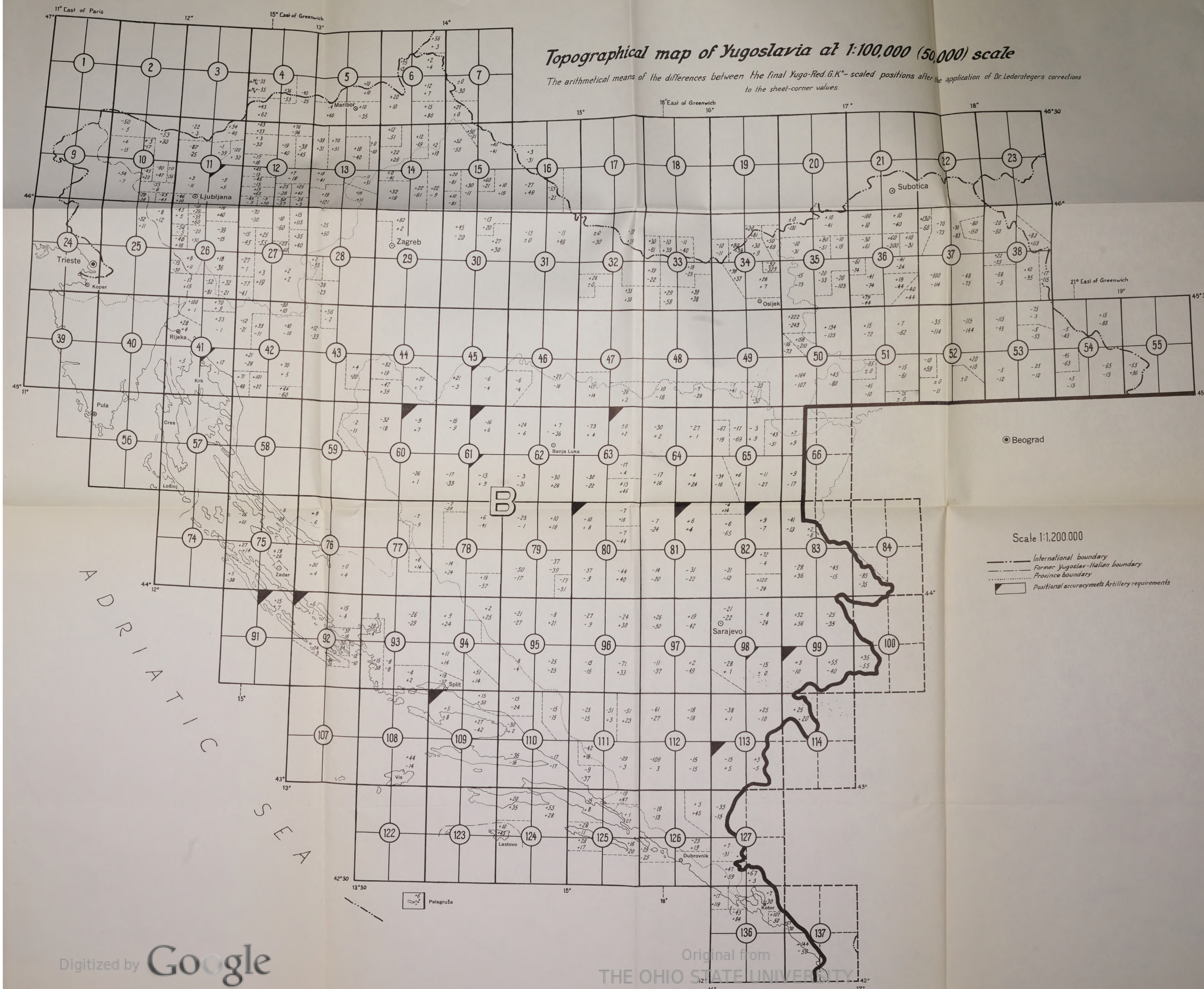
NO.		AREA	Trigonometric Points				Orientation and detail points				CLASS	
			Probable error		Mean square error		Probable error		Mean sq error		A	B
			E m	E mm	E_2 m	E_2 mm	E m	E mm	E_2 m	E_2 mm	90% 0.5mm	90% 1mm
1	A_5	Eastern Serbia Topo-Svy. 1928	20.2	0.20	30.3	0.3	36	0.36	54	0.54	65%	94%
2	A_3	Serbia & Montenegro Topo-Svy. 1925-28	24.9	0.25	37.3	0.4	39	0.39	58	0.58	61%	91%
3	A_4	Parts of sh.116,117, 118,131,132,133	25.9	0.26	38.8	0.4	40	0.40	60	0.60	60%	90%
4	B_2	Bosnia & Herzegovina +	26.3	0.26	39.4	0.4	40	0.40	60	0.60	60%	90%
5	B_1	Dalmatia +	28.2	0.28	42.3	0.4	41	0.41	61	0.61	59%	90%
6	A_1	Eastern Serbia Topo-Svy.1920-22 *	34.1	0.34	51.1	0.5	45	0.45	67	0.67	54%	86%
7	B_4	West Slovenia	39.0	0.39	58.5	0.6	49	0.49	73	0.73	51%	83%
8	B_1	Croatia & East Slovenia +	40.2	0.40	60.3	0.6	50	0.50	75	0.75	50%	81%
9	A_2	Macedonia **	41.4	0.41	62.1	0.6	51	0.50	76	0.76	49%	81%
10	B_3	Vojvodina +	65.1	0.65	97.6	1.0	72	0.72	107	1.07	36%	65%

Remarks: * Values were obtained from the comparison of the final

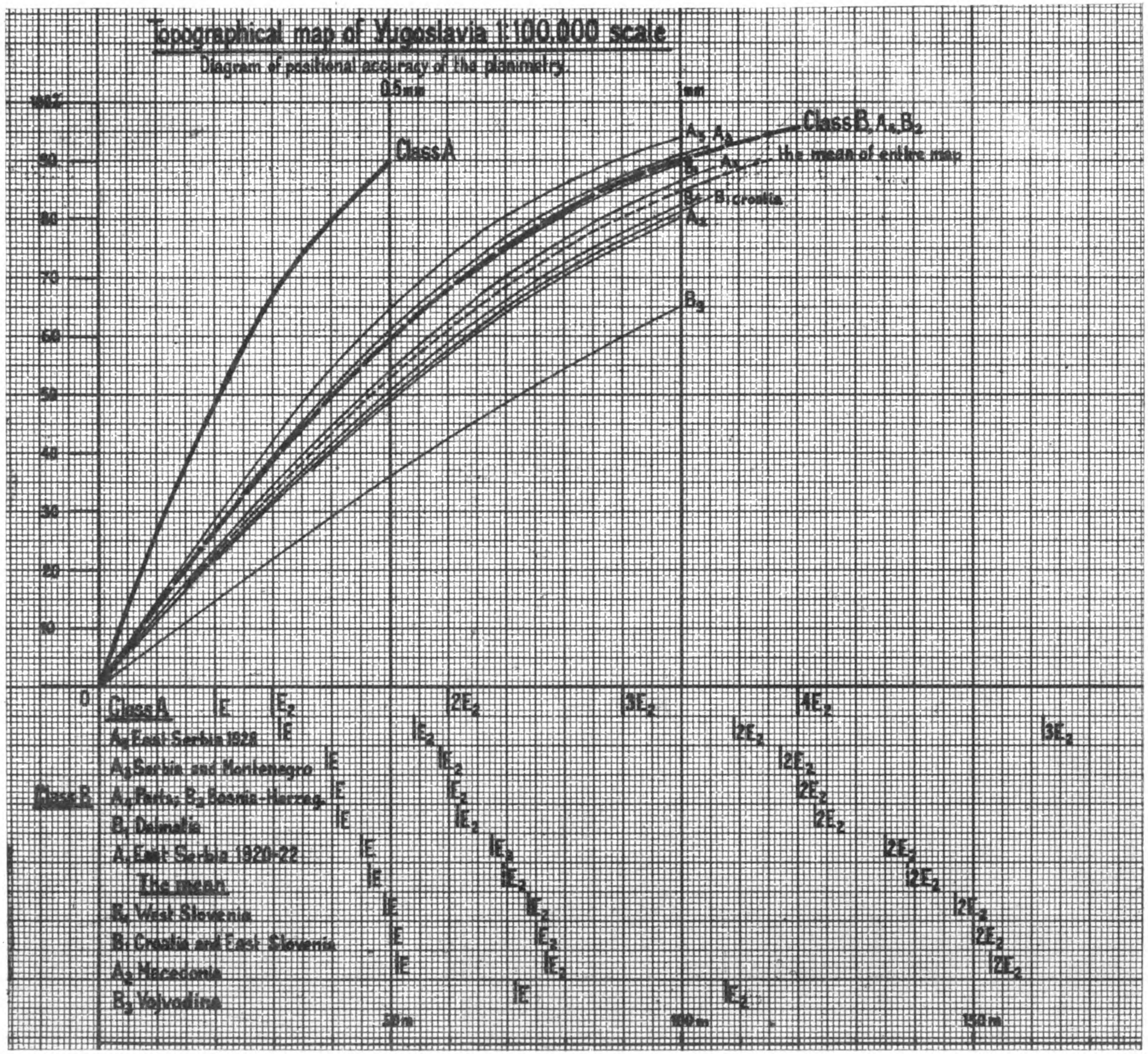
Inclosure 38



Inclosure 39



Inclosure 40



Yugo-Red. GK's of the triangulation executed in 1925-28 with scaled positions of the old Serbian 1900-06 triangulation on which the sheets are based. Identity of trig points (except for permanent landmarks, i.e. churches, smokestacks etc.) are assumed. In case the coordinates of old Serbian triangulation are available and compared, the probable error of position determined from these sheets would be approximately of the same magnitude as of the sheets covering Serbia and Montenegro (A3).

** Since the scaled positions are in terms of Yugo-Red. GK grid superimposed upon the sheets which refer to Clarke 1880 ellipsoid the grid is inconsistent with the geographic sheet corner values; hence the disparities between the Yugo-Red. GK's and scaled positions in addition to the erratic shifts due to poor composition of the sheets contain the ellipsoidal differences which largely increase their magnitude. If the ellipsoidal differences are eliminated, i.e. the sheets recasted and provided with a consistent grid, the positions from the sheets covering Macedonia would be determined with an accuracy equal to that of sheets covering Serbia and Montenegro (A3).

+ The probable and mean square errors were computed from the disparities obtained in the comparison of final Yugo Red GK's with scaled positions in terms of inconsistent Yugo-Red. GK grid after the elimination of datum difference Hermannskogel - Vienna University by means of corrections to sheet corner values computed by Dr. Ledersteger.

In order to determine the degree of accuracy of the 1:100,000 topographical map of Yugoslavia considered as a whole, computation was made of the mean square error as a weighted mean with which the orientation and detail points - planimetry - can be scaled from the map. The weight was determined proportionally to the number of sheets covered by each area. The magnitudes of the mean square error and corresponding probable error are as follows:

$$E_2 = \pm 69.42 \text{ m} = \pm 0.69 \text{ mm}/1{:}100{,}000$$

$$E = \pm 46.27 \text{ m} = \pm 0.46 \text{ mm}/1{:}100{,}000$$

Hence the entire map would meet the AMS requirements for positional accuracy of the planimetry in class A by merely 53% and in class B only by 85%.

In the attached diagram constructed according to the Gaussian law of distribution of accidental errors the accuracy of the topographical map of Yugoslavia is graphically expressed. (See Inclosure 40).

(d) Vertical accuracy: The elevations determined in the topographical survey of area A (Serbia, Macedonia and Montenegro) are based upon the vertical control attached to precise leveling referring to the leveling datum Trieste, Molo Sartorio. The elevations were determined by means of trigonometrical leveling with the following accuracy:

trig points	$E_2 = \pm 0.05$ m
graphical points	$E_2 = \pm 0.2$ m
detail points	$E_2 = \pm 0.5$ m

Depending upon the shape of the relief 5-30 elevations per 1 square kilometer were measured. The vertical net (elevations) on which the expression of the relief by contours is based should be considered homogeneous.

Meanwhile in the area B (former Austro-Hungarian Provinces) the vertical control used in the topographical survey does not refer to the same vertical datum, hence the following variances in respect to the datum, number and accuracy of the elevations should be considered:

- the elevations in the area B_4 (See Inclosure 30) covered by the IV Topographical survey of the Austro-Hungarian Empire were determined from vertical control attached to the precise leveling referring to vertical datum Trieste, Molo Sartorio; hence should be considered homogeneous. In respect to the shape of the terrain there were determined 4-22 elevations per 1 km^2. The required standards of accuracy for elevations are as follows:

trig points	$E_2 = \pm 0.15$ m ($E_3 = \pm 0.5$ m)
graphical points	$E_2 = \pm 0.3$ m ($E_3 = \pm 1.0$ m)
detail points	$E_2 = \pm 1.0$ m ($E_3 = \pm 3.0$ m)
barometric points	$E_2 = \pm 3.0$ m ($E_3 = \pm 10.0$ m).

- In the III Topographical survey of the Austro-Hungarian Empire the elevations along the level in Eastern Slovenia, Croatia and Slavonia were determined in sympathy with precise leveling. The regions of Croatian Coastland, Dalmatia, Bosnia and Herzegovina as well as Vojvodina (West part of area B_1, areas B_2 and B_3) are covered with topographical survey in which the elevations were determined from cadastral vertical control. The elevations of cadastral control were determined by means of trigonometric leveling and refer to various starting elevations established by primitive method along the Adriatic Coast. The relation of these starting elevations (which all refer to the Adriatic Sea level) to the mean Sea level determined in 1875 at Trieste remains unknown. Consequently the vertical control used in the III Topographical survey is not homogeneous and the values of the elevations on the map differ from those later established in sympathy with precise leveling. The differences fluctuate within limits + 3 to - 3 meters.

The required standards for accuracy of elevations are as follows:

graphical points within ± 1 m
detail points within ± 3 m
barometric points within ± 10 m.

In order to express the relief by contours 1-6 elevations per 1 square kilometer were measured.

The corrections of elevations and contours made within the reambulation of the Austro-Hungarian manuscripts carried out by Military Geographic Institute of Yugoslavia are based upon the elevations of the control utilized in the original topographical survey; therefore the above explained relation was not affected by reambulation.

The mentioned variances of the vertical control in respect to uniformity, accuracy and number of measured elevations should be considered in the evaluation of the accuracy of contour lines by which the relief is expressed. This accuracy particularly depends upon the number of elevations measured per 1 square kilometer. From the comparison of the previously mentioned standards required in the topographical surveys it is evident that the sheets of 1:100,000 topographical map of Yugoslavia covering Serbia, Macedonia and Montenegro (Area A) are the best in respect to the accuracy by which the relief is expressed. The sheets compiled from the manuscripts of the IV Topographical survey of the Austro-Hungarian Empire in West Slovenia (Area B_4) are almost equal in vertical accuracy to the sheets covering area A. The sheets compiled from manuscripts of the III Topographical survey of the Austro-Hungarian Empire have a considerably lower accuracy of expression of relief, but also among them are differences which were found during the reambulation, i.e. the relief in the sheets covering Bosnia and Herzegovina (Area B_2) and Dalmatia is expressed with a higher accuracy than in the sheets covering East Slovenia, Croatia and Vojvodina (eastern part of area B_1 and area B_3). Among the 1:100,000 sheets covering the entire territory of Yugoslavia sheets 12, 13, 14, 15, 27, 28, 29, 30, 42 and 43 are considered to have relief expressed by the lowest accuracy.

An exact analytical evaluation of the accuracy of a map is possible only if the data shown on the map are compared with the records of a special check-survey of higher accuracy (small triangulation, precise traverses, traverses with taped sides, numerical tachymetry) than the survey applied in the mapping. Meanwhile an approximate evaluation would be obtained if the sheets are compared with a photogrammetric compilation or manuscripts of a more recent plane table survey of higher accuracy.

Since in the western part of Yugoslavia along the former Italian boundary in 1935-38, an artillery survey, including fourth order triangulation and transit traverses with elevations of all points determined by means of trigonometric leveling, was carried out (See chapter DV 1c (4a), pp 248-249) the numerical records of this artillery survey were used in the analytical evaluation of vertical accuracy of the sheets:

26 Cerknica, compiled from the manuscripts of the IV Topographical survey of the Austro-Hungarian Empire, in 1929 reambulated by the Yugoslav topographers and

41 Sušak, compiled from the manuscripts of the III Topographical survey of the Austro-Hungarian Empire, reambulated in 1908 by Austro-Hungarian and in 1929 by Yugoslav topographers.

In the evaluation only ground elevations of points which could be positively identified on the map such as objects, cross-roads and confluences, were used. The corresponding sheets of 1:25,000 topographical map of Yugoslavia in which all points used by artillery are plotted in red and blue colours facilitated rapid and certain indentification of those points in the 1:100,000 (1:50,000) sheets.

The following results for the accuracy of contour lines were obtained:

- Sheet 26 Cerknica, contour interval 20 m. Compared 115 elevations in quad 1. Plain 20%, mountains up to 1107 m height with slopes up to 40° 80%. Open terrain 35%, forest 65%. Surveyed 1900-01.

Slope	0° - 2°	2° - 5°	5° - 10°	10° - 15°	15° - 20°	20° - 30°
α_m	1° 03'	3° 30'	7° 16'	12° 04'	17° 13'	25° 40'
tg α_m	0.018	0.061	0.128	0.214	0.310	0.481
No. of elevs.	38	19	22	16	8	12
$[\Delta h^2]$	227	166	677	452	441	2184
E_2	±2.44m	± 2.96m	±5.55m	±5.32m	±7.42m	±13.49m

Mean square error for entire area investigated:

$$E_2 = \pm\sqrt{\frac{4147}{115}} \pm 6.01 \text{ m} = 90\% \text{ of errors within } \tfrac{1}{2} \text{ of contour interval.}$$

Vertical mean square error of contours expressed by formula of Prof. Koppe: $Eh_2 = \pm (c + k \cdot tg\,\alpha)m$

$$Eh_2 = \pm (2.10 + 18 \cdot tg\,\alpha)\text{meters.}$$

(See enclosed diagram Inclosure 41).

- Sheet 41 Sušak, compared 105 elevations in quad 1. Plain 5%, hilly Karst 35%, mountains up to 1462 m height with slopes up to 40° 60%. Open terrain 5%, olive orchards 35%, forest 60%. Contour interval 20 m. Surveyed 1879.

Slope	0°-2°	2°-5°	5°-10°	10°-15°	15°-20°	20°-25°	25°-30°
α_m	1°54'	3°44'	7°35	12°35'	17°00'	22°30'	28°23'
$tg\,\alpha_m$	0.032	0.065	0.133	0.223	0.306	0.414	0.540
No. of elevs	21	27	22	12	9	6	8
$[\Delta h^2]$	685	655	1034	394	1352	608	3306
E_2	±5.71	±4.93	±6.89	±5.73	±12.26	±10.07	±20.33

Mean square error for the entire area investigated:

$$E_2 = \pm\sqrt{\frac{8034}{105}} = \pm 8.75\text{m} = 74.5\% \text{ of errors within } \tfrac{1}{2} \text{ of contour interval.}$$

Vertical mean square error of contours expressed by formula of Prof. Koppe:

$$Eh_2 = \pm (4.2 + 20\ tg\,\alpha)\text{meters}$$

(See enclosed diagram, Inclosure 42).

In connection with these results it should be noted that the majority of available points used in the comparison are located along the roads and trails where topographical surveys also are carried out accurately and with a larger number of measured elevations.

Due to the manner in which topographical surveys at that time were carried out and considering the density of measured elevations it can be concluded that if there were included into the check-survey points arbitrarily selected on the slopes of the wooded mountains, plateaus and in the regions of Karst the results would show considerably lower accuracy of contours, particularly in the sheets compiled from the manuscripts of the III Topographical survey of the Austro-Hungarian Empire. For these sheets it could be assumed that the vertical accuracy expressed by formula of Prof. Koppe would drop to a magnitude:

$$Eh_2 = \pm (5 + 30 \text{ tg}\,\alpha)\text{meters.}$$

There are no available numerical records on which to base an analytical evaluation of the sheets in area A, compiled from the 1:50,000 topographical survey of Serbia, Macedonia and Montenegro. Considering the manner in which the survey was carried out, the number and accuracy of measured elevations, it could be concluded that the vertical accuracy of sheets covering area A is higher than that of sheets covering area B_4 (IV Topographical survey of the Austro-Hungarian Empire). By knowledge that in the 1:50,000 topographical survey of Serbia, Macedonia and Montenegro:

- barometric leveling was not applied in the determination of the elevations,

- the accuracy requirements for trigonometrical leveling are twice as high as those in the IV Topographical survey of the A-H.E.,

- a larger number of elevations was measured, and

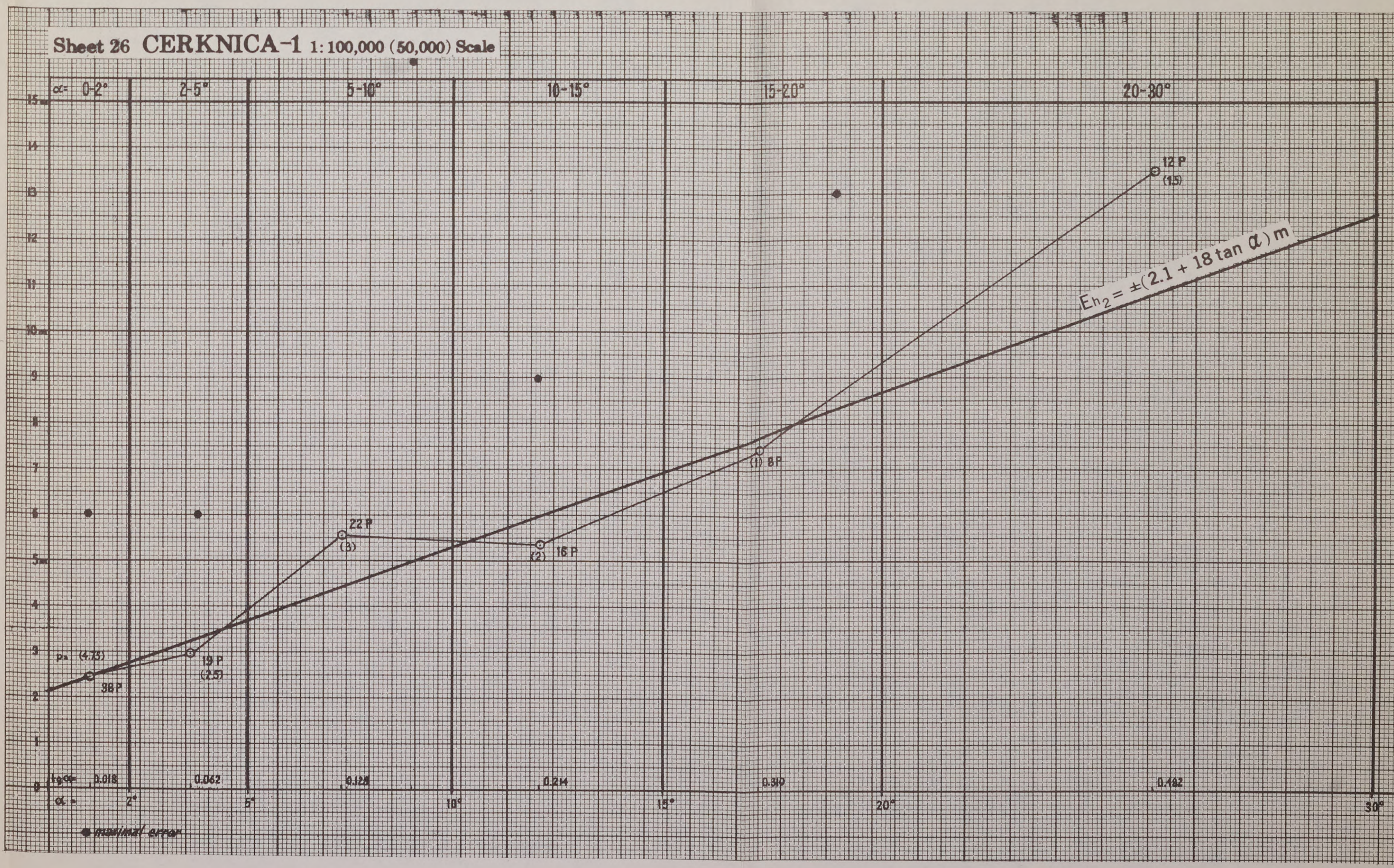
- contours were drawn immediately in the field,

it is evident that in the formula of Prof. Koppe the constant c should be about $\frac{1}{2}$ of the magnitude 2.1 obtained in the analysis of the sheet 26 Cerknica. Furthermore, greater density of measured elevations, abandonment of barometric points and drawing of the contours in the field would considerably improve the magnitude of the coefficient k; therefore an estimation that the vertical accuracy, by which the contour lines in 1:100,000 (1:50,000) sheets covering area A are drawn, would be nearly to the magnitude expressed by:

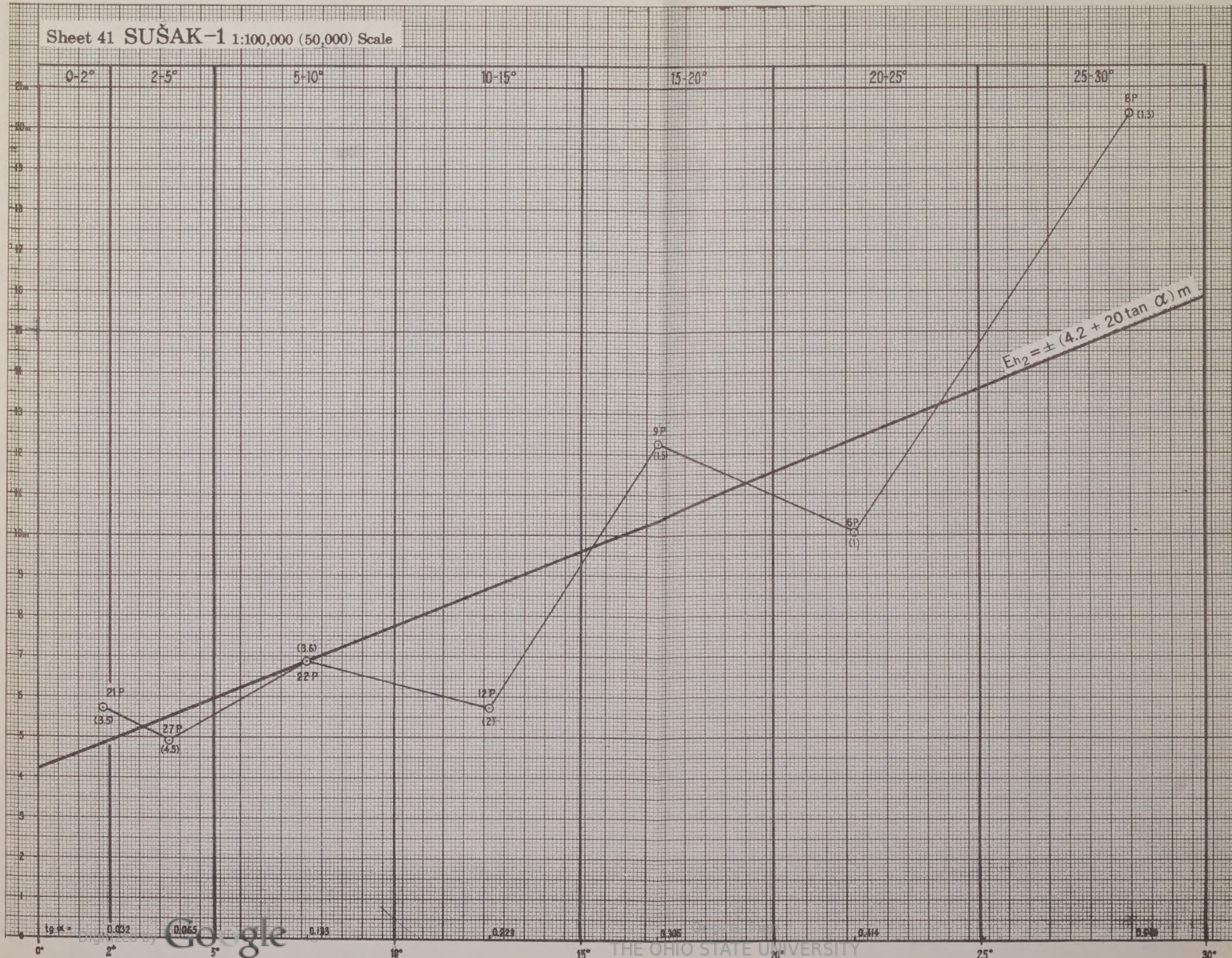
$$Eh_2 = \pm (1 + 15 \text{ tg}\,\alpha)\text{meters,}$$

certainly is not an optimistic one.

Inclosure 41



Inclosure 42



(e) Compilation and reproduction: The publishing manuscripts - color separations were composed of the blue lines of plane table sheets which were drawn in black ink prior to the composing. The topographical features are expressed by Serbian topographic symbols published in 1918 which are similar to the symbols used in the Austro-Hungarian 1:75,000 special map.

The relief is expressed by 20m contour lines (100m index contours) with 10m and 5m auxiliary contours. The nomenclature and elevations are hand-lettered. Since the blue lines of the topographical manuscripts at original 1:50,000 scale served as the base for drawing of color separations there was a very limited generalization of the cultural features. Except for the omitted unimportant buildings in the compact settlements and some fences the 1:100,000 sheets include everything shown in the 1:50,000 topographical manuscripts. The relief, hydrography and woodland never were generalized.

The color separations at 1:50,000 scale were photographically reduced to 1:100,000 scale and from negative glass plates positive alumimum printing plates produced photoalgraphically. The sheets of 1:100,000 map originally were printed in four colours by offset press, i.e. cultural features, nomenclature and elevations, graticule and marginal information in black colour, relief in brown colour, hydrography in blue colour and woodland in green colour. Since 1934 in the reproduction of 1:100,000 sheets more colours were used i.e. the high ways were red filled and the international boundaries were accentuated with colored strips.

(3) Supplementing with additional information. Within the Cartographic Division the Evidence section ("Evidencija") has the responsibility to keep the 1:100,000 (50,000) map up to date. This section collected all information important for supplementing of the maps from civilian and military authorities as well as from private sources. The supplementary records about the newly constructed or reconstructed railroads, roads and newly-established settlements as well as changes in other topographical features were plotted into publishing manuscripts (color separations) and then appeared in the reprinted sheets of the maps. Such sheets in upper left corner have a legend explaining the included supplementary information. Furthermore the Evidence section was responsible for the supply of the cartographic material of the neighbouring countries and foreign maps used in the map compilation of the regions along the Yugoslav frontiers. Prior to World War II only the sheets covering Macedonia published after 1939, are provided with supplementary information and corrections. Since 1934, in the north-western part of Yugoslavia a new topographical survey at 1:25,000 scale was carried out it should be noted that prior to World War II the 1:100,000 (50,000) sheet covering the respective area were neither recompiled nor at least supplemented with the cartographic material resulting from the new topographical survey.

(4) Revision: The topographical survey for the purpose of the compiling of the 1:100,000 map started in 1920, therefor because of extensive colonization and construction of many roads and some railroads the 15 years old 1:100,000 (50,000) sheets covering Eastern Serbia and Macedonia already should be revised prior to World War II. Since all topographers were assigned to the 1:25,000 topographical survey, which was along the northern boundary carried out with a forced speed, the badly needed revision of the 1:100,000 map had not been started prior to World War II.

(5) Various editions of 1:100,000 (50,000) map:

(a) Pre-World War II editions: The 1:100,000 (50,000) map has two editions which vary only by alphabet used in nomenclature and marginal information. The Cyrillic edition covers only the regions of Serbia, Macedonia, Montenegro and eastern part of Bosnia. In 1928, there was started the edition published in the Latin alphabet which primarily covered the western part of the country; but in the years immediately prior to World War II also the Cyrillic sheets covering the eastern part of the country were published in the Latin edition. Since the basic color separation sheets including the cultural features along with the nomenclature handlettered in Latin were entirely redrafted and later provided with the Yugo-Red. GK grid the positions scaled from the 1:50,000 sheets with Latin nomenclature slightly differ from that scaled from the Cyrillic sheets. The differences would be within limits of ± 0.3 mm which include the error of grid construction and error of scaling.

In 1940, in the compilation of 1:100,000 sheets the new topographical symbols published in 1939 were introduced, the contour interval was changed from 20 to 40 m with 200 m index contours and 20, 10 and 5m auxiliary contours and the hand-lettering of the nomenclature was replaced by printed names and elevations.

(b) World War II editions: In 1940-41, the Germans published the 1:100,000 topographical map of Yugoslavia the sheets of which are merely copies of the Yugoslav sheets with some added names and German marginal information and provided with 5 km unreduced (scale factor = 1) Gauss-Krueger grid plotted in sympathy with the sheet corner values, therefore inconsistent with plotted trig points.

British editions of the 1:100,000 topographical map of Yugoslavia, like the German edition, consist of direct copies of the Yugoslav sheets. From 1943-46, there were published three editions by the Geographical Section of the General staff of the War Office. The original polyhedric sheets are provided with a 1 km Lambert conical orthomorphic grid computed on Bessel ellipsoid in four zones of which North Italian and South Italian Zone are based on Italian datum

(Genova 1908) meanwhile the Danubian and Mediterranean Zone are based on Greek datum. Consequently the grid is inconsistent with the geographic sheet corner values and graticule.

Since German and British editions are direct photolithographical reproductions of printed Yugoslav sheets, without a new drawing of color separations, the legibility is much less than that of original sheets, many details of the relief are not clear and some parts of contour lines were lost in the photolithographical process.

(c) Post World War II editions of GIJNA: The Military Geographic Institute of the Yugoslav People's Army in 1948, started to publish a new "provisional edition" of 1:100,000 sheets. The sheets published in 1948-1951, are pre-war M.G.l. sheets supplemented by some additional information collected by the Evidence section. These sheets are superimposed with a 5 km Yugo-Red GK grid plotted in sympathy with geographic sheet corner values, in area B, referring to Vienna University datum and therefore inconsistent with the GK coordinates of plotted trig points. Meanwhile in area A with sheet corners referring to Hermannskogel datum the grid is consistent. The 1:100,000 sheets of the provisonal edition are still kept up to date by the Evidence section and for the areas not covered by the new 1:25,000 topographical survey have to be considered as basic cartographic material.

In 1951 GIJNA started the compilation of a new edition of the 1:100,000 topographical map of Yugoslavia. The sheets are cut in graticule system of International map (starting meridian Greenwich) with dimension $20'_{\phi} \times 30'_{\lambda}$ and are constructed in Gauss-Krueger (Transverse Mercator) projection with 3° Zones. The geographic sheet corner values referring to Hermannskogel datum and 5 km Yugo-Red GK grid are in sympathy with the Yugoslav triangulation. In the compilation of these sheets the latest cartographic material consisting of topographical manuscripts at 1:25,000 and 1:50,000 scale and for the regions of neighbouring countries of latest foreign 1:25,000, 1:50,000 and 1:100,000 maps has been used. From this material a cartographic manuscript for each sheet at 1:100,000 scale has been compiled. In the compilation topographical symbols of 1939 were used, the nomenclature is printed and the relief is expressed by 40 m contour lines with 200 m index contours and 20, 10 and 5 m auxiliary contours. The cartographic manuscripts are photo-enlarged to 1:75,000 scale and on the base of their blue-lines, publishing manuscripts (color separations) drawn. After the photographical reduction to 1:100,000 scale and photoalgraphically processed printing plates the sheets are printed by offset press in seven colors; cultural features, graticule, grid, nomenclature and marginal information in black, contours in brown, hydrography with respective names in dark blue, the fill of hydrography in light blue, woodland in green, the fill of highway in red and the international boundaries in violet. The entire territory of Yugoslavia would be covered by 231 sheet. This edition is classified secret and at the end of 1953, there were 39 sheets completed covering the regions of neighbouring countries. [172]

(6) Remarks:

The 1:100,000 topographical map of Yugoslavia has been considered a tactical-operational map, i.e. in the areas covered by 1:25,000 and 1:50,000 map it is operational. Larger units particularly would find in this map all information which should be included in a tactical map with the exception of firing data which would entirely satisfy the artillery requirements. Although many remarks were included in the chapter discussing the 1:100,000 map some observations in respect to the completeness, legibility and accuracy still should be added.

(a) Completeness: Since the compilation of the 1:100,000 map was influenced by too many requirements of the various agencies of the newly created state; this resulted in an overabundance of details. Nevertheless the manner of compilation itself contributed to the inclusion of superfluous information. Since the cartographical manuscripts for the sheets were not compiled the contents of the topographical manuscripts were not submitted to a generalization carried out systematically. Consequently, publishing manuscripts (colour separations) include almost everything shown in topographical manuscripts. These dense contents were supplemented by a rich nomenclature, therefore the sheets with dense settlements and cultural features, particularly in the regions of very detailed Karst in northwestern part of Yugoslavia and along the Adriatic Coast, are very crowded and despite multicolored reproduction appear to be dark.

(b) Legibility: In a careful generalization the features included in the map would be selected in respect to the degree of general topographical and special military importance; therefore many details included in the topographical manuscript, in the compilation of the cartographical manuscript and in drawing of colour separations will be omitted. A tactical map at 1:100,000 scale would not lose any important features if some trails, sheds, barns, fences and hedges in the expression of the dense settled areas are omitted, but contrariwise its clearness and legibility would be greatly improved. This is not always the case with the 1:100,000 topographical map of Yugoslavia.

The topographical features are adequately expressed. The number of topographical symbols - 289 - (Austria 273, USSR 362) is sufficient to express the topography of Yugoslavia. The size of the symbols and lettering is too small for a "saddle map", though sufficiently large to be read without magnifying glass by people having normal sight. (Swiss and new German 1:100,000 maps have even smaller symbols and letters).

The drawing of color separations at a ratio 2:1 assured a sharp and distinct shape of the symbols and together with the multicolored reproduction produce an artistic appearence. The 20 m contour lines in the expression of mountainous regions even without shading produce a considerable plastic of the relief. The cliffs are drawn without index contours; this should be considered a deficiency of the map, but this deficiency characterizes the majority of maps compiled prior to World War II. (With photogrammetrical compilation of large areas the contours were added to the perspective drawing or shadowing in the expression of cliffs. Austria and Switzerland introduced this method in the period between the two World Wars.) The hand-lettering is too heavy, particularly in respect to the names of settlements where the black part is larger than the white part of the surface covered by a name. The cartographical weight - ratio in emphasized expression of various features - is properly solved; meanwhile the graphical burden in developed areas is extremely heavy.

The uniform appearence of the map is in a certain degree disturbed by:

- addition of colors and little changes in tone of the tints which occured during the long period of publishing (1924-41);

- not enough equalized hand-lettering;

- improvement in the skill of cartographers and draftsmen;

- considerable improvement in the reproduction.

With proper planning and experimentation completed before the production of the map started, many of these deficiences would not have occured and others would have been minimized.

(d) Accuracy: In addition to the extensive discussion about the horizontal (positional) accuracy of the Yugoslav 1:100,000 topographical map some conclusive remarks should be made. Considering the map as a whole its horizontal accuracy is expressed by the mean square error

$$E_2 = \pm 69.42 \text{ m} = 0.69 \text{ mm}.$$

This error, with which the position of a detail point could be determined from the map, in respect to some results obtained in the compiling of contemporary maps in which compilation the paper was replaced by stable material such as astralon, should be considered quite large and therefore requires a logical explanation.

In the previously-mentioned testing of the various European maps, actually there were tested topographical manuscripts obtained by plane table survey or from photogrammetical compilations mounted upon the aluminum plates. In these tests the positions of detail points scaled from the manuscripts were compared with the coordinates of the same points computed from the records of numerical survey (small triangulation, traverses and tachymetry). From the tests of topographical manuscripts (plane table sheets) at 1:25,000 scale carried out in 1932-34, German surveyors F. Schwiegk and M. Pehnack computed that the planimetry is plotted with a mean error ± 0.4 - 0.5 mm, Russian geodesist Gapochko testing in 1939, the manuscripts of topographical surveys at 1:25,000, 1:50,000 and 1:100,000 scale found that detail points used in the drawing of planimetry are plotted by a mean square error ± 0.46 mm.[177] In 1940 German photogrammetrist Richter tested the multiplex compilation at 1:25,000 scale and stated that planimetry is plotted with an accuracy expressed by mean square error ± 0.48 mm.[69] Consequently it should be concluded that the detail points used in the drawing of planimetry in the topographical surveys carried out in the period between the two World Wars were determined with a horizontal accuracy expressed by a mean square error:

$$E_2 = \pm\ 0.45\ \text{mm}$$

or probable error:

$$E = \pm\ 0.3\ \text{mm.}$$

In 1927, Swiss Engineer B. Cueni tested the magnitude of distortion of the 1:25,000, 1:40,000 and 1:50,000 maps caused by the reproduction process. From these tests, which include many samples with various results it is concluded that:

- the displacement of the points due to redrawing of manuscripts by preparing of colour separations would be expressed by a mean square error:

$$E_2 = \pm\ 0.062\ \text{mm} \qquad [31]$$

- and the displacement of a point in the multicolored printed map in respect to its position in the manuscript would be expressed by a mean square error:

$$E_2 = \pm\ 0.2\ \text{mm}$$

If the standard of the Yugoslav 1:100,000 (1:50,000) map, whose compilation and reproduction coincide approximatelly with the period in which the mentioned tests were carried out, would correspond with the above stated results, then its horizontal accuracy would be expressed as follows:

- The accuracy of the publishing manuscript compiled at 1:50,000 scale:

mean square error of detail points	± 0.45 mm
mean square error of drafting	± 0.062 mm
mean square error of superimposed grid	± 0.23 mm

$$E_2 = \pm\sqrt{0.45^2 + 0.062^2 + 0.23^2} = \pm 0.52 \text{ mm}$$

- The accuracy of 1:50,000 maps:

mean square error of manuscript	± 0.52 mm
mean square error of reproduction	± 0.2 mm

$$E_2 = \pm\sqrt{0.52^2 + 0.2^2} = \pm 0.56 \text{ mm}$$

- The accuracy of 1:100,000 printed maps:

mean square error of 2:1 photoreduced manuscript	± 0.26 mm
mean square error of reproduction	± 0.2 mm

$$E_2 = \pm\sqrt{0.26^2 + 0.2^2} = \pm 0.33 \text{ mm}$$

This result differs from the mean square error expressing the accuracy of the entire 1:100,000 map by

0.36 mm.

Considering the cartographic material used in the compilation of the Yugoslav 1:100,000 topographical map, only for the new 1:50,000 topographical survey could there be assumed that the detail points were determined with an accuracy very close to that expressed by the mean square error ± 0.45 mm. Since the results obtained in this investigation for the sheets covering the areas A_1 and A_2 are influenced by systematical errors (questionable identity of restored and reobserved points, ellipsoidal differences ignored in the compilation), which cannot be entirely eliminated from the scaled values, only the difference between the mean square error expressing the horizontal accuracy of the sheets covering areas A_3, A_4, and A_5 and the mean square error computed by application of the results obtained in the testing of European maps E_2 0.58 mm - 0.33 mm = 0.25 mm has an exact explanation. This difference (0.25 mm) comprised within the mean square error (± 0.58 mm) represents the part of the error contributed by construction and particularly by poor composition of the sheets as previously pointed out in the discussion about the horizontal accuracy of the sheets which cover areas A_3, A_4 and A_5.

The sheets composed from the reambulated Austro-Hungarian plane table sections have an inferior horizontal accuracy because of poor composition and due to the old and less accurate topographical survey into which the cadastral planimetry was inaccurately incorporated (except sheets of Bosnia and Herzegovina). Nevertheless, the magnitudes of the mean square errors in certain areas (B_3 Vojvodina) are considerably larger because by application of Dr. Ledersteger's corrections the datum differences were not entirely eliminated from the scaled positions. In conclusion of the discussion about the horizontal accuracy of the Yugoslav 1:100,000 topographical map it should be noted that in the contemporary professional literature still can be found statements that the distances on a printed map because of irregular deformation of paper and error of scaling are measured with an accuracy ± 1 mm, consequently a detail point would be determined with an accuracy expressed by

$$E_2 = \pm \frac{1\ \text{mm}}{\sqrt{2}} = \pm 0.71\ \text{mm}.$$

It is well known that a large majority of the maps compiled prior to World War II, in which compilation, stable materials as a base were never used, particularly those with the sheets composed of four or more sections (patches), belong to the class having the above-mentioned horizontal accuracy. The fact that the horizontal accuracy of the Yugoslav 1:100,000 topographical map is expressed by the mean square error ± 0.69 mm justifies the statement that it belongs to this class of maps.

Concerning the vertical accuracy of the 1:100,000 (1:50,000) topographical map of Yugoslavia the following should be mentioned: An exact evaluation of the vertical accuracy of a map, which would produce a value really expressing the mean square error of vertical accuracy by which the contours in the entire map are drawn, requires an extensive check-survey in the field and then a dilatory analysis. In order to obtain a mean value the check-survey must cover all types of terrain; since there are large personal differences in the accuracy by which topographers carry out the plane table survey or the photogrammetrists compile photocompilations, the check-survey should include at least one topographic manuscript of each individual participating in the mapping. For instance: In the check survey executed by German surveyors Schwiegk and Pehnack in 1932-34, there were covered 12 manuscripts surveyed by 12 topographers in the area of moraines in Pomerania with a maximal slope of 12°. The vertical accuracy of contours for these 12 manuscripts vary from $\pm$ (1 + 0 tgα)m to $\pm$ (0.5 + 10 tgα)m. To the present time no one country has carried out such an extensive survey and analysis. One of the most extensive testing of maps was the above-mentioned check-survey of 1:25,000 manuscripts carried out by the German surveyors Schwiegk and Penhnack which includes 1660 measured points and covers merely 6 km^2. There are many fragmentary works covering small areas of some sheets from which there were obtained quite diverse results. On the basis of this fragmentary analytical evaluation the vertical accuracy for the entire map was then estimated.

Since the test of maps compiled from reduced topographical manuscripts, if the contours were generalized, evidently is futile (though theoretically possible), only the topographical manuscripts were tested. The majority of these tests were executed in Germany and are discussed in conjunction with the results published in various German professional periodicals.

For comparative purposes the results obtained in the testing of vertical accuracy with which the contours are drawn in German topographical manuscripts were compiled and are listed in the following list:

1:25,000 scale

Idler:	1880 plane table sheet 6521 in Baden, $\alpha_m = 8°$	$Eh_2 = \pm(4.0 + 13.7 \text{ tg}\alpha)\text{m}$	[69]
Idler:	1881 pl. t. sh. 8013 Freiburg in Baden, $\alpha_m = 16°$	$Eh_2 = \pm(- \quad + 28.4 \text{ tg}\alpha)\text{m}$	[69]
Koppe:	1899 Prussian pl. t. sh. surveyed by beginners	$Eh_2 = \pm(3.0 + 45.0 \text{ tg}\alpha)\text{m}$	[35]
Merkel:	1875-1899 plane table sheets in Baden	$Eh_2 = \pm(2.8 + 17.0 \text{ tg}\alpha)\text{m}$	[120]
Müller:	1903 plane table sheets in Hessen	$Eh_2 = \pm(0.7 + 16.0 \text{ tg}\alpha)\text{m}$	[138]
Koppe:	1905 New Prussian plane table sheet	$Eh_2 = \pm(0.5 + 5.0 \text{ tg}\alpha)\text{m}$	[120]
Pehnack:	1932-34 New German plane table sheets	$Eh_2 = \pm(0.55 + 3.3 \text{ tg}\alpha)\text{m}$	[138]

1:5000 scale

Graeser: 1925-26 pl. t. sh. of "Grundkarte". $\alpha_m = 5^\circ$ $\qquad Eh_2 = \pm(0.16 + 1.35\ tg\,\alpha)m$ [55]

Dahl: 1928 pl. t. sh. of "Grundkarte" $\alpha_m = 6^\circ$ $\qquad Eh_2 = \pm(0.19 + 1.67\ tg\,\alpha)m$ [35]

Prof. Merkel considered a 1:25,000 plane table sheet having the contours drawn with

$$Eh_2 = \pm\ (0.6 + 8\ \ tg\,\alpha)m$$ [120]

as a very good one. Dr. Idler in 1942, stated that for a modern 1:25,000 map a maximal error of the vertical accuracy of contours

$$Eh_3 = \pm\ (1 + 15\ \ tg\,\alpha)m$$ [69]

should be permitted. Since this limit is prescribed in the instructions for the compiling of the German 1:5000 topographical map (Grundkarte) it should be considered very rigorous for a 1:25,000 scale and it is not satisfied in the flatland even by the best results obtained under certain circumstances by Schwiegk and Pehnack expressed by a maximal error of vertical accuracy of contours

$$Eh_3 = \pm\ (1.8 + 10\ tg\alpha)m,$$ [138]

where the constant $c = 1.8$ m, representing the accuracy in the plain, is nearly double the magnitude of those given by Dr. Idler.

If we note that Schwiegk and Pehnack were chiefs of topographical sections and executed the check-survey immediately trailing their topographers surveying a very detailed area of moraines with maximal slope of 12° which was expressed by 2.5 m and 1.25 m contours for which contouring 200 - 350 elevations per 1 km^2 were measured (it is hard to believe the statement that the topographers did not know the purpose of the numerical check-survey); that Prof. Merkel testing the plane table sheets in the hills and lower mountains considered a plane table sheet having the contours drawn with a vertical accuracy expressed, by:

$$Eh_2 = \pm\ (0.6 + 8tg\alpha)m$$

as very good one; as well as if we consider other results listed above, than such a conclusion should be made:

- In order to determine exact standards by which the contours in 1:25,000 maps are drawn, extensive check-surveys should be measured which would cover all types of relief from plain to high mountains;

- that these standards if applied to all types of terrain hardly would exceed the magnitudes

$$Eh_2 = \pm (0.7 + 7 \text{ tg}\,\alpha) \text{ m or}$$

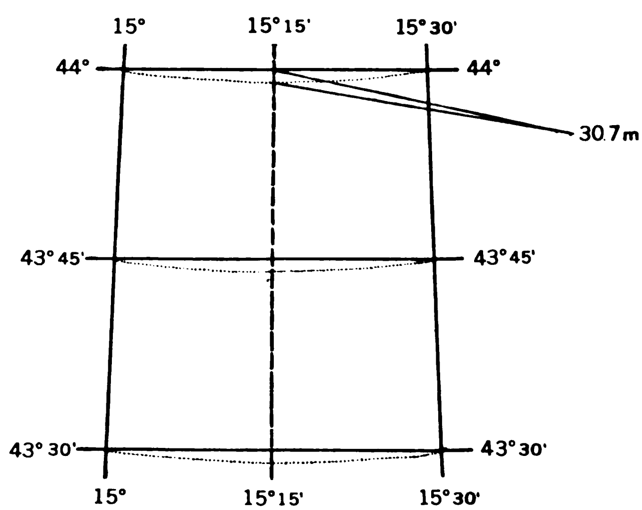
$$Eh_3 = \pm (2.0 + 20 \text{ tg}\,\alpha) \text{ m.}$$

In the compilation of the 1:100,000 (1:50,000) topographical map of Yugoslavia the relief was included without any generalization. The contours were exactly copied from the topographical manuscripts, therefore the 1:100,000 (1:50,000) sheets covering the areas where an adequate check-survey has been executed could be submitted to an exact analytical evaluation. In this study the numerical records of the artillery survey were used in order to determine the vertical accuracy of contours in the sheets 26 Cerknica and 41 Sušak. The artillery survey includes 3825 points and covers 26.5 1:25,000 plane table sheets (1810 km^2) of the area along the Italian boundary. If a proper planning had been made this survey with an average 144 points per 1 plane table sheet, for which the Yugo-Red GKs were computed, would have been carried out prior to the topographical survey, and this large number of points determined by fourth order triangulation and traverses utilized in plane table survey would have greatly increased the accuracy of the map. Since the artillery survey trailed by 1-2 years the topographical survey, the records obtained have been utilized in the analytical evaluation of the 1:100,000 (1:50,000) and 1:25,000 topographical maps. The Military Geographic Institute of Yugoslavia in 1938-41 evidently did not have time to analyze the accuracy of the Yugoslav maps.

Some observations could be made because the Military Geographic Institute of Yugoslavia did not correct the elevations in the 1:50,000 reambulated Austro-Hungarian topographical manuscripts as well as in the 1:100,000 (1:50,000) sheets in which compilation these manuscripts were used. Since the Military Geographic Institute of Yugoslavia was not in possession of the records of the triangulation used in the topographical survey of the former Austro-Hungarian provinces, correction of elevations in order to bring them into sympathy with precise leveling would require, not merely some additional survey and a partial recomputing, but a complete resurvey and computation of horizontal and vertical control including all spot elevations. The urgent need for an adequate map and the magnitude of maximal differences of elevations ± 3 m would not have justified such an extensive work, particularly since the new 1:25,000 topographical survey of the entire territory, based upon a new geodetic foundation, which started in 1934, had already been planned.

f. <u>The topographical map of Yugoslavia at 1:50,000 scale.</u> Strictly speaking there is no topographical map of Yugoslavia at 1:50,000 scale and the 1:50,000 sheets would be more properly called either, "enlarged edition of the 1:100,000 map" or "the 1:100,000 sheets reproduced at 1:50,000 scale of compilation". Such a title of the edition would have a self explanatory meaning which would properly express the origin of the 1:50,000 sheets of the topographical map of Yugoslavia.

(1) The construction of the sheet lines and grid: Since the Yugoslavs in the construction of graticule for 1:100,000 sheets of the topographical map of Yugoslavia adopted the polyhedric projection with the meridians and parallels considered as straight lines, as it was used in the "uniform graticule system "of the Austro-Hungarian special map, the Yugoslav map also is not a rigorous graticule map. In order that, in this projectioning, the replacement of spheroidal trapezoids by plane trapezoids would be within limits of graphical accuracy permitted for the respective scale, the spheroidal surface projected as a plane has to decrease with the growing scale. This is not the case with the Yugoslav 1:50,000 sheets having dimensions of $15'_\phi \times 15'_\lambda$ which as parts along the central meridian and central parallel of the decomposed $30'_\phi \times 30'_\lambda$ trapezoidal sheet remain in the common projectioning plane. In respect to deformation of a printed map, the rise between the 30' arc of parallel and the respective chord, which at the center of Yugoslavia ($\phi 44°$) amounts to 30.69 m, in the construction of a 1:100,000 map could be ignored. This difference, expressed in the rise, creates along the central meridian of the $30'_\phi \times 30'_\lambda$ sheets a shift of positions of 30.7 m to the north with their accurate geographic latitude for quite 1" larger than that of the graticule.



The $15'_\phi \times 15'_\lambda$ sheets at 1:50,000 scale should be independently constructed as isosceles trapezoids then the rise between the 15' arc of parallel and respective chord at the center of Yugoslavia would amount to 7.67 m = 0.15 mm which is tolerable in the construction of the sheets at 1:50,000 scale. Since the 1:50,000 sheets merely are rectangular trapezoids of a decomposed $30'_\phi \times 30'_\lambda$ isosceles trapezoid and the grid was constructed in sympathy with the sheet corner values of the 1:100,000 sheets the shift of the geographic positions (increase of geographic latitudes for 0."994) of the internal 1:50,000 sheet corners located along the central meridian of the 1:100,000 sheets (n^o 15' and n^o 45') was ignored. Consequently, by means of the Yugo GK grid scaled northings of the positions along the meridians n^o 15' and n^o 45' are 30-31 m too small. In order to avoid this deficiency the computed Yugo-Red GK sheet corner values of the internal sheet corners had to be increased by 30-31 m and the grid constructed into 1:50,000 sheets according to the corrected sheet corner values.

The 2 km (4 cm) Yugo-Red GK grid, as previously explained on page 110, is constructed in sympathy with the geographic sheet corner values considering that these refer to Bessel ellipsoid and to Hermannskogel datum, which is not the case with all sheets of the 1:100,000 (1:50,000) topographical map of Yugoslavia. The plotting data (sheet corner values) applied in the construction of the grid are computed in terms of Yugo-Red GKs which refer to Bessel ellipsoid and to Hermanskogel datum. Since the sheets in the area B refer to Vienna University datum and in area A_2 (Macedonia) to Clarke 1880 ellipsoid the grid is consistent with the plotted triangulation merely in the sheets covering Serbia and Montenegro (Areas A_1, A_3, A_4 and A_5).

The 1:50,000 edition of the 1:100,000 topographical map of Yugoslavia was considered an emergency map for the artillery and should be replaced by the new 1:25,000 map. The previous discussions about its accuracy are based upon the comparisons of the scaled positions of about 5500 trig points with their respective coordinates. These comparisons show, if from the results obtained in the comparisons the systematical differences, (i.e. datum differences, and ellipsoidal differences) would be eliminated within the sheets a large internal inconsistency would still remain expressed by the positional error of the trig points which for the entire map represent

$$\text{probable error} \quad E = \pm 35 \text{ m, or}$$

$$\text{mean square error } E_2 = \pm 52 \text{ m.}$$

A map with such a large internal inconsistency cannot be regarded as an artillery map. Consequently the 1:50,000 edition of the 1:100,000 topographical map of Yugoslavia as a whole can not be considered an artillery map. But all these sheets in which the mean positional displacement of the trig points is equal to

$$\Delta M_S = \sqrt{M_N^2 + M_E^2} \leq 20 \text{ m}$$

should be regarded as sheets which meet the artillery requirements in respect to horizontal accuracy. Evidently, in such sheets of area B the corrections for the datum shift should be taken into consideration. The sheets of area B do not meet the requirements for vertical accuracy. These sheets which meet the artillery requirements in the diagrams of arithmetical means of the differences between the final Yugo-Red. GKs and scaled positions are shown for area A in red color; meanwhile the sheets of area B, which only in respect to horizontal accuracy would meet the artillery requirements, are shown in blue color. (The sheets with the positional displacement within limits ± 20 m established upon insufficient control available for the comparison area not blue tinted.) See Inclosures 36 and 39.

(2) The publishing of the 1:50,000 sheets started in 1930. These sheets are exact 1:1 copies of the publishing manuscripts of the 1:100,000 sheets compiled and drafted at 1:50,000 scale, therefore all evaluations and remarks concerning the 1:100,000 sheet are applicable to 1:50,000 sheets. Altogether there were published 684 sheets. Since the sheets were reproduced at the drafting scale the legibility is much better than that of 1:100,000 sheets, but this also caused the sheets to have a rough unfinished appearence.

(3) The map of Northwest Balkan at 1:50,000 scale: In 1941, with their occupation of Yugoslavia Germans came in possession of the Yugoslav geodetic and cartographic material. Using the original Yugoslav printing plates they published "Karte des Nordwestbalkans 1:50,000", i.e:

- in 1943, the first edition "Ausgabe No. 1" was published, which is identical with the Yugoslav 1:50,000 sheets, except preliminary boundaries dictated by the Nazi-regime superimposed in orange color, some information obtained by partial revision from aerial photography included in violet color and marginal information consisting of symbols and abbreviations explained in German which were added by the Germans.

- in 1944, Germans started with publication of the second edition "Ausgabe No. 2" which is the same as the first edition except that if has a superimposed DHG grid, referring to Potsdam datum and information obtained by partial revision from aerial photography included in corresponding color. The symbols and abbreviations in marginal information are omitted. This edition was not completed and covers merely the regions of Vojvodina of the Yugoslav territory and some areas along the Adriatic Coast. The sheets which were published were not recast according to Dr. Lederstegerʼs study.

(4) In 1951, GIJNA reprinted the 1:50,000 sheets using the original pre World War II printing plates and publishing manuscripts. The sheets are supplemented by some additional cartographic material collected by the Evidence section.

(5) Dr. Lederstegerʼs corrections of sheet corners: With the new compilation of the 1:100,000 (1:50,000) topographical map of Yugoslavia, which recently has been carried out and based upon the new uniform geodetic foundation, the corrections to the sheet corners of the 1:100,000 (1:50,000) sheets covering area B will lose their meaning. Since the sheets of the new compilation at the present time are not available and because in this study Dr. Lederstegerʼs corrections are mentioned, many times there is a need for the following brief explanation.

During World War II the German Army proceeded to unify heterogeneous European geodetic data and cartographic material, Yugoslav triangulation, among others was included into European "Einheitssystem" (Potsdam) and intended to provide the Yugoslav maps with a uniform German Army grid (DHG). Since only in area A does the 1:100,000 (1:50,000) topographical map of Yugoslavia have sheet lines and the grid consistent with the Yugoslav triangulation oriented at Hermannskogel datum, as the first step in this program Dr. Lederstegerʼs in 1944 computed the corrections which should be applied to the sheet corner values of the sheets covering area B, in order to bring those sheets into sympathy with K. und k. Military triangulation. (The differences between K. und k. M.T. and Yugoslav first order net, maximal 5 m in Western Slovenia, were not considered.) The sheets of area B compiled from reambulated Austro-Hungarian manuscripts are based upon the geographic positions listed in the "Positions Rechnungen" which, except for positions of a few sheets in northeastern part of Vojvodina, all refer to Vienna University datum. Because of lack of polygonal adjustment of triangulation chains the positions within one system could not be considered a homogeneous basis for the mapping; therefore the area B is divided according to the systems of triangulation and triangulation chains, from which the positions used in the Austro-Hungarian topographical surveys were computed, into three transformation areas. (See Inclosure 43):

(a) System Vienna University (Bosnian adjustment) - 1. The area of "Bosnian adjustment" mostly covers the entire area B. In this area 69 stations having the geographic positions listed in the "Positions Rechnungen" were considered identical with the first order stations of the K. und k. Military Triangulation with the coordinates published in the "Ergebnisse der Triangulierungen". Comparing the coordinates ("Ergebnisse minus "Positions Rechnungen") of the identical points the differences $\Delta\phi$ and $\Delta\lambda$ were formed and in terms of corrections to the GPs of "Positions Rechnungen" classified according to the sheets of the 1:200,000 "Generalkarte". Since the coordinates of some stations listed in the "Positions Rechnungen" were computed from various chains and differ up to 30 m in the comparisons of these stations, the mean values were used. From these differences using the Helmert method of systematical disparities between the positions used in the mapping and the K. und k. Military Triangulation were derived as well as the transformation elements for the central point ($\phi_o = 44^\circ 30'$ and $\lambda_o = 34^\circ 30'$) which were determined to be as follows:

$$\Delta\phi_o = -\ 2''.61$$

$$\Delta\lambda_o = +\ 5.019$$

$$\Delta\alpha_o = +\ 16.56$$

$$k = +\ 5023 \times 10^{-8}$$

By means of these elements and transformation equations the following uniform changes in the value of $\Delta\phi$ and $\Delta\lambda$ for the one degree increase in latitude ($\Delta_1\phi$; $\Delta_1\lambda$) and longitude ($\Delta_2\phi$; $\Delta_2\lambda$) were computed:

$$\Delta_1\phi = +\ 0''.181 \quad \Delta_1\lambda = +\ 0''.405$$

$$\Delta_2\phi = -\ 0.206 \quad \Delta_2\lambda = +\ 0''.144$$

[104]

The linear corrections (linear values of $\Delta\phi$ and $\Delta\lambda$) to the sheet corners obtained by interpolation are given in the inclosed diagram. (See Inclosure 38).

(b) System Vienna University (Hungarian adjustment) - 2. The triangulation chains extending along the Danube and Drava Rivers despite belonging to the Vienna University system differ in scale and orientation from the triangulation covering the area of "Bosnian adjustment"; therefore it was necessary in the transformation to consider southwestern Hungary and the Yugoslav regions along Drava River and North Vojvodina as a separate area. Since the triangulation in this area already was incorporated into European "Einheitssystem" the comparisons were made in terms "Einheitssystem" minus "Positions Rechnungen", and in the same manner as for the area of "Bosnian adjustment" using the Helmert method derived the following transformation elements which refer to central point $\phi_o = 46^o\ 30$; $\lambda_o = 37^o$

$$\Delta\phi_o = +\ 0''.158$$

$$\Delta\lambda_o = -\ 4.897$$

$$\Delta\alpha_o = -\ 3.18$$

$$k = -\ 41 \times 10^{-8} \qquad [107]$$

The positions of the map transformed by means of these transformation elements to "Einheitssystem" were then transformed to the Yugoslav first order net (for the cartographic purposes considered identical with the K. und k. M.T.) using the transformation elements by which the North field of the Yugoslav first order net was transformed to the "Einheitssystem" (Potsdam), considering the first order station 6 Cer ($\phi = 44^o 36'\ 12''.99$; $\lambda = 19^o\ 29'\ 45''.\ 32$) as central point. Evidently for this inverse procedure the algebraic signs were reversed and the transformation elements used were as follows:

$$\Delta\phi_o = -\ 1''.46$$

$$\Delta\lambda_o = +\ 10.34$$

$$\Delta\alpha_o = +\ 3.164$$

$$k = +\ 229 \times 10^{-8} \qquad [136]\ [171]$$

(c) System St. Anna ("Transylvanian adjustment")-3. The sheets along the Yugoslav-Romanian and Romanian-Hungarian boundaries of the Yugoslav 1:100,000 (1:50,000) topographical map, of which no one covers the Yugoslav territory, are based on the geographic positions belonging to St. Anna system. The positions of these sheets were transformed to the "Einheitssystem" by the following transformation elements referring to central point $\phi_o = 47^o00$; $\lambda_o = 39^o00$.

$$\Delta\phi_o = -\ 3''.071$$

$$\Delta\lambda_o = +\ 13.541$$

$$\Delta\alpha_o = +\ 21.73$$

$$k = +\ 13915 \times 10^{-8} \qquad [107]$$

These transformation elements were derived from the disparities obtained in the comparisons of 7 first order stations located far north from the area concerned (ϕ 48° - 48° 40'). Meanwhile in the area concerned there are stations: Elek, Kurtics, Mokra, Hegys, Drocsa, Segenthau, Mogura Korbest and Pless having coordinates computed in Vienna University system and in St. Anna system. These stations already were used in the derivation of the transformation elements for "Hungarian adjustment"; hence they have coordinates referring to Potsdam datum. Furthermore in the area concerned there are also eleven first order stations of the k. und k. Military triangulation having coordinates referring to St. Anna and to Hermannskogel datums. Evidently, if these stations had been used in the derivation of transformation elements a better result would have been obtained.

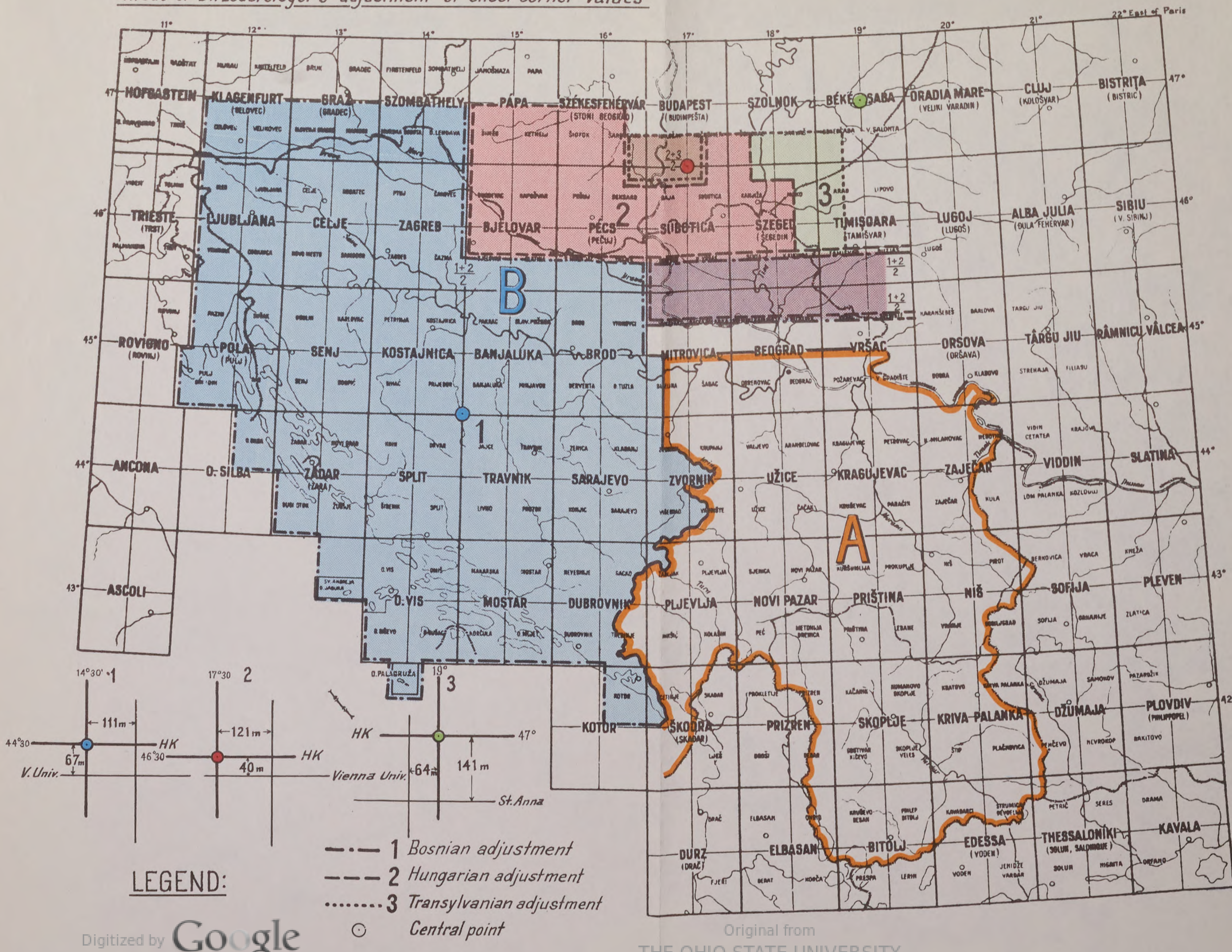
The transformation of the positions from the Einheitssystem (Potsdam) to Yugoslav first order net (Hermannskogel) was carried out by use of the same elements as in the "Hungarian adjustment".

(d) For a smmother passage among the areas of adjustment the transitive zones were created by using the mean values of corrections of the respective areas. These zones together with the areas of adjustments are shown in the inclosed diagram (See Inclosure 43).

The linear values of the corrections $\Delta\phi$ and $\Delta\lambda$ which should be applied to sheet corner values of the Yugoslav 1:100,000 sheets covering area B in order to be in sympathy with the Yugoslav first order net (K. und k. M.T.) are given in the diagram showing the original arithmetical means of the differences between the final Yugo-Red. GKs and scaled positions. (See Inclosure 38). In the second diagram are shown the residuals of the arithmetical means of differences after the application of Dr. Ledersteger's corrections to the sheet corner values by which the datum differences should be eliminated. (See Inclosure 39). The diagram with residuals shows that Dr. Ledersteger's operation in the area of Bosnia and Herzegovina (B_2) is quite successful. Meanwhile the sheets covering Slovenia and Croatia (B_1) after the application of the corrections still have considerable positional displacements. In the Vojvodina (B_3), Dr. Ledersteger's corrections based upon the differences between the GPs of the "Ergebnisse" minus "Positions Rechnungen" failed because the plotted positions in the Austro-Hungarian manuscripts represent the GP's of Vienna University system enlarged with the corrections growing up to N = + 98 m and E = + 70 m from 36°30' meridian toward the northeast. (See chapters BIII-1c (3) pp 17-25 and DV-2c (2b) pp 292-293.) The transitive zones created by application of the mean corrections of the "Bosnian" and "Hungarian" adjustments and of "Hungarian" and "Transylvanian "adjustments evidently did not sufficiently improve the displacement of the sheets in area B_3 caused by the fact that the sheet lines of these sheets, in order to satisfy

Inclosure 43

Areas of Dr. Ledersteger's adjustment of sheet-corner values



along the $40^{\circ}30'$ meridian the desired junction between the sheets of Vienna University and St. Anna systems, were erratically shifted toward the southwest.

Considering the entire area B it should be concluded that the internal inconsistency of the sheets, estimated by Dr. Ledersteger to be 70 and more meters, was caused by:

- inaccurate recasting od Cassini's sheets to polyhedric sheets (area B_3);

- inaccurate incorporation of cadastral planimetry due to the insufficient density of the Military Triangulation net upon which the construction of the "Uniform graticule system" and positioning of the cadastral planimetry are based, and

- composing of the sheets by means of compromising positioning of the plane table sheets.

This would explain the reason for the internal inconsistency within the sheets of area B expressed by the residuals having diversified magnitude and direction as shown in the enclosed diagram, (See Inclosure 39). Since in the area B_3, due to the erratic shifts of the sheet lines (ignored in the transformation), the positional displacement of the sheets in respect to the Hermannskogel system by the application of Dr. Ledersteger's corrections to the sheet corner values is not entirely eliminated the residuals are larger than in other areas. Meanwhile the sheets covering Bosnia and Herzegovina (B_2) where the cadastral and topographical surveys have common projection, sheet lines and control are considerably better positioned and have the smallest internal inconsistency. This is easy to comprehend, because in area B_2 there were no problems about the recasting or with the incorporation of cadastral data.

g. <u>The general map of Yugoslavia at 1:200,000 scale:</u> The polyhedric sheets are isosceles trapezoids framed by 1° arcs of parallels and meridians cut in the manner that the whole degree meridians and parallels intersect at the center of the sheets. The starting meridian is the meridian of Paris ($\lambda = 2^{\circ}\ 20'\ 13''.98$ East of Greenwich). One 1:200,000 sheet is composed of four 1:100,000 sheets. The 1:200,000 sheets were compiled from 1:100,000 sheets in the following manner: The 1:100,000 sheets were mounted on glass plates and covered by heavy transparent paper. On transparent paper the cartographic manuscript was drafted along with the generalization of topographical features. The relief was expressed in the first edition by 40 m contours (200 m index contours) 20 m and 10 m auxiliary contours; after 1940 by 100 m contours (500 m index contours), 50 m, 25 m and 12.5 m auxiliary contours and gray shading. The cartographic manuscript was photographically reduced to 1:175,000 scale, blue lines printed on drafting paper and colour separations drawn. The publishing manuscript (colour separations) were photographically reduced to 1:200,000 scale and from negative plates positive printing plates processed photoalgraphically.

(1) The first edition includes merely two sheets Niš and Skoplje published in 1922-23. These two sheets are reproduced in the same manner as the 1:100,000 sheets. The relief is expressed by 40 m contours as previously explained. The Cyrillic nomenclature is handlettered.

(2) The second edition was prepared in 1937-40, and published in 1940. It includes the following five sheets: Bjelovar, Celje, Pécs, Segedin and Zagreb. In the expression of the topographical features for this map specially designed topographical symbols, which slightly differ from the symbols published in 1939, were used. The nomenclature is printed in the Latin alphabet. The relief is expressed by combination of 100 m contours and shading. The sheets were printed in 7 colours i.e. cultural features (except highways, first and second class roads) nomenclature and graticule in black; highways, first and second class roads in red; relief in combination of brown contours with gray shading; hydrography blue with light blue fill, woodland green and the international boundaries were accentuated by dark green tinted strips.

(3) The third edition includes the sheets Beograd, Pula, Rovinj Senj and Sremska Mitrovica completed and published in 1940, and the sheets Kostanjica, Kriva Palanka, Skadar, Slavonski Brod and Trieste published in 1940-41 without the relief. The topographic features were expressed by the topographical symbols published in 1939. The relief is expressed in the same manner as in the second edition. The nomenclature is printed in Latin alphabet using Gothic, round and Italic letters, the sheets are reproduced in seven colors i.e. cultural features (except highways, automobile roads and tourist paths) nomenclature and graticule in black; highways, automobile roads first and second class and tourist paths in red; relief by brown contours and gray shading, hydrography in blue with light-blue fill; woodland green and international boundaries are accentuated by dark green tinted strips.

(4) The fourth edition was published in 1947-1954, by GIJNA. This edition includes 88 sheets, covering the entire territory of Yugoslavia with surrounding boundary regions, which were compiled and reproduced in the same manner as the previously discussed third edition. In this edition are included also redrafted sheets of the first second and third editions. All sheets have 10 km (5 cm) 6° Gauss-Krueger grid superimposed in blue color. In 1954 38 sheets were corrected, and reprinted.

(5) Remarks: The 1:200,000 general map of Yugoslavia is an operational map designed to be used in the headquarters of divisions and higher; it is not a field map but it could be used by motorized units as a road map. As a synoptical map it would satisfy many needs outside of the Armed Forces. Since the sheets of the first, second and third editions were compiled from 1:100,000 sheets of the topographical map of Yugoslavia they do not include the topographic material of the 1:25,000 topographical survey of Yugoslavia. The fourth edition published by GIJNA was compiled after World War II and includes also 18 sheets published in 1922-41 which were redrafted. From the entire 88 sheets published by GIJNA in 1944, 38 sheets were supplemented with additional information and published as the second GIJNA edition. The 1:200,000 sheets published by GIJNA, except four sheets covering mostly the regions of neighbouring countries, are not available, but it should be assummed that the planimetry was supplemented by the cartographic material of 1:25,000 topographical survey and by information obtained in partial revision of 1:100,000 (1:50,000) sheets as well as from map intelligence sources (Evidence section).

The first two 1:200,000 sheets drawn in the manner of 1:100,000 map were over crowded with details and place names, hence they were insufficiently legible. The five sheets of second edition have the place names too heavily printed and populated places represented by symbols, showing the blocks of houses, larger than necessary therefore appear to dark.

The compilation of the last two editions was carried out without these deficiencies and these 1:200,000 sheets represent a good synoptical map. Adequately generalized topographical features produce a good legibility and shading by a combination of vertical and oblique light give an excellent plastic effect. The reproduction in respect to intensity and tone of colors is not uniform, and some sheets having too dark shading are less legible. A serious deficiency should be noted in that the superimposed 6^{o} GK grid is inconsistent in respect to the 3^{o} Yugo-Red GK grid by which the rest of Yugoslav maps are provided.

h. The synoptical map of Yugoslavia at 1:300,000 scale: Since in 1885 the Austro-Hungarian 1:200,000 general map replaced the old 1:300,000 "General Karte von Zentraleuropa", both published by K. und k. M.G.I., the 1:300,000 scale practically disappeared from the military mapping of the Danubian basin. Meanwhile the German official cartographical circles in 1905, adopted W. Liebenow's 1:300,000 synoptical map covering various German provinces and developed it into the official synoptical map of Central Europe (Uebersiehts - Karte von Mitteleuropa) which was used as an operational map by the German general staff. Prior to World War II the fast moving motorized units created a need for an operational map of smaller scale which would cover a larger surface than the 1:200,000 map, but would include nearly the same contents and also serve as a good road map. Many of the European countries decided that a 1:300,000 synoptical map would meet all these requirements and began to compile and publish them. The Military Geographic Institute of Y.P.A. (GIJNA) after World War II decided to publish the 1:300,000 synoptical map of Yugoslavia. The decision was based upon an exhaustive study, including many tests of the methods which should be used in the compilation and reproduction of the 1:300,000 map.

The sheets are constructed in the Gauss Krueger (3^o Zone) projection and cut in the system of the International map, having the dimensions $1^o_{\phi} \times 1^o\ 30_{\lambda}$, as previously explained in the chapter DV-1b (See pp. 214-216); and are provided with 10 km (3.33 cm) Yugo-Red. GK grid. [112]

The basic cartographic material used in the compilation are the 1:200,000 sheets, but in some cases also data from 1:100,000, 1:75,000, 1:50,000 and even 1:25,000 were used. The cartographic manuscripts are compiled at 1:300,000 scale and include:

- all settled places including larger hamlets;

- all railroads and automobile roads, as well as roads connecting settlements and important trails and paths in the mountainous regions;

- a rich net of hydrography;

- relief expressed by the combination of adequately generalized 100 m contours and two-tone shading considering the oblique light coming from the northeast;

- woods, vineyards, and rice fields;

- nomenclature which in respect to 1:200,000 map includes 80% of the place names in the plain and 50% of the place names in mountainous regions as well as 50% of the names pertaining to orographical and hydrographical features.

The topographical features are represented by symbols especially designed for this map where the cities and towns are shown by blocks and villages by circles. The trig points and spot elevations are shown as dots.

From the cartographic manuscript for each sheet, there were processed blue lines for three publishing manuscripts. The first publishing manuscript is drawn on the blue line at 1:220,000 scale and it includes everything except relief. In this manuscript the printed nomenclature and marginal information are mounted. The first publishing manuscript is then photo-reduced to 1:300,000 scale and by the retouching process color-separations were made. The second publishing manuscript has the contours drawn on the blue lines at 1:300,000 scale. On the base of this drawing, contours are later engraved into a glass plate covered by emulsion or into astralon. For the third publishing manuscript shading is drawn by pencils and black water-color on the blue lines of contours. From the color separations the positive zinc printing plates are made and the map printed by the two-color offset press in the following ten colors:

- sheet lines, grid, settlements, railroads roads wood-lines, vineyards, nomenclature in Latin alphabet and spot elevations in black color;

- hydrography and rice fields in dark blue and the fill of the sea, lakes and rivers in light blue color;

- contours in brown color;

- fill of woodland in green color

- fill of high-ways, and first class automobile roads and strip accentuating the international boundary in red color;

- fill of second class automobile road in dark green color;

- shading of the relief in two tones of gray color.

The sheets are provided with a rich marginal information which includes the symbols, abbreviations, coordinatometer, index sheet, sources of compilation, numerical and graphical scale etc.

The preparations for this map started in 1950. By 1954 there had been published 9 sheets and 23 sheets were in progress. The entire territory of Yugoslavia would be covered by 39 sheets, but it is planned to cover a much larger territory of the neighbouring countries. The compilation started with the sheets covering these areas of neighbouring countries which were not covered by the 1:200,000 general map of Yugoslavia.

The construction and compilation of the map is based upon the adjusted Yugoslav first order net; therefore the sheet lines and the grid are in sympathy with the Yugoslav triangulation oriented on Hermannskogel datum. Since the largest part of Yugoslavia is not yet covered by the new 1:25,000 topographical survey the basic cartographic material - 1:200,000 sheets - used in compilation belongs to pre World War II 1:50,000 topographical survey and reambulation. The data, compiled from 1:200,000 sheets covering Yugoslavia are supplemented by the recent information obtained from the new survey, revision and map intelligence. Special care was given to the exact size of blue lines and to composition of the manuscripts; therefore the displacement of the positions in the published 9 sheets does not exceed ± 0.2 mm.

The published sheets are not available. In the periodical "Geodetska Služba" (Geodetic Service) Vol. 5, No. 2 p.p 216-218 two samples of the 1:300,000 sheet L-32-503-302 (Novara, Italy) are enclosed. The first sample with the relief expressed by hypsometric tints was not adopted. The second sample with the relief expressed by the combination of contours and shading was adopted and represents a very successfully solved master-sheet for an operational and road map. The cartographic weight is properly solved, the graphical burden is adequately distributed and the harmony of the multicolored edition produces and artistic appearence. The legibility in general is excellent, but still some improvements are possible if the 500 m index contours are to be added and the shading eliminatedfrom the roads shown with double lines so that the fill would have a bright colour. Despite these minor deficiencies, if all sheets are uniformly reproduced in the manner of the master sheet, this will be the best map ever published in Yugoslavia.

In respect to the spelling of foreign names, a deficiency pertaining to all Yugoslav military maps should be noted. This deficiency, having the appearance of illiteracy occured also in the enclosed master sheet of 1:300,000 map, i.e. phonetical spelling of Italian names. Phonetical spelling of foreign names should be used only in a Cyrillic edition. The rule adopted by Geographers is that geographic names have to be given in native language and orthography should be strictly observed therefore, the rules for transliteration and phonetical script may be included in the contents of marginal information.

i. The synoptical map of Yugoslavia at 1:500,000 scale: In the years 1934-40, in order to satisfy primarily the need of higher headquarters for a synoptical map which would facilitate various strategic studies and secondarily to be of use in the schools and other civilian institutions the Military Geographic Institute of Yugoslavia published the 1:500,000 synoptical map of Yugoslavia.

The map as a whole is constructed in the Tissot's projection with 1^{o} graticule considering meridian of Paris as starting meridian;

ignoring the graticule it is cut into 6 sheets, covering Yugoslavia and large regions of neighbouring countries.

The cartographic manuscript is compiled at 1:500,000 scale. The cartographic material used in the compilation of the region of Yugoslavia consisted of reduced 1:100,000 sheets and in the areas of neighbouring countries, mostly 1:200,000 and 1:500,000 foreign maps.

The topographic features are represented by the symbols especially designed for this map with populated places classified into 6 categories according to population, of which those places with 100 thousands and more inhabitants are shown by blocks and the places below 100 thousands by various types of circles. The relief is expressed by hypsometric tints in 13 shades and depths below sea level by bathymetric tints in seven shades.

The map was reproduced on the offset press in 14 colors, i.e: graticule, populated places, railroads, roads and paths (shown in mountainous areas only), nomenclature (printed in Cyrillic alphabet only), elevations, and marginal information in black; relief in shades of green, brown and blue (glaciers); drainage in blue and bathymetric tints in shades of blue. The woodland and other vegetations are not shown in this map.

Although the choice of the colors was not very appropriate the legibility is good. Since the hypsometric scale in respect to the relief of Yugoslavia was not properly selected above 1000 m merely 500 m intervals - hence the extensive Karst regions with small changes in elevation and large plateaus usually are within limits of an interval and consequently the map has a monotonous appearence.

j. <u>The GIJNA synoptical map of Yugoslavia at 1:500,000 scale:</u> In 1946 the Geographic Institute of Y.P.A. concluded to publish a new 1:500,000 synoptical map of Yugoslavia which has no connection with the previously discussed 1934-40 edition. Covering the areas of Central Europe and Balkans within 36° and 50° latitude and 6° and 30° longitude this map should satisfy the requirements of Armed Forces as well as the needs of schools, other civilian agencies and private circles. The area is covered by 47 sheets.

The map is constructed in the secant polyconic projection with the belts of 2° latitude. The sheets are limited by 2° arcs of meridians drawn as chords and 3° parallel arcs having the lengths corresponding to the lengths of the spheroidal arcs. The sheets are not provided with a grid, but they have a 30' graticule. The projection was computed upon the elements of Bessel ellipsoid. The sheets are cut and numbered in the system of International map and each sheet covers one fourth of a sheet of the 1:1,000 000 International map.

All phases of compilation and reproduction in advance were thoroughly planned and tested. In order to achieve a map with properly selected, reduced and generalized contents the cartographic manuscript at 1:500,000 scale was compiled. In the compilation the following basic cartographic material was utilized:

- for the territory of Yugoslavia 1:100,000 sheets of topographical map of Yugoslavia and 1:200,000 sheets insofar as they existed,

- for the neighbouring territories the 1:100,000, 1:200,000 1:500,000 maps of the adjacent countries as well as statistical data.

The cartographic material was reduced to the scale of compilation, blue lines printed and mounted into the constructed sheet lines. The selected features were outlined in pencil and then drawn in ink and water colors. The features are shown by symbols expecially designed for this map; i.e. cities and towns by blocks; villages according to population by three types of circles; railroads classified as double and single track normal gauge, narrow gauge, and industrial railroads; roads classified as highways, first, second and third class automobile roads and in the areas with few roads those temporarily passable for motorized units. The relief is expressed by the combination of contours and shading, 100 m contours are used up to 500 m elevation and above, 250 m contours are used. In the generalization of contours geomorphological formation of the relief was considered. The drainage is in sympathy with the relief properly generalized. Of the vegetations only woodland is shown. In this manner compiled and drawn cartographic manuscripts are photo-enlarged to 1:400,000 scale and blue lines printed. On the blue lines for each sheet two publishing manuscripts were drawn, i.e. a basic manuscript which includes sheet lines and graticule, cultural features, drainage, wood lines printed nomenclature in Latin alphabet and marginal information mounted; and a second manuscript with contours. From basic manuscript by the process of retouching the color separations are made and printing plates processed. The second manuscript with contours serves for the processing of the printing plates for the relief after that on the blue lines of contours the shading is drawn.

The 47 sheets of the 1:500,000 synoptical map are reproduced by offset press in 7 colours, i.e. roads, blocks of cities and towns, nomenclature of the orography and elevations in black; other cultural features, graticule, names of populated places and marginal information in dark brown; hydrography with pertaining names in dark blue, with fill and glaciers in light blue; woodland in green; contours in brown with the relief in brown screen shading; international boundaries accentuated by violet strips.

A special edition of this map has the colors used in the representation of the cultural features and nomenclature reversed, i.e: the roads and blocks of cities and towns are printed in dark brown with a orange fill, meanwhile the other cultural features and nomenclature is shown black; the relief has a dark brown screen shading. These sheets are provided with a chart showing isogonic lines for the year 1950 covering Yugoslavia.

These two GIJNA editions cartographically are very well prepared, properly generalized and reduced, therefore, in high mountainous regions are very legible. The expression of the relief is good also in the large plateaus of Karst. Meanwhile the reproduction in respect to the color register could have been improved and the fill of roads should not have been covered by shading nor by green color of woodland. The edition with orange filled roads has an excellent plastic effect but in general it is too dark and the sheets have large variances in the intensity of shading. Unfortunately the foreign names, in these two editions also, are spelled phonetically.

k. The automobile (road) map of F.P.R. Yugoslavia at 1:500,000 scale: The road map of Yugoslavia consists of 12 sheets. Its compilation is based upon the 1:500,000 synoptical map of GIJNA. The roads are classified into highways, first, second and third class automobile roads, and provided by various symbols for long, medium and short distances. The map is reproduced in 9 colours in a manner similar to the GIJNA synoptical map with the highways and the first class roads with respective distance marks and distances in kilometers in red, second class in green and third class in yellow colour. The relief is expressed by brown shading.

l. The synoptical map of Yugoslavia at 1:750,000 scale: This map consisting of 6 sheets covering the territory of Yugoslavia and parts of neighbouring countries is a reduced and redrafted edition of the 1:500,000 synoptical map of Yugoslavia published 1934-40. Its preparation started before the end of the war with limited means. The first edition was published in 1945, under the name "Map of Federal Democratic Yugoslavia", two slightly improved subsequent editions under title "Federal People's Republic Yugoslavia" were published in the following years. The map is reproduced in 10 colors with the cultural features (except automobile roads), graticule, nomenclature (printed in Latin alphabet) and marginal information in black; highways, first, second and third class automobile roads in red; hydrography with respective names in dark blue with light blue fill; international boundaries are accentuated by violet strips. The relief is expressed by the combination of hypsometric tints in 8 shades and gray shading.

The nomenclature is printed in the Latin alphabet and it is remarkable that this GIJNA map alone includes foreign names in correct native spelling. The map is sufficiently legible; particularly, the combination of hysometric tints with shading produces a plastic relief.

A special edition of this map with the relief expressed only by gray shading and the highways and first class automobile roads printed in green color, with the distances among the towns in kilometers, was published in 1947, as a road map of F.P.R. of Yugoslavia.

m. The International map at 1:1,000,000 scale: The Yugoslav territory cover the sheets L 33, L 34, K 33 and K 34 of the 1:1,000,000 International map. In 1953 GIJNA started with the compilation of the cartographic manuscripts and in 1954 the publishing manuscripts for the above mentioned four sheets were drawn to be published in 1955. The map was prepared according to instructions adopted in 1913 by the International Congress of Geographers in Paris.

n. Private-Cartography in Yugoslavia:

(1) The synoptical maps, school maps, administrative maps, road maps and even aeronautical charts in Yugoslavia prior to World War II were mostly published by professors of geography and by geodetic officers of the Military Geographic Institute of Yugoslavia. The cartographic material used in the compilation of numerous private editions were the sheets of the 1:100,000 topographical map of Yugoslavia or sheets of the 1:200,000 and 1:750,000 synoptical maps of the K. und k. Military Geographic Institute, as well as various maps published by cartographic enterprises of the adjacent countries. Compilation and drawing of a large number of private maps were carried out by experienced civilian employees of the Military Geographic Institute. The maps were reproduced by lithographic installations of the Military Geographic Institute and by Beranek's printing enterprise at Belgrade, by printing houses J. Čaković and Kugli in Zagreb and by the Yugoslav Printery (Jugoslovanska tiskarna) in Ljubljana.

Among others the following maps of Yugoslavia were published:

Prof. Dr. Jovan Cvijić:	1:1,200,000	synoptical	map
A. Lazić	1:1,200,000	synoptical	map
Gen. S.P. Bošković	1:1,000,000	synoptical	map
Prof. Dr. Franović-Gavazzi	1:1,000,000	synoptical	map
Prof. Vlad. Marinković	1:1,000,000	synoptical	map
	1: 800,000	synoptical	map
	1: 650,000	synoptical	map
	1: 500,000	school	map
Col. Tih. Arandjelović	1:1.000,000	admin.	map
Col. Petar Madjarević	1: 900,000	admin.	map
	1: 750,000	admin.	map
	1: 600,000	road	map.

Maj. G. A. Skrivanić — 1:500,000 aerial chart of Yugoslavia consisting of 20 $2^\circ_\phi \times 2^\circ_\lambda$ sheets in Mercator projection reproduced in the manner of the 1:500,000 synoptical map of Yugoslavia published by M.G.I. in 1934-40.

(2) In the period after World War II the republics cartographic enterprises "Učila" at Zagreb and "Geokarta" in Belgrade were founded. These enterprises, to the present time have published 3 school atlases and a considerable number of wall maps covering individual republics, entire Yugoslavia, Balkan Penisula, Europe, Africa, Asia, Australia, North and South America, Eastern Hemisphere and WesternHemisphere, which are used in Yugoslav schools and in private circles. In these cartographic enterprises are, among leading professionals, former geodetic officers and officers of the Naval Hydrographic Institute which after World War II because of new circumstances did not join the Army or Navy. Among private editions should be mentioned Gen. S.P. Bošković 1:500,000 synoptical map of Yugoslavia published by the Serbian Academy of Science and printed by the Yugoslav Printing Enterprise in Belgrade and the synoptical maps of Yugoslavia at 1:1,000,000 and 1:500,000 scale compiled and edited by Prof. Dr. V. Bohinec and Prof. Planina, drafted by I. Selan and printed by "People's Right" printing house (formerly Yugoslav Printery) at Ljubljana.

o. The topographical survey at 1:10,000 scale of the Naval Base Boka Kotorska: The reorganization of defense of the Naval Base, which the Yugoslavs provided with many new coastal batteries, necessitated a new topographical survey at 1:10,000 scale based upon a sufficiently dense net-work of horizontal and vertical control. To satisfy this control requirement in 1931 the M.G.I. established a new triangulation in Boka Kotorska originating from the adjusted first order side 91/320 Orjen - 92/324 Lovćen which consists of 3 first order stations, 21 second order, 131 third order and 154 fourth order stations, for a total 309 trig points covering an area of 450 km^2. This triangulation of Boka Kotorska was never adjusted. It was computed in the field and immediately utilized by topographers.

Since this triangulation covers only a small area well-framed by the first order net, and because the sides were computed from the adjusted first order side Orjen-Lovćen and the coordinates derived from the coordinates of the adjusted first order stations, it can be assumed to be satisfactory for military purposes. Later adjustment shows a displacement of trig points within limits of ± 1 m.

In order to provide the coastal batteries equipped with vertical rangefinders with exact elevations, as well as to establish an accurate vertical control for the topographical survey a technical leveling of higher accuracy (probable error $\eta_r = \pm 5$ mm/km) was carried out and about 200 benchmarks established.

The topographical survey based upon the above explained horizontal and vertical control covers merely 140 km^2 and was carried out by 8 topographers in four months. The average norm achieved by one topographer is 4.4 km^2 in one month. The survey was carried out by the method of plane table tachymetry in the manner discussed on pp. 265-268. The topographical parties were provided with plane table equipment of "Teleoptik Co." The use of rangefinders was not permitted. In respect to scale the following requirements were prescribed:

- measurement of stadia distances up to 300 m;
- measurement of 200-500 detail points per 1 km^2;
- measurement of 50-300 elevations per 1 km^2;
- contour interval 5 m with 50 m, index contours, 2.5 m and 1.25 m auxiliary contours.

The plane table sheets with dimensions $1'52.5''_{\phi} \times 3'\ 45''_{\lambda}$ are constructed in the polyhedric projection and provided by 1 km (10 cm) Yugo-Red GK grid. In each sheet there were plotted about 12 trig points (1 trig point per 1.5 km^2) from which the topographer developed a graphical net consisting of about 30 graphical points.

The survey of the entire area considered to be surveyed and covered by the triangulation (450 km^2) never was completed and by 1937, of the completed 140 km^2 there were published only two sheets of 1:10,000 map of Boka Kotorska i.e. Kotor-Klinci and Kotor-Prevlaka. These two sheets with dimensions $3'45''_{\phi} \times 3'45''_{\lambda}$ covering the entrance into the Naval Base include merely 19 km^2 of the surveyed area (dry-land).

The sheets are each composed of two plane table sheets which served as cartographical manuscripts. The reproduction was carried out in the manner of the 1:50,000 sheets. The elevations are shown to one tenth of a meter.

The horizontal (positional) accuracy of the above mentioned two sheets determined from the comparisons of the preliminary coordinates of M.G.I. triangulation with the scaled positions of 11 available trig points would be expressed as follows:

The positions of trig points could be determined with a probable error

$$E = \pm 0.76 \text{ m} = 0.076 \text{ mm, or}$$

by mean square error

$$E_2 = \pm 1.14 \text{ m} = 0.114 \text{ mm.}$$

Consequently the positions of detail points would be determined by a probable error

$$E = \pm\sqrt{0.076^2 \text{ mm} + 0.3^2 \text{mm}} = 0.309 \text{ mm} = \pm 3.09 \text{ m; or}$$

$$E_2 = \pm 0.464 \text{ mm} = \pm 4.64 \text{ m.}$$

Hence 72% of the positions of planimetry could be determined from this map by an accuracy of 0.5 mm.

p. The Topographical Survey at 1:25,000 scale between the two World Wars: When reambulation of the Austro-Hungarian topographical manuscripts had been completed it had become obvious that the 1:100,000 (1:50,000) topographical map of Yugoslavia compiled from these manuscripts could be merely a temporary solution for the need to cover the territory of newly created Yugoslavia with a usable map. Altho from the military point of view this temporary solution was necessary, the situation required immediate commencement of a new topographical survey of Yugoslavia which would meet contemporary mapping requirements. Consequently the 1:25,000 topographical survey was started in 1934 by the Military Geographic Institute of Yugoslavia.

(1) Since it was decided that the new survey should cover primarily the boundary regions of the north-western part of the country not yet covered by the Yugoslav triangulation, the K. und k. Military Triangulation published in the "Ergebnisse der Triangulierungen Vol. IV covering the 1:200,000 sheets Ljubljana and Trieste and including 980 first, second and third order stations, was re-established in the field i.e: above the markers still in existence signals were errected and lost stations were newly-determined by means of observations. (See chapter DV-1c (1), page 217) East and South of this area in the regions covered by the 1:100,000 sheets 4, 5, 6, 7, 12, 13, 14, 15, 16, 27, 41 and 42 the second and third order nets were newly established on the basis of the first order net of the K. und k. Military Triangulation published in Vol. I of the "Ergebnisse der Triangulierungen". The newly-observed second and third order nets never were adjusted. Since in the computation of the triangles and coordinates as starting data there were used the sides and coordinates of the adjusted K. und k. Military Triangulation, published in Volumes I and IV of the "Ergebnisse der Triangulierungen", the preliminary coordinates used in the topographical survey for mapping are considered to be in sympathy with the K. und k. Military Triangulation. Later comparisons of preliminary values with the adjusted values show the differences, similar to the differences of ΔN up to + 1.70 m and of ΔE up to - 5 m, which the coordinates of stations of the K. und k. Military Triangulation have in respect to the coordinates of the

identical stations of the adjusted Yugoslav first order net. (See chapter DV-1c (1j) pp. 235-236).

(2) The elevations of these trig points are determined by means of trigonometrical leveling attached to the precise leveling referring to the vertical datum Trieste, Molo Sartorio (1875).

(3) The topographical survey was carried out by the method of plane table tachymetry as previously discussed on pp. 265-268. The topographical parties were provided with plane table equipment "Teleoptik Co" and with Zeiss and Goerz rangefinders having 0.80 m and 1 m bases respectively. By the instructions for this survey it was prescribed:

- measurement of distances up to 800 m;
- determination of 100-250 detail points per 1 km^2;
- measurement of 20-150 elevations per 1 km^2.

The relief is expressed by contours with 10 m contour interval, 50 and 100 m index contours and 5 m, 2.5 m in the plain 1.25 m auxiliary contours.

The plane table sheets with dimensions 3'45" x 7'30" are constructed in polyhedric projection and provided by 1 km (4 cm) Yugo-Red. GK grid. The plane table sheets include 6-10 plotted trig points (1 trig point per 6.5-10 km^2) on the basis of which the topographers developed a graphical net consisting of about 30 graphical points. Cadastral planimetry was not utilized.

(4) The application of photogrammetry in the Yugoslav topographical survey began in 1935. The Military Geographic Institute in 1934, obtained the following photogrammetric equipment:

1 Hugershoff hand camera 13 x 18 cm f=18 cm;
1 Zeiss automatic aerial camera RMK 18 x 18 cm, f=21 cm;
1 Hugershoff aerial-cartograph with attached coordinatograph;
1 Hugershoff-semiautomatic rectifier.

With this equipment there was covered and compiled by aerial photography:

in 1935 268 km^2
in 1936 340 km^2
in 1937 520 km^2
Total 1128 km^2 which cover the regions of the Alps in Slovenia. (See Inclosure 44). The utilization of photogrammetry in these three years should be considered as a training and testing stage.

As tie points there were used trigonometrical points (in 1937, also graphical points), determined horizontally and vertically in such a density (1 point per 1.5 km^2 or about 46 points per 1 plane table sheet) that at least 3 well distributed points would be located within each stereogram (60% overlapping of two vertical photographs). The tie points prior to the time of the aerial photography were panelled in the field. In order to obtain the photographs at 1:18,000 scale the altitude of flight was about 3,800 m above the mean elevation of the area covered by photography. The compilation by aerial-cartograph was carried out on plane table sheets at 1:25,000 scale. The plane table sheets with plotted sheet lines, grid and tie points were mounted on aluminum plates. The contents included during the compilation were clearly pencilled and after the field revision, by the method of plane table survey, inked in the manner of topographical manuscripts.

The tests showed that graphical determination of tie points by plane table triangulation was not sufficiently accurate for the compilation by aerial-cartograph; therefore it was no longer applied.

In 1937, the additional photogrammetric equipment consisting of the Zeiss automatic wide angle aerial camera RMK 30 x 30 cm, f=10 cm, Zeiss-Bauersfield C4 stereoplanigraph, Zeiss SEGI automatic rectifier, Zeiss aerialprojector-multiplex with 6 normal and 3 wide angle projectors, Zeiss radialtriangulator and Zeiss-Pulfrich stereocomparator were bought. In order to employ at full scale this expensive equipment there was covered by photography in 1938 an area of 3000 km^2, i.e. the entire 1:100,000 sheet 112 Nevesinje, where an artillery range was located, and the area of coastal defense between Dubrovnik and Budva including the Naval base at Boka Kotorska.

In order to provide a sufficiant number of tie-points the areas prior to photographing were covered by a fourth order net of triangulation and the trig points were panelled. In the coastal area the triangulation established in 1931, for the 1:10,000 topographical survey of Boka Kotorska was panelled. Since the method of compilation applied in 1935-37, required a very dense triangulation with at least 40 tie-points determined horizontally and vertically and panelled in the field, in order to reduce these extensive works in 1938 there were utilized the wide angle photographs. For this purpose the area was photographed with the wide angle camera at 1:30,000 scale. At this scale the usuable overlapping area of one 30 x 30 cm photo-pair is about 24 km^2 and a plane table sheet (66 km^2) is covered by 3-4 photo-pairs. To orient 4 photo-pairs in the space there are needed merely 16 tie points determined and panelled in the field. Because the 1:30,000 photographs are not adequate for the compilation at 1:25,000 scale, the area also was covered by the photography of the 18 x 18 cm f=21 cm camera at 1:18,000 scale (usuable surface of a photo-pair about 4 km^2) which was utilized in the compilation. In order to provide a sufficient number of tie points for the orientation of the 18 x 18 cm photographs the wide angle 30 x 30 cm photo-pairs were oriented in the stereoplanigraph, and in the 1:25,000 plane table sheets, used in compilation, about 50 additional tie points plotted and the elevations determined as a mean from three readings. Beside 16 trig points panelled in the field these additional 50 tie points were then used in the orientation of 18 x 18 cm photo-pairs. Accuracy of this "aerial triangulation" satisfied the requirements and its application considerable reduced the field and computing work.

The coastal area of 850 km^2 was compiled in this manner, but the penciled manuscripts were not revised in the field; consequently the respective 1:25,000 sheets were never published. The growing tensions among the European countries gave priority to other works; therefore the computing of triangulation and the compilation of area Nevesinje was postponed.

In 1939, the areas of 3310 km^2 in Slavonia and 122 km^2 in Vojvodina in the same manner were photogrammetrically surveyed. The compilation of plane table sheets covering Slavonia was completed in 1940 but was never revised in the field and published. The two plane table sheets covering 122 km^2 of Vojvodina were in 1939 photographed, compiled and revised and in 1940 published as 1:25,000 sheet 1c Sombor.

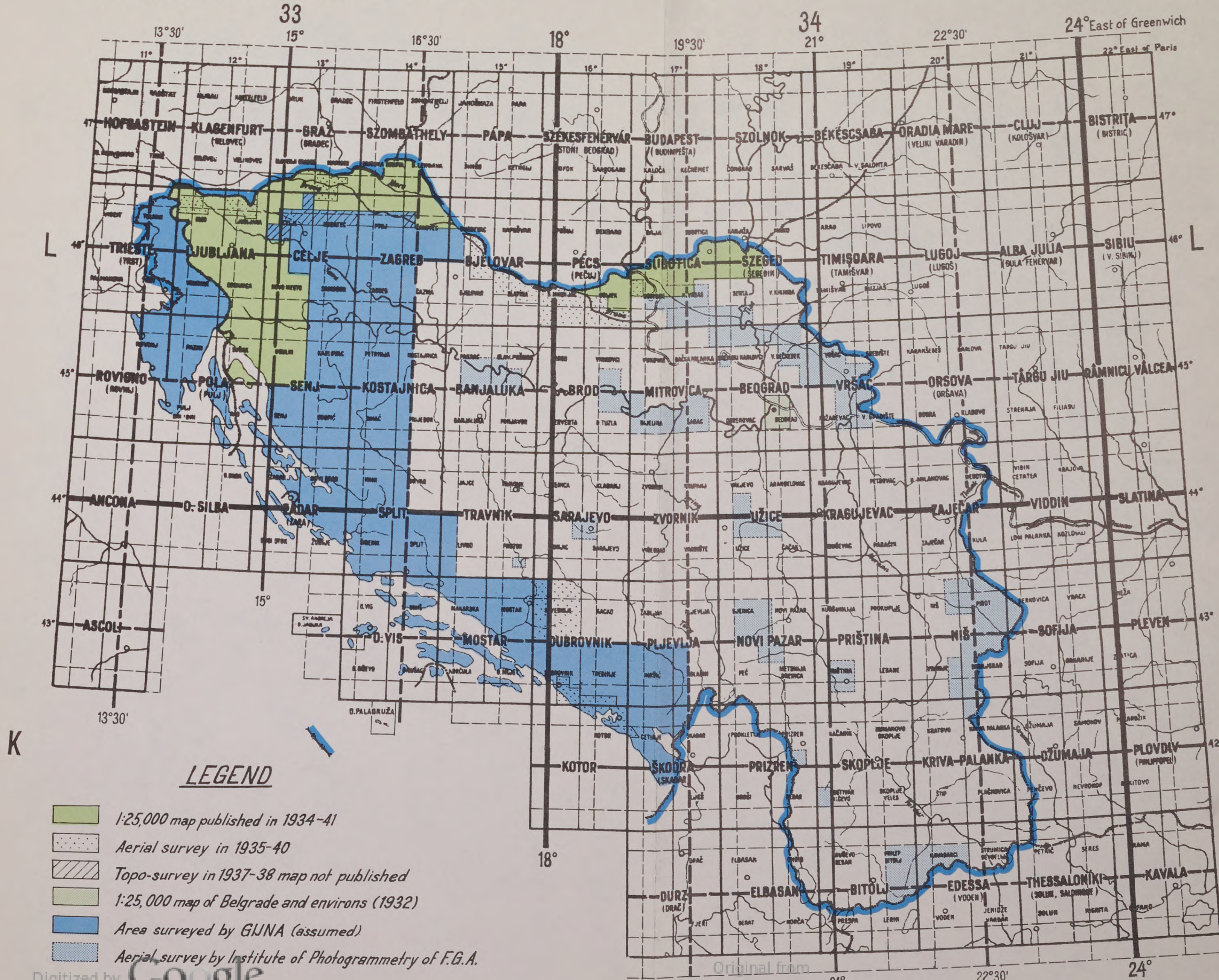
In 1940, the Military Geographic Institute bought from the Zeiss-Aerotopograph Co. 1 stereoplanigraph C5, 9 multiplexes, 9 automatic rectifers SEG IV and 50 stereoscopes with mirrors and stereometers as well as numerous surveying equipment. All those brand new instruments together with the old equipment and all geodetic and cartographic material in April 1941 fell into the hands of the German Army.

(5) The topographical survey at 1:25,000 scale carried out in the period between two the World Wars has the following coverage (See Inclosure 44):

AREA	Total surf. km^2	Topo-Svy. km^2	photocovered km^2	photocompil. km^2	map publ. km^2
(1934-38) Slovenia & Croatia	16,563	15,434	1128	1128	15,331
Vojvodina (1939)	4,280	4,158	122	122	4,280
Slavonia (1939)	3,310		3310	3310	
Herzegovina (1938)	2,112		2112		
Boka Kotorska (1938)	850		850	850	
Total surface	27,115	19,593	7522	5410	19,611
% of the entire surf. of Yugoslavia	11.0%	7.9%	3.0%	2.2%	7.9%

Inclosure 44

Topographical survey at 1:25,000 scale



The average norm achieved by one topographer in the summer period of six months is 87 km^2. In respect to the various types of relief the average norm was obtained as follows:

Plain	93 km^2
Hills	75 km^2
Mountains	66 km^2
High mountains	62 km^2
Karst	58 km^2

In the photogrammetrical survey by application of the previously described method the norms achieved are as follows:

1 triangulator in 6 months covered with panelled tie points (16-20 tie points per plane table sheet) 5 plane table sheets i.e. 330 km^2;

1 aerophotogrammetrist compiled 1 plane table sheet of 66 km^2 at 1:25,000 scale in 240 work hours or $1\frac{1}{2}$ months (The norm computed by formula $\frac{\text{scale}}{100,000}$ $km^2 = \frac{1}{4}$ km^2 per 1 hour or 264 work-hours).[163]

1 topographer revised, supplemented and inked 3-5 plane table sheets in 6 months.

Hence the photogrammetrical survey of four plane table sheets (264 km^2) required 6 months-work of 1 triangulator, 1 photogrammetrist and 1 topographer. Consequently the saving in time and in the work of the professionals was merely 25%, but from this combined method of survey there resulted a map of higher accuracy, particularly the sheets covering impassable terrain.

The 1:25,000 topographical survey executed in Yugoslavia between the two World Wars (1934-40) should be considered a modern topographical survey which meets the requirements of artillery as well as other technical requirements expected to be met by a 1:25,000 topographical survey.

q. <u>The topographical map of Yugoslavia at 1:25,000 scale</u>: The territory of pre World War II Yugoslavia would be covered by 2031 sheets of the 1:25,000 topographical map. The polyhedric sheets with the dimensions $7'30_{\phi} \times 7'30_{\lambda}$, each composed of two plane table sheets, are provided with 1 km (4 cm) Yugo-Red. GK grid.

(1) The compilation and reproduction were carried out in a manner similar to that of 1:100,000 (1:50,000) sheets. The topographical

manuscripts served as cartographical manuscripts. The blue lines of topographical manuscripts at 1:25,000 scale were reproduced and for each sheet four colour separations drawn from which the printing plates were processed photoalgraphically. The topographical features are shown with the same symbols as in the 1:100,000 (1:50,000) sheets. The nomenclature up to 1938 was handlettered with the same types of letters as used in the 1:100,000 (1:50,000) map. In 1938, the nomenclature had begun to be printed and the spot elevations were shown to one tenth of a meter. The relief is expressed by contours as in the topographical manuscripts. Actually, the sheets represent, for the purpose of reproduction, redrafted topographical manuscripts without any reduction and generalization but supplemented with nomenclature, elevations and marginal information.

The reproduction was carried out in six colours i.e: sheet lines and grid, cultural features, nomenclature, elevations and marginal information in black, hydrography with pertinent nomenclature in blue with fill in blue screen lines; relief in brown, woods in green, fill of first and second class automobile roads in red and international boundaries accentuated by strips in dark green or orange colours.

Altogether there were reproduced 194 sheets, covering 19.611 km^2 or 7.9% of the entire Yugoslav territory and 5737 km^2 of the boundary regions of neighbouring countries in compilation of which the foreign 1:25,000 maps were used.

(2) The sheets, as newly published just prior to World War II, were neither revised nor supplemented with any additional information. There exists only the primary edition of the 1:25,000 sheets published by the Military Geographic Institute.

(3) The Germans published two editions of the Yugoslav 1:25,000 sheets covering the western region of Slovenia and Croatia and the northern region of Slovenia. The first edition consists of 84 Yugoslav 1:25,000 sheets, covering the region along the former Italian boundary, reproduced in black colour (direct reproduction), with woods in green tint and 1 km (4 cm) DHG grid superimposed in violet colour. The second edition consisting of 76 sheets which cover the northern part of Slovenia is not uniform. All sheets are direct reprints of the Yugoslav sheets, but 38 of them have German marginal information including interpretation of symbols. The sheets are reproduced in the same colours as the Yugoslav sheets , except 38 sheets with German marginal information having the woodland reproduced in light green tint.

(4) <u>The accuracy of the 1:25,000 sheets:</u>

(a) The horizontal (positional) accuracy of the 1:25,000 sheets determined from the comparisons of the preliminary coordinates of M.G.I. triangulation with scaled positions of 184 trig points is expressed as follows

The positions of trig points could be determined with a probable error

$$E = \pm\ 4.16\ \text{m} = \pm\ 0.17\ \text{mm; or}$$

by a mean square error

$$E_2 = \pm\ 6.23\ \text{m} = \pm\ 0.25\ \text{mm}.$$

Consequently the positions of detail points would be determined by a probable error

$$E = \pm\sqrt{0.17^2 + 0.3^2} = \pm\ 0.345\ \text{mm} = \pm\ 8.62\ \text{m, or}$$

by a mean square error

$$E_2 = \pm\ 0.517\ \text{mm} = \pm\ 12.92\ \text{m}.$$

Hence, 68% of the positions of planimetry could be determined from this map by an accuracy of 0.5 mm; or 95% within an accuracy of 1 mm. (In certain areas a better result was obtained; for instance from the comparisons of 48 stations in the sheets 41 Sušak 1a, 1b, 1c, 1d, 2a and 2c the mean square error of detail points would be determined by $E_2 \pm 0.46$ mm = ± 11.5 m, or the positions of 73% of detail points could be determined by $E_2 \leq 0.5$ mm). Since in the positional analysis the printed sheets were used, the accuracy of the topographical manuscripts would be determined if the distortion caused by drafting and reproduction as well as error of scaling are considered as follows:

error of reproduction	± 0.2 mm
error of drafting	± 0.062 mm
error of scaling	± 0.1 mm

$$E_2 = \pm\sqrt{0.517^2 - (0.2^2 + 0.1^2 + 0.062^2)} = \pm\sqrt{0.213445} = \pm\ 0.46\ \text{mm}.$$

The mean square error ± 0.46 mm or probable error 0.3 mm resulted also from the tests of the manuscripts of various European topographical surveys carried out in the period between two World Wars.

(b) Vertical accuracy: The elevations determined in the topographical survey at 1:25,000 scale are based upon the vertical control attached to precise leveling referring to the leveling datum Trieste, Molo Sartorio (1875). The elevations were determined by means of trigonometrical leveling with the following accuracy:

trig points $E_2 = \pm 0.05$ m

graphical points $E_2 = \pm 0.2$ m

detail points $E_2 = \pm 0.5$ m.

In the plain (Vojvodina, Slavonia) trig points have elevations determined by precise and technical leveling and the elevations of graphical and detail points were determined by spirit leveling with the following accuracy:

graphical points $E_2 = \pm 0.05$ m

detail points $E_2 = \pm 0.10$ m.

In this area the spot elevations included in the map are shown to one tenth of a meter.

The vertical net (elevations) on which the expression of the relief is based is homogeneous. In order to express the relief by contours with an accuracy which would satisfy artillery and technical requirements, 20-150 elevations per square kilometer, depending upon the shape of the relief were measured.

Since an exact analytical evaluation of the accuracy of a map is possible only if the data shown on the map are compared with the records of a special check-survey of higher accuracy, the numerical records of the 1935-38 artillery survey carried out along the former Italian boundary were used in the analytical evaluation of vertical accuracy of the sheets Cerknica 1-a and Sušak 1-b. In the evaluation only the ground elevation of points which could be possitively identified on the map (mostly picture points) were used and the following results for the accuracy of contour lines were obtained:

- Sheet 26 Cerknica 1-a. Plane table survey 1934. Plain 25%, mountains up to 1000 m height with slopes up to 40° 75%, open terrain 45%, forest 55%. Contour interval 10 m. Compared 110 elevations.

Slope	0° - 2°	2° - 5°	5° - 10°	10° - 15°	15° - 20°	20° - 30°
α_m	1° 03'	3° 33'	7° 18	12° 04'	17° 14'	25° 34'
$tg\,\alpha_m$	0.018	0.062	0.128	0.214	0.310	0.478
Number of elevations	38	18	18	14	13	9
$[\Delta h^2]$	32	22	49	80	256	421
E_2	±0.92 m	±1.10 m	±1.65 m	±2.39 m	±4.44 m	±6.84 m

Mean square error for entire area investigated:

$$E_2 = \pm\sqrt{\frac{860}{110}} = \pm 2.80 \text{ m} = 92.6\% \text{ of errors within } \tfrac{1}{2} \text{ of contour}$$

interval (5 m).

Vertical mean square error of contours by formula of Prof. Koppe:

$$Eh_2 = \pm (0.75 + 9.8 \text{ tg}\,\alpha)\text{meters.}$$

(See Inclosure 45).

- 41 sheet Sušak 1-b. The sheet is composed of two plane table sheets surveyed by two topographers. Since there is a considerable difference in the shape of the terrain covered by each of these two plane table sheets as well as in the accuracy of the plane table survey, the analysis of vertical accuracy of contours for each plane table sheet was carried out separately.

Northern plane table sheet: Plane table survey 1935. Wild Karst with karstic plateaus and mountains of which elevations range between 780 - 1481 m 94% covered by forest, merely 4 km^2 of open terrain consisting of small clearings. Contour interval 10 m. 50 available elevations were compared.

Slope	0°-2°	2°-5°	5°-10°	10°-15°	15°-20°	20°-25°	25°-30°	30°-40°
αm	2°0'	4°10'	8°43'	13°13'	16°38'	23°00'	28°00	36°00
tgαm	0.035	0.073	0.153	0.235	0.299	0.424	0.532	0.727
No. of elev	7	6	7	9	8	6	4	3
$[\Delta h^2]$	2	5	16	17	40	36	37	70
E_2	±0.53m	±0.91m	±1.51m	±1.37m	±2.24m	±2.45m	±3.04m	±4.08m

Mean square error for the entire plane table sheets is:

$$E_2 = \pm\sqrt{\frac{203}{50}} = \pm\sqrt{4.06} = \pm 2.01 \text{ m} = 98.7\% \text{ within } 5 \text{ m } (\tfrac{1}{2} \text{ of CI}).$$

Vertical mean square error of contours expressed by formula of Prof. Koppe:

$$Eh_2 = \pm (0.32 + 6.1 \text{ tg}\,\alpha)\text{meters}$$

(See Inclosure 45).

Southern plane table sheet: Plane table survey 1935. 24% of high karstic plateau similar to terrain of the northern plane table sheet with elevations between 1100 and 1400 meters. 68% of mountains with large slopes, elevations between 300-1300 m. 8% of field and fine sloping alluvial deposits, elevation 280-300 m. 45% of entire area covered by forest (mostly karstic plateau and mountain slopes). Contour interval 10 m. 67 available elevations were compared.

Slope	0°-2°	2°-5°	5°-10°	10°-15°	15°-20°	20°-25°	25°-30°	30°-40°
α_m	1°40'	3°44'	7°24'	12°15'	16°45'	24°00'	28°40'	34°00'
$tg\alpha_m$	0.029	0.062	0.130	0.217	0.301	0.445	0.547	0.675
No. of elev.	18	15	10	12	4	2	3	3
$[\Delta h^2]$	42	119	141	308	482	13	437	338
E_2	±1.53m	±2.82m	±3.75m	±5.07m	±10.98m	±2.55m	±12.07m	±10.61m

The mean square error for the entire plane table sheet is:

$$E_2 = \pm\sqrt{\frac{1880}{67}} = \pm\sqrt{28.0597} = \pm\ 5.30\ \text{m} = 65\%\ \text{within}\ 5\ \text{m}\ (\tfrac{1}{2}\ \text{of CI}).$$

Vertical mean square error of contours expressed by formula of Prof. Koppe is:

$$Eh_2 = \pm\ (1.10 + 21.0\ tg\,\alpha)\text{meters.}$$

Since the vertical accuracy of the contours could be determined merely for a few selected sheets on the basis of which only an approximate estimation of the accuracy for the entire map could be assumed, there were chosen intentionally, three areas having various shapes of terrain, which were surveyed by four topographers, i.e. sheet Cerknica 1-a by two topographers rated as mean-class topographers, Sušak 1-b North by a high-class topographer and Sušak 1-b South by a low-class topographer. My personal acquaintance with them facilitated a proper selection which was entirely justified by the results obtained.

From the results obtained from the above-mentioned three areas investigated, the following vertical accuracy of contours for the entire area was obtained:

$$E_2 = \pm\sqrt{\frac{1880 + 203 + 860}{67 + 50 + 110}} = \pm\sqrt{\frac{2943}{227}} = \pm\sqrt{12.9647} = \pm 3.60 \text{ m}$$

or 86.3% within 5 m ($\frac{1}{2}$ of CI).

Expressed by formula of Prof. Koppe, if the results

$$Eh_2 = \pm (0.32 + 6.1 \text{ tg}\,\alpha)\text{meters}$$

$$Eh_2 = \pm (0.75 + 9.8 \text{ tg}\,\alpha)\text{meters, and}$$

$$Eh_2 = \pm (1.10 + 21.0 \text{ tg}\,\alpha)\text{meters,}$$

are properly weighted in respect to the number of points if would be

$$Eh_2 = \pm (0.75 + 12.5 \text{ tg}\,\alpha)\text{meters.}$$

The evaluated sheets mostly cover mountainous terrain and karstic plateaus covered by extensive woods creating very difficult conditions for topographical survey. Furthermore there are no numerical records available which would make possible the analysis of the sheets covering the hilly land of East Slovenia and Croatia and the plain of Vojvodina, evidently surveyed with higher vertical accuracy of contours. Therefore, it is evident that the value $Eh_2 = \pm (0.75 + 12.5 \text{ tg}\,\alpha)$m is not an acceptable expression for the vertical accuracy of contours by which the relief is shown in the 1:25,000 sheets compiled from the topographical survey carried out in 1934-40. This statement also would be supported by the facts, that there are very few plane table sheets with such a low vertical accuracy of contours as that of the sheet 41 Sušak 1-b South, that the vertical accuracy of photogrammetrically surveyed sheets would be about $Eh_2 = \pm (1.5 + 6.3 \text{ tg}\,\alpha)$m and that the sheets covering open, hilly and flat land with elevations determined mostly by spirit leveling represent about 40% of the 1:25,000 sheets published in 1934-41. Considering all these facts it should be assumed that the vertical accuracy of contours by which the relief in the sheets of the 1:25,000 topographical map of Yugoslavia published in 1934-1941 as expressed would be:

$$Eh_2 \doteq \pm (0.75 + 10 \text{ tg}\,\alpha)\text{meters;}$$

hence the map as a whole would meet the requirement that the contours be drawn with an accuracy expressed as

$$Eh_2 \leq \frac{CI}{2} = 5 \text{ m.}$$

(5) Remarks: The compilation of polyhedric sheets of the 1:25,000 topographical map of Yugoslavia in 1941 was discontinued. These sheets represent the tactical map of Yugoslavia of the largest scale compiled, primarily, to meet the artillery requirements, to be used in various technical planning and in scientific research in the fields of geology, geomorphology and hydrology, as well as to be the basic cartographic material for the compilation of the 1:50,000 and 1:100,000 topographical maps. The 1:25,000 sheets satisfy these requirements despite certain deficiencies which are explained as follows:

- The sheet lines were constructed in the polyhedric projection, but should have been constructed on the same projection as the grid i.e. on the Gauss-Krueger projection with 3^{o} zones.

- The topographical survey for the 1:25,000 sheets is based upon 6-10 trig points per plane table sheet, but should be based upon a triangulation with much higher density i.e. about 35 trig points per plane table sheet (1 trig point per 2 km^2). In this case there would be no need for a graphical net and the plane table traverses in the wooded regions would be no longer than 1.5 km.

- The triangulation was not adjusted and the stations were plotted by means of preliminary coordinates.

- The plane table sheets were not provided with cadastral triangulation and cadastral planimetry because the cadastral survey in the areas considered to be topographically surveyed due to the poor coordination between M.G.I. and Cadastral Direction, was never completed.

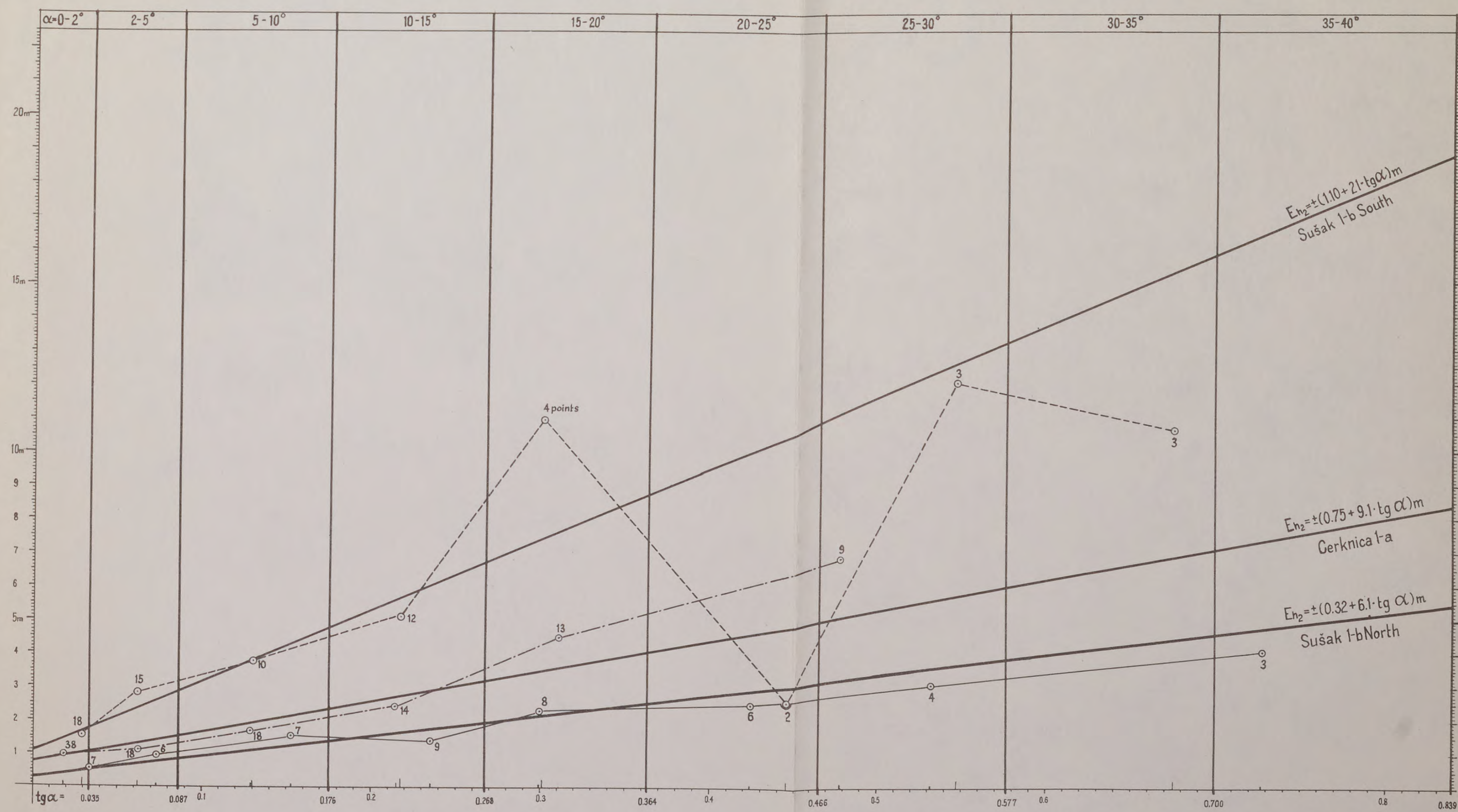
- The norms required to be achieved by topographers were too high, particularly in the karstic and mountainous regions. The survey was carried out too hastily

- The topographical manuscripts were used as cartographic manuscripts and each plane table sheet was merely redrafted. Hence, there was no reduction of superfluous details or accentuating of the important objects, or speaking technically, the cartographic weight was not properly solved and uniformity of sheets in respect to contents was not achieved.

- The drawing of colour separations at ratio 1:1 despite that it was carried out by highly-skilled draftsmen (topographers and cartographers) caused the reproduced sheets to lack a perfect appearence. Since there was no planning and since no experimentations and tests were carried out before the compilation and reproduction started, there resulted such deficiencies as undersized

Inclosure 45

1:25,000 Topographical map of Yugoslavia, vertical accuracy of contours



symbols for churches, chapels, shrines, monuments, sign-bords, mills, saw-mills and factories; heavy handlettered nomenclature with undersized place names of villages; in the expression of cliffs in the sheets photogrammetrically compiled the index-contours were added meanwhile in other sheets the cliffs are expressed without index contours. The lack of uniformity in the appearence of the sheets was made even more apparent by the printed nomenclature and elevations, shown to one tenth of a meter, first introduced in 1938. This was a direct result of the lack of planning and absence of tests prior to publication of the map.

Despite the above-noted deficiencies, the sheets of the 1:25,000 topographical map of Yugoslavia published in the period between the two World Wars should be considered a modern large scale map which satisfies artillery and other technical requirements placed upon 1:25,000 topographical maps.

r. The 1:25,000 topographical map of Belgrade and environs: The Military Geographic Institute in the spring of 1928-29 and 1930 surveyed, at 1:25,000 scale, the City of Belgrade and it's environs located south of the Danube and Sava rivers, and in 1931 reambulated the old 1:25,000 map north of the Sava and Danube rivers covering the former Austro-Hungarian territory. From this new survey and reambulation there was published in 1932 the 1:25,000 topographical map of Belgrade and environs, consisting of 4 sheets with dimensions $6'30''_{\varphi} \times 11'_{\lambda}$ covering each 192 km^2. Total coverage of the map, constructed as a whole in the polyhedric projection and limited by $44^{\circ}41'$ and $44^{\circ}54'$ parallels and $17^{\circ}58'$ and $18^{\circ}20'$ meridians (East of Paris), amounts to 768 km^2 of which the southern surveyed part covers 440 km^2 and northern reambulated part 328 km^2.

The topographical survey was carried out by the method of plane table tachymetry as previously discussed on pp. 265-268 and the reambulation in the manner as discussed on pp. 274-276 of chapter DV with the exception that the relief is expressed by contour lines with the contour interval of 5 m, 25 m index contours and 2.5 m auxiliary contours. The norm achieved in the survey was 80 km^2 by one topographer in six months.

The map is reproduced in the manner of the 1:50,000 map. The topographic manuscript served as a cartographic manuscript, on the blue lines of which the colour separations at 1:25,000 scale were drawn. This map was published only in one edition using the Latin alphabet. The contents of the 1:25,000 map were incorporated into sheet 69 Belgrad of the 1:100,000 (1:50,000) topographical map of Yugoslavia.

Prior to World War II the Germans enlarged the sheets of the 1:25,000 map of Belgrade and environs to 1:12,500 scale, which was used as a target map in the bombardment of Belgrade on 6-9 April, 1941, by the German Air-force.

s. The 1:25,000 topographical survey and map carried out by GIJNA: The topographical survey at 1:25,000 scale and the sheets of the 1:25,000 topographical map of Yugoslavia carried out prior to World War II were classified as secret. The activities on the continuation of the 1:25,000 topographical survey and the 1:25,000 topographical map executed by GIJNA are kept even in higher secrecy and are very rarely mentioned in the Yugoslav professional literature. From the compilation of these fractional records the following conclusions were made:

(1) Topographical survey: The plane table sheets with dimensions $5'_\phi \times 7'30''_\lambda$ (about 93 km^2 at 44° of latitude) are constructed in the Gauss-Krueger projection with 3° zones and provided with 1 km (4 cm) Yugo-Red. GK grid. The starting meridian is the meridian of Greenwich. In the sheets there are plotted up to 100 trig points (about 1 trig point per km^2). The adjusted cadastral triangulation is utilized in the topographical survey. Since cadastral trig points are without measured elevations, the topographers have to determine the elevations by means of trigonometrical leveling based upon precise leveling with elevations referring to the vertical datum of Trieste, Molo Sartorio (1875). 3135 sheets would cover, the entire territory of Yugoslavia.

The cadastral planimetry is pantographed into plane table sheets. Since the plane table sheets are provided with such a high number of trig points the development of the graphical net evidently became superfluous. The detail survey consists of checking and bringing up to date the cadastral planimetry and the survey of relief expressed in the same manner as in the 1934-40 topographical survey.

In order to establish an approximate accuracy of plane table survey in 1955 there were tested, 36 topographical stations determined by means of graphical resection and 48 detail points determined by means of plane table tachymetry. The coordinates of these points were computed from the records of numerical survey (triangulation, traverses and numerical tachymetry) and then compared with the coordinates scaled by means of the A.R. Rost's coordinatograph. The elevations of topographical stations were taken from the topo-manuals and elevations of detail points were obtained by means of interpolation from the contours. From these tests the following results were obtained:

- Topographical stations are determined by a horizontal error expressed by:

$$E_2 = \pm 4.59 \text{ m} = \pm 0.18 \text{ mm}/1:25,000$$

$$Eh_2 = \pm 0.43 \text{ m}; \text{ and}$$

- Detail points by:

$$E_2 = \pm 6.97 \text{ m} = \pm 0.28 \text{ mm}/1:25,000$$

$$Eh_2 = \pm 1.68 \text{ m}. \quad [18]$$

The results obtained in testing of one 1:25,000 topographical manuscript are excellent. Since the test was made on one plane table sheet covering a hilly area with slopes between 0° and 4° and numerical and graphical data of a relatively small number of points were compared, the results obtained could not be considered an adequate criterion of accuracy of the entire topographical survey executed after World War II.

In the years 1947-53, 14,000 km^2 were surveyed by the plane table method. [20]

<u>Photogrammetrical survey:</u> The abundant photogrammetric equipment bought prior to World War II was lost, but the desire and the need for the photogrammetrical survey remained. The GIJNA in order to proceed with the photogrammetric survey started in 1950 by its predecessor M.G.I. began to order (mostly from Switzerland) photogrammetric cameras and instruments, among which were the following:

1 Zeiss RMK 30 x 30 camera f=10 cm
2 Wild RC-5a 18 x 18 cameras with objectives
  Aviogon f=11.5 cm and Aviotar f=21 cm

1 phototheodolite TAN 18 x 13 cm, f=19.3 cm.
2 Wild A7 autographs
2 Wild A8 autographs.
1 Zeiss C-8 stereoplanigraph

Evidently there are also rectifiers and some other photogrammetric instruments.

In the photogrammetrical survey the GIJNA is collaborating with the Institute of Photogrammetry of the Federal Geodetic Administration (Cadastral Survey) which has the following equipment:

1 Wild Rc-7 14 x 14 cm plate-camera with objectives Aviogon f=10 cm and Aviotar f=17 cm.

1 SOM 13 x 18 hand-camera
1 Wild phototheodolite
1 Zeiss C-8 stereoplanigraph
1 Wild A5 autograph
1 SOM Poivillieurs B stereotopograph
4 Wild A8 autographs
1 Wild Ag stereorestitutor
2 Wild E2 automatic rectifiers.

The Institute of Photogrammetry in 1953, employed 9 geodetic engineers and 200 geometers and a certain number of mechanics; 5 engineers and 7 geometers attended photogrammetrical courses in Switzerland, Germany, France and Italy and 2 mechanics were sent for special training in foreign factories of photogrammetric equipment. [32]

The personnel of the Institute of Photogrammetry in the period from 1948, to 1956, surveyed photogrammetrically 20,452 km^2.

The productional capacity in the compilation at 1:20,000 scale of the above mentioned photogrammetric equipment of GIJNA and Institute of Photogrammetry is 15,000 km^2 per year if employed in two shifts (14 hours per day). i.e. 12,000 km^2 compiled stereophotogrammetrically and 3000 km^2 compiled by one plate photogrammetry (rectifying). Since the Institute of Photogrammetry is producing 1:2500 cadastral plans and the 1:5000 (1:10,000) basic national map (which recently are reduced and used in the compilation of the 1:25,000 topographical map of Yugoslavia), in the direct production of the 1:25,000 topographical manuscripts only GIJNA should be considered. The capacity of GIJNA photogrammetrical equipment in stereo-compilation at 1:20,000 scale (some small areas were compiled at 1:10,000 scale) is about 6000 km^2 per year. In the recent productional stage of compilation the mean norm achieved at 1:20,000 scale was 0.23 km^2 and maximal norm 0.40 km^2 per hour. In the testing and training stage 1951-52 8000 km^2 were photographed and compiled. By the end of 1957 about 40,000 km^2 should have been photographed. In the revision and supplementing of the photocompiled manuscripts in 1952-58 there were employed about 25 topographers. (Revision of photogrammetrically compiled manuscripts usually is carried out during the next year and the map published one or two years after the revision).

The topographical survey by plane table method in 1953, covered 14,000 km^2. At that time GIJNA had about 40 topographers. The average norm achieved by one topographer in 6 months was 60 km^2. Since 1953, about 25 topographers are revising photocompilations and because the Geodetic Academy of GIJNA, every two years, produces about ten topographers who start their practical work with the classical method of topographical survey, it should be assumed that by the end of 1957 the 1:25,000 topographical survey carried out by plane table method will cover about 20,000 km^2. By the knowledge that 19.611 km^2 are covered by the sheets of the 1:25,000 topographical map published in 1934-41 which are in possession of GIJNA, (manuscripts and printing plates were partially lost in World War II) it could be assumed that by the end of 1958 GIJNA would have about 80,000 km^2 or 31% of present Yugoslavia (256,393 km^2) covered by a modern 1:25,000 topographical survey. Since the area of 20,000 km^2 photogrammetrically surveyed by the Institute of Photogrammetry recently was included in the process of compilation of the 1:25,000 topographical map of Yugoslavia the estimated surface of present coverage should be even higher. The fact that in various discussions about the topographical survey carried out by GIJNA, there are mentioned place names such as Dalmatia, Coastland of Montenegro, Biševo Island, Split, Otočac and Sutla river, indicates that priority in this survey was given to the western part of the country. From a military point of view such a decision is logical and should have been expected. (See Inclosure 44).

(2) The 1:25,000 topographical map of Yugoslavia: The 5' ϕ x 7' 30" λ sheets constructed in the Gauss-Krueger projection with 3° zones, cut in the system of International map and provided with the 1 km (4 cm) Yugo-Red GK grid are reproductions of the topographical manuscripts. The topographical manuscripts are photo-enlarged to 1:20,000 scale and blue lines processed on which the colour separations are drawn. In the expression of topographical features the 1939 topographical symbols are used. The nomenclature is printed in the Latin alphabet and mounted into colour separations. The relief is expressed in the same manner as in the topographical manuscripts. The reproduction has been made in 6 colours, i.e. sheet lines, grid, cultural features and nomenclature in black; hydrography and pertinent nomenclature in dark blue with fill of rivers, lakes and sea in light blue; relief in brown; forests in light green and orchards in dark green. The sheets are provided with detailed marginal information including topographical symbols.

Up to the end of 1953, 94 sheets had been printed. Since there are no records pertaining to the strength of the cartographic division and concerning the reproductional capacity of GIJNA (they are not smaller than in the former M.G.I.) it should be assumed that at least 300 sheets of the new 1:25,000 topographical map of Yugoslavia up to the present time have been printed. The old polyhedric sheets with dimensions $7'30_{\phi} \times 7'30_{\lambda}$ and starting meridian of Paris have to be recast to the new sheet lines and redrafted according to the 1939 topographical symbols in order to obtain continuity with the new sheets. This procedure was not discussed in any publication. Evidently it will be carried out along with the revision of the 1934-41 sheets.

The new sheets of the 1:25,000 topographical map of Yugoslavia are designed to satisfy the same needs as had to be met by the sheets published prior to World War II. There is not available a single copy of the new sheets by which one could facilitate an approximate evaluation of the new 1:25,000 topographical map. From the known data about the projection, density of triangulation and the methods applied in the topographical survey used in the compilation of 1:25,000 sheets the following conclusion could be made: The new 1:25,000 sheets have sheet lines and grid constructed in the same projection; the sheets are positioned upon the adjusted triangulation; into each sheet there are plotted up to 100 trig points and the sheets are provided with pantographically reduced cadastral planimetry; in the plane table survey, practically reduced to the checking of pantographed planimetry and to surveying of the relief an average norm of about 60 km^2 surveyed by one topographer in 6 months was achieved, which is considerably smaller than the norm of 87 km^2 achieved in the 1934-40 topographical survey which next to the survey of relief included also graphical triangulation and the survey of planimetry; two thirds of the sheets are compiled from the photogrammetrical survey based upon panelled triangulation and tie points determined by numerical survey (aerial triangulation was not utilized) with the restitution carried out on the newest first and second class photogrammetrical instruments at 1:20,000 scale and the photo-compiled manuscripts revised and completed in the field by the method of plane table tachymetry; hence the new 1:25,000 sheets in comparison with the sheets of the 1934-41 topographical map of Yugoslavia should have a considerably higher accuracy.

Since the colour separations for the new sheets are prepared at 1:20,000 scale and then photo-reduced to 1:25,000 scale and because the GIJNA reproductional technique in respect to that of M.G.I. is improved, the new sheets also should have a better appearence and improved legibility.

3. <u>The topographic survey and maps carried out by civilian agencies:</u>

In the Kingdom of Serbia and in the pre World War I Yugoslavia the topographical survey and the compilation and publishing of topographical maps were the exclusive responsibility of the Military Geographic Institute. The civilian agencies were active merely in the surveys utilized in the construction of public buildings, railroads, roads and canals, and in the cadastral survey.

The cadastral survey in Serbia started actually with the survey of district Loznica in 1890. Meanwhile, the organization of a cadastral agency was considered late in World War I by the Serbian government in exile and the Serbian Bureau of Cadaster was created on 28 September, 1918.

After the creation of the Yugoslav state (Kingdom of Serbs, Croats and Slovenes) from the Serbian Bureau of Cadaster and of the cadastral offices of former Austro-Hungarian provinces on 9 February 1919 the Direction General of Cadaster (Generalna Direkcija Katastra) as a division of the Ministry of Finance was established; later renamed the Division of Cadaster and State Domains of the Ministry of Finance (Odelenje Katastra i Državnih Dobara Ministarstva Financija).

In the period 1924-1941, the territories of Serbia and Macedonia and small areas of Vojvodina, Croatia, Bosnia and Herzegovina, Montenegro and Slovenia were covered by 2nd, 3rd and 4th order nets of the cadastral triangulation (adjusted to Yugoslav 1st order net), covering altogether 97,000 km^2 with 62,885 trig points.

The cadastral survey based on this triangulation and carried out in the settlements by the orthogonal method and in the rest of the country by the method of numerical tachymetry covered in 1941 about 50,000 km^2 of the territories of Serbia and Macedonia. The cadastral planes constructed in the Gauss-Krueger projection at 1:500, 1:1000 scale (cities and large settlements) and 1:2500 scale are planimetric planes without expression of the relief and prior to World War II were not utilized in the topographical survey and in the compilation of the topographical maps.

After World War II the Division of Cadaster and State Domains has been succeeded by the Chief Geodetic Administration of the F.P.R.Y. (Glavna Geodetska Uprava FNRJ) in 1953, renamed Federal Geodetic Administration (Savezna Geodetska Uprava).

The Federal Geodetic Administration is the supreme civilian agency which in establishment of triangulation and leveling collaborates with the Geographic Institute of Y.P.A. (GIJNA) and performs the research, planning and execution of work in the field of triangulation, precise leveling and technical leveling of higher accuracy, topographical survey at 1:5000 and 1:10,000 scale, photogrammetry and cadastral surveys. In order to carry out these numerous activities it has the following subordinate agencies:

- Institute of Photogrammetry in Belgrade, primarily responsible for the surveys (detail triangulation, detail spirit leveling, trigonometric leveling, determination of tie points, photogrammetrical survey and field revision of photocompilations) utilized in the compilation of the basic national maps at 1:5000 (1:10,000) scale. (See pp. 347-348).

- Republic's Geodetic Administrations in Belgrade, Zagreb, Ljubljana, Sarajevo, Skoplje and Titograd responsible for cadastral survey, revision of cadastral planes and technical leveling. Each Republic Geodetic Administration for the execution of triangulation, leveling and cadastral survey has a corresponding number of geodetic field sections and for the maintenance of the cadastral planes has district cadastral offices. The Geodetic Administrations of P.R. Slovenia and P.R. Croatia for the research and scientific works have Geodetic Institutes (Geodetski Zavod and Geozavod respectively) and Geodetic Administration of P.R. Serbia has the Cartographic Institute of NRS "Geokarta" employing 245 technicians and specialized workers.

The present civilian geodetic professional manpower of Yugoslavia consists of about 250 geodetic engineers and 2800 geometers (surveyors) of which 90% are employed in the Federal Geodetic Administration and its branches.

The Federal Geodetic Administration has its permanent delegate in the National Committee for Geodesy and Geophysics of F.P.R. Yugoslavia (Nacionalni Komitet za geodeziju i geofiziku FNRJ), which is the highest national authority coordinating and representing the entire geodetic and geophysical work in Yugoslavia.

a. <u>The topographical survey at 1:5000 scale</u>: This survey, in order to produce the topographic manuscripts for the compilation of the basic national map needed in the planning of national economy, started in 1947. Since the need for the basic national map exists primarily in the areas of large construction and other industrial developments, the survey has been carried out only in the areas where such a need occurs, hence it does not yet cover large closed areas. (See Inclosure 44). The basic national map in the compilation of 1:25,000 topographical maps of Yugoslavia has been utilized since 1954. The entire territory of Yugoslavia would be covered by about 38,000 sheets of the basic national map at 1:5000 scale.

The sheet lines of the topographic manuscripts at 1:5000 scale and of the 1:5000 sheets of the basic national map as well as of the cadastral plans at larger scales, i.e. 1:2500, 1:2000, 1:1000 and 1:500 are rectangulars constructed in the Gauss-Krueger projection with 3° zones.

Since each 3° zone (5,6,7) is divided by columns A-L and horizontal belts 1-42 into rectangular index-sheets of the 4th order triangulation net with sheet lines parallel to x (N) and y (E) axis of the projection system, the basic sheet in the construction of the 1:5000 sheets and larger is the index-sheet of 4th order trigonometric net with dimensions:

$$15{,}000\,m_N \times 22{,}500\,m_E.$$

This index sheet divided by 10 columns (A,B,C,D,E,F,G,H,I,J) and 5 horizontal belts (a,b,c,d,e) is divided into 50 sheets (numbered 1-50) at 1:5000 scale with dimensions of each

$$3000\,m_N \times 2250\,m_E \ (60 \times 45 \text{ cm}) \text{ and surface } 6.75 \text{ km}^2. \quad [50]$$

One 1:5000 sheet is composed of the cadastral plans constructed at various scales as follows:

2	1:2500 sheets with $1500\,m_N \times 2250\,m_E$ (60 x 90 cm);	$S = 3.375$ km^2
4.5	1:2000 sheets with $1000\,m_N \times 1500\,m_E$ (50 x 75 cm);	$S = 1.5$ km^2
18	1:1000 sheets with $500\,m_N \times 750\,m_E$ (50 x 75 cm);	$S = 0.375$ km^2
75	1: 500 sheets with $250\,m_N \times 375\,m_E$ (50 x 75 cm);	$S = 0.09375$ km^2

The 1:5000 sheets are coded in the system of the Gauss-Krueger projection. The code number printed in the upper right corner of the sheet is composed of the code number of the index-sheet showing index number of zone, letter of column and number of horizontal belt and of the code number of the 1:5000 sheet composed of the letters designating the position of sheet within the index-sheet, for instance 7H35-Gd. In addition to code number at the center of the upper margin of the sheet the name of the largest settlement located within sheet and number of the sheet (1-50) in capital letters are included.

In order to facilitate the positioning of the 1:5000 sheets within the graticule sheets cut in the system of International map, the sheet corner values of the 1:10,000 graticule sheet with dimensions 2'30"$_{\phi}$ x 3'45"$_{\lambda}$ ($\frac{1}{4}$ of 1:25,000 sheet) and the coordinates of intersections of the sheet lines of 1:5000 sheet with the sheet lines of 1:10,000 sheet in terms of Yugo-Red. GKs are given.

The first two years of the survey should be considered as a testing stage. The instructions for the compilation of the basic national map, were published as follows: part I-field works in 1948; part II-compilation of the topographical (field) manuscript in 1950; and in part III in 1952. According to these instructions the survey may be carried out by the application of:

- graphical (plane table) method,

- photogrammetrical method (terrestrial stereophotogrammetry and aerial photogrammetry);

- numerical method (orthogonal method and tachymetrically by polar method).

The survey has to cover only those areas of the country not covered by cadastral surveys at a larger scale than 1:5000. In the areas covered by cadastral plans at 1:2880, 1:2500, 1:1000 and 1:500 scale in the compilation of the 1:5000 sheets of the basic national map the pantographically or photographically reduced contents of these plans are utilized. The areas covered by cadastral planes will be newly surveyed only in the case if the planes are of lower accuracy then required for the 1:5000 sheets, incomplete or obsolete. Since the cadastral plans cómpiled prior to World War II include merely planimetry and the 1:5000 basic national map is a topographical map including the expression of the relief the survey for the purpose of the determination of the configuration of the surface (relief) has been carried out in the manner of detail spirit leveling, and by numerical or plane table tachymetry.

(1) The survey by numerical method: The detail survey is based upon 4th order triangulation, traverse net including small points and benchmarks of leveling net. In the case if the density of triangulation, traverse net and leveling net is not sufficient the additional fixed points have to be determined by means of detail triangulation, transit traverses, supplementary spirit and trigonometrical leveling to a density of 1 fixed point per 0.25 km^2. In order that these supplementary fixed points could be utilized later in the cadastral survey the accuracy standards and methods used in their establishing are the same as those prescribed for the cadastral survey. The cadastral standards of accuracy (much higher of those needed in the survey for the 1:5000 map) slightly vary in respect to the classification of the terrain into three classes:

- 1st class: cities, towns, industrial regions and plain where large technical developments may take place.

- 2nd class: agricultural areas outside of the first class areas,

- 3rd class: mountainous regions and areas of large forests. For instance, the traverses measured in the 1st and 2nd class terrains are taped using steel tapes with lengths 20 or 50 m or measured by the method of precise polygonometry; traverses in 3 class terrain are measured tachymetrically with the length of sides up to 120 m.

(a) The detail survey: In the settlements it should be carried out by the orthognal method with ordinates not longer than 50 m. Outside of settlements the detail survey has been carried out tachymetrically by application of polar method. The largest sights permitted in tachymetrical measurements of the detail points in respect to the class of terrain are: 1st class 200 m, 2nd class 240 m and 3rd class 300 m. The sights for tachymetrical determination of elevations should be not longer than 120 m.

The number of detail points measured in order to plot the planimetry vary from 300-1500 per square kilometer. The number of determined elevations to be used in the construction of contours vary from 300-500 per square kilometer. The elevations in plain are determined by detail spirit leveling in the hilly and mountainous terrains by method of trigonometrical leveling and tachymetrically.

In addition to the manuals needed in cadastral survey carried out by numerical method the master sketch of the survey and contour skeleton outline are carried out in the field. The average norm achived by one party consisting of two surveyors in the plain was 8.8 km^2 per 6 months.

Since the Federal Geodetic Administration, i.e. the Institute of Photogrammetry did not have topographers but only geometers experienced in the numerical survey for the cadastral plans at 1:2500 scale and larger the plane table method in the survey for 1:5000 basic national map practically has been not applied; though the plane table method with stations determined numerically (combined terrestrial method) and the detail surveyed graphically evidently would give the best results in the completeness of detail and in the expression of the relief if the 1:5000 survey is carried out in classical manner. In order to remedy the deficiency in the expression of the relief the geometers (surveyors) were given courses in geomorphology and practical training in the interpolation and drawing of contours. In addition to this the application of aerial photogrammetry has been increased to such a degree that at the present time covers 80% of the 1:5000 survey.

(b) The topographical manuscript: The compilation of the topographical manuscript based upon the numerical records, master sketch and contour skeleton outline is carried out during the winter time in the office. The data are plotted on the correctostat (metal folio) paper or on drawing paper mounted upon aluminum plates. The sheet lines, 5 cm (0.25 km) grid intersections, trig points, traverse stations and all other points having Yugo-Red. GKs are plotted by coordinatograph, the detail points and spot elevations are plotted by small rectangular polar coordinatographs and protractors. The planimetry is included according to the master sketch. In the expression of the relief there are used two contour intervals:

- In the plain and rolling areas with the slopes within an entire sheet smaller than 5° the 0.5 m contour interval with 2.5 index contours is used if the elevations are determined by spirit leveling or if the elevations of stations are determined by spirit leveling attached to the national leveling net and the elevations of detail points are determined tachymetrically with sights not longer than 120 m and slope angle not larger than $\pm 5^{\circ}$.

- In the terrain with slopes larger than 5° and in the plain and rolling areas if the elevations are determined by trigonometrical leveling and tachymetrically the 5 m contour interval with 25 m index contour and 2.5 m and 0.5 m auxiliary contours is used.

The construction of contours in the office is the major deficiency of the numerical method of survey. The so called "technical contour" obtained by the mechanical interpolation based upon given spot elevations produces a rigid expression of the relief which not only slightly differs from its true shape but also in many cases gives a distorted interpretation of its geomorphological structure. For this reason the Geographic Institute of Y.P.A. (GIJNA) hesitated up to 1954 to compile the sheets of the 1:25,000 topographical map of Yugoslavia from the sheets of 1:5000 basic national map. Along with the decision to use the 1:5000 sheets in the compilation of 1:25,000 sheets it was also decided that topographical manuscripts thus obtained have to be revised in the field prior to being utilized in the production of publishing manuscripts.

In the drawing of the manuscripts are used the topographic symbols prescribed:

- in 1949, consisting of 242 symbols in four colours,

- in 1951, consisting of 340 symbols in two colours; and

- in 1954, consisting of 556 symbols. Consequently the sheets compiled in various periods are not uniform. [36]

The toponymy is included into topographical manuscript by handlettering.

The manuscripts were drawn in four colours, i.e. cultural features and toponymy in black, relief in brown, woodland in green and hydrography (everything that in the map is blue) in red. Since 1952 only black colour for planimetry and brown for relief have been used. [51]

(2) Aerial photogrammetric survey: Since the survey for the basic national map at 1:5000 scale is carried out by the Photogrammetric Institute of F.G.A. extensive application is evident. (See pp. 347-348). The photographs are taken at 1:10,000 scale at times that trees have no leaves. All existing control is panelled. The tie points are determined by triangulation and transit traverses and the elevations by means of spirit or trigonometrical leveling. The determination of tie points by aerial triangulation is in stage of testing but not yet applied. In the photogrammetric compilation the universal method (stereocompilation) and the combined method (rectifying-one plate photogrammetry) have been applied.

(a) Universal method (stereocompilation): Vertical photographs with 60% stereo-pairs and 20% strip overlapping are used. The tie points are selected on the photographs, along with the classification of features, and determined in the field. The compilation is carried out by stereoplanigraph, autographs A5 and A8 and stereotopograph SOM Poivillieurs. The control for each sheet is plotted on two astralon sheets and than planimetry and relief compiled separately. The planimetric and the relief sheets are inked and used in the reproduction of corresponding 1:5000 sheet without any field revision.

(b) Combined method (one plate photogrammetry): In the flat land (25% of Yugoslavia) since 1949, the combined method has been applied. The photographs have been rectified on the basis of panelled control and tie points selected on photographs along with the classification of features and determined in the field. The radial triangulation because of insufficient accuracy is not used in the determination of tie points. The old 1:2880 cadastral planes in order to be used as a basis in the rectifying in the areas covered by the Austro-Hungarian cadastral survey were tested. The tests show various scales, irregular deformation of paper and changed positions of many objects; hence old 1:2880 cadastral planes can not serve as a basis in the rectifying of photographs for the purpose of compilation of the 1:5000 sheets of the basic national map.

The accuracy obtained in rectifying of photographs at 1:5000 scale with Wild E_2 automatic rectifiers is expressed by the mean square error

$$E_2 = \pm 0.173 \text{ mm.} \qquad [141]$$

The photoplans have not been revised in the field. The contours, by which the relief is expressed in the areas surveyed by method of one plate photogrammetry are constructed on the basis of detail spirit leveling.

b. The topographical survey at 1:10,000 scale: Since it was decided that the basic national map at 1:5000 scale has to cover the entire territory of Yugoslavia and the sheets of the topographical map 1:10,000 scale is needed will be obtained by means of reduction and generalization of the 1:5000 sheets the topographical survey at 1:10,000 scale has been carried out merely in the regions not covered by 1:5000 sheets where special needs for a 1:10,000 topographical map occurs (constructions, hydrotechnical works, melioration, planning of urbanization, mining areas etc). The largest areas surveyed for the purpose of the 1:10,000 topographical map are those not covered by the cadastral survey or where the cadastral records including plans during the World War II were destroyed. In order to carry out the organization and registration of cadaster such areas have been covered by photogrammetrical survey and the compilations at 1:10,000 scale are utilized in the preliminary cadastral works as well as basic material for the compilation of 1:10,000 topographical map. For this purpose in Serbia, Macedonia, Montenegro, Bosnia and Herzegovina only in 1953, more than 8000 km^2 were photogrammetrically surveyed at 1:10,000 scale (See Inclosure 44).

The survey has been carried out in the same manner as at 1:5000 scale by application of universal method (stereocompilation) and combined method (rectifying).

c. Maps: The large scale maps published by the Federal Geodetic Administration (former Chief Geodetic Administration) are the basic national maps at 1:5000 scale and 1:10,000 scale and the 1:25,000 map. The publishing manuscripts for these maps have been prepared and the reproduction carried out by the Cartographic Institute "Geokarta".

(1) The basic national map at 1:5000 scale: In the compilation of 1:5000 map have been used 1:5000 topographical plans have been used, for instance in the sheets covering Vojvodina settlements were compiled from 1:2880 plans. If the entire area of a 1:5000 sheet was covered by the special survey for 1:5000 map in its compilation the topographic manuscript at the same time is also

a cartographic manuscript. In case the 1:5000 sheet has to be compiled from cadastral planes or partially from cadastral manuscript and survey the cartographic manuscript at 1:5000 scale is compiled.

The dimensions of sheets, grid, code number and name of the sheets are retained the same as used in topographical (cartographical) manuscripts. The intersections of the 1:10,000 sheets graticule with the 1:5000 sheet lines are plotted and corresponding geographic coordinates included. The positional diagram showing the position of 1:5000 sheet in respect to 1:10,000 sheets is included into marginal information. Since the present system of code numbering of the sheets of Yugoslav maps by GIJNA was adopted in 1953 in the positional diagram of the 1:5000 sheets published prior 1954 included code numbers of corresponding 1:10,000 sheets, cut in the graticule system of International map, are those of USSR system of code (for instance L-34-98-Ac-3) used in the period 1945-1954, in the Yugoslav mapping.

The reduction of cadastral planes to 1:5000 scale has been carried out pantographically or photographically. In order to avoid the reproductional distortion of a multicolored map and preserve its cartometric value since 1952, the map has been reproduced in two colours, i.e. planimetry (including hydrography and vegetations), relief made by man, toponymy, sheet lines with 5 cm (0.25 km) grid intersections and marginal information in black; relief with spot elevations in brown. Consequently only two colour separations at 1:4000 scale are drawn. Printed toponymy is included into basic colour separation. The marginal information consisting of topographical symbols, positional diagram, diagram showing the administrative subdivision, scale and contour interval includes also remarks about the material used in the compilation.

The 1:5000 basic national map, despite some criticism expressed in respect to the not uniform classification of roads, changes of topographical symbols, sparse nomenclature, rigid expression of the relief by means of "technical contours" and not sufficiently emphasised expression of the orientation points (land marks), should be considered a modern basic topographic map. It should be noted that the 1:5000 map already passed its testing stage, always consisting of reconstructions, changes, innovations, and attained its final shape. There is no doubt that this map will satisfy the requirements of the engineers and technicians in the planning of communications, industry, colonization and forestry; nevertheless after a small revision has been utilized as an excellent cartographic material in the compilation of 1:25,000 topographical map.

Exact records of present coverage are not known. From the discussions in professional periodicals it is evident that large regions of Vojvodina (in period 1947-51, 1500 manuscripts compiled) and some areas of Serbia, Macedonia, Croatia, Bosnia and Herzegovina are covered. The entire coverage of Yugoslavia would consist of about 38,000 sheets. Since the yearly production as reported in 1954, by "Geokarta" includes about 200 sheets the present coverage represents about 4% of the entire territory. Up to the end of 1957, 1388 sheets were published. In respect to the importance of the areas 64-200 copies of each sheet were printed.

(2) The basic national map at 1:10,000 scale: The sheets are trapezoids with dimensions $2'30''_{\phi} \times 3'45''_{\lambda}$ with 5 cm (0.5 km) constructed in the Gauss-Krueger projection with 3° zones and covering 23.3 km^2 at $\phi = 44^{\circ}$. The sheets are cut in the system of International map and until 1954 were coded in the same manner as USSR 1:10,000 sheets (for instance L-34-89-A-b-3). The sheets are reproductions of the 1:10,000 topographical manuscripts obtained by photogrammetrical survey or could be compiled from the reduced manuscripts (or sheets) of 1:5000 basic national map. The compilation and reproduction has been carried out in the manner similar to that of 1:5000 sheets.

The entire territory of Yugoslavia would be covered with about 12,000 sheets. The exact records about present coverage are unknown. The coverage discussed in periodicals largely would be in regions of Macedonia, Serbia, Montenegro, Serbia, Bosnia and Hercegovina. The areas surveyed photogrammetrically for the purpose of compilation of 1:10,000 topographical map cover more than 10,000 km^2 (430 sheets). The topographic material largely still is in the stage of compilation of manuscripts. From the periodicals it is evident that merely about 50 sheets were published covering the areas of Beograd, Novi Sad, Novi Pazar, Skopsko polje, Kočansko polje and part of the Beograd-Bar railroad (under construction).

(3) The 1:25,000 topographical map compiled from the 1:5000 basic national map: In the topographical survey at 1:25,000 scale carried out by GIJNA the cadastral planimetry in the areas covered by the Yugoslav cadastral survey has been utilized and by means of pantographic reduction included into 1:25,000 plane table sheets.

In 1952, the Cartographic Enterprise of P.R. Serbia "Geokarta" from the 1:5000 sheets of the basic national map compiled the 1:25,000 sheet Bezdan L-34-74-B-d (L-34-503-102-52-25/4). The sheet is cut in the system of International map with sheet lines, dimensions and grid identical with those used by GIJNA. Compilation was carried out at 1:20,000 scale by means of pantographical reduction and a careful generalization of features. Considering the cartometric aspects the sheet was reproduced, like 1:5000 sheets, in two colours.

This experimental sheet and the 1:5000 sheets of basic national map covering province of Vojvodina in order to coordinate the efforts in the production of 1:25,000 topographic map of Yugoslavia were evaluated by a special commission composed of 3 geodetic engineers of SGU and 2 majors of GIJNA. This commission in January 1953 recommended:

- compilation of the 1:25,000 sheets of the topographical map of Yugoslavia from 1:5000 sheets. By a minimal revision needed in this way there will be obtained about 100 sheets 1:25,000 scale covering Vojvodina;

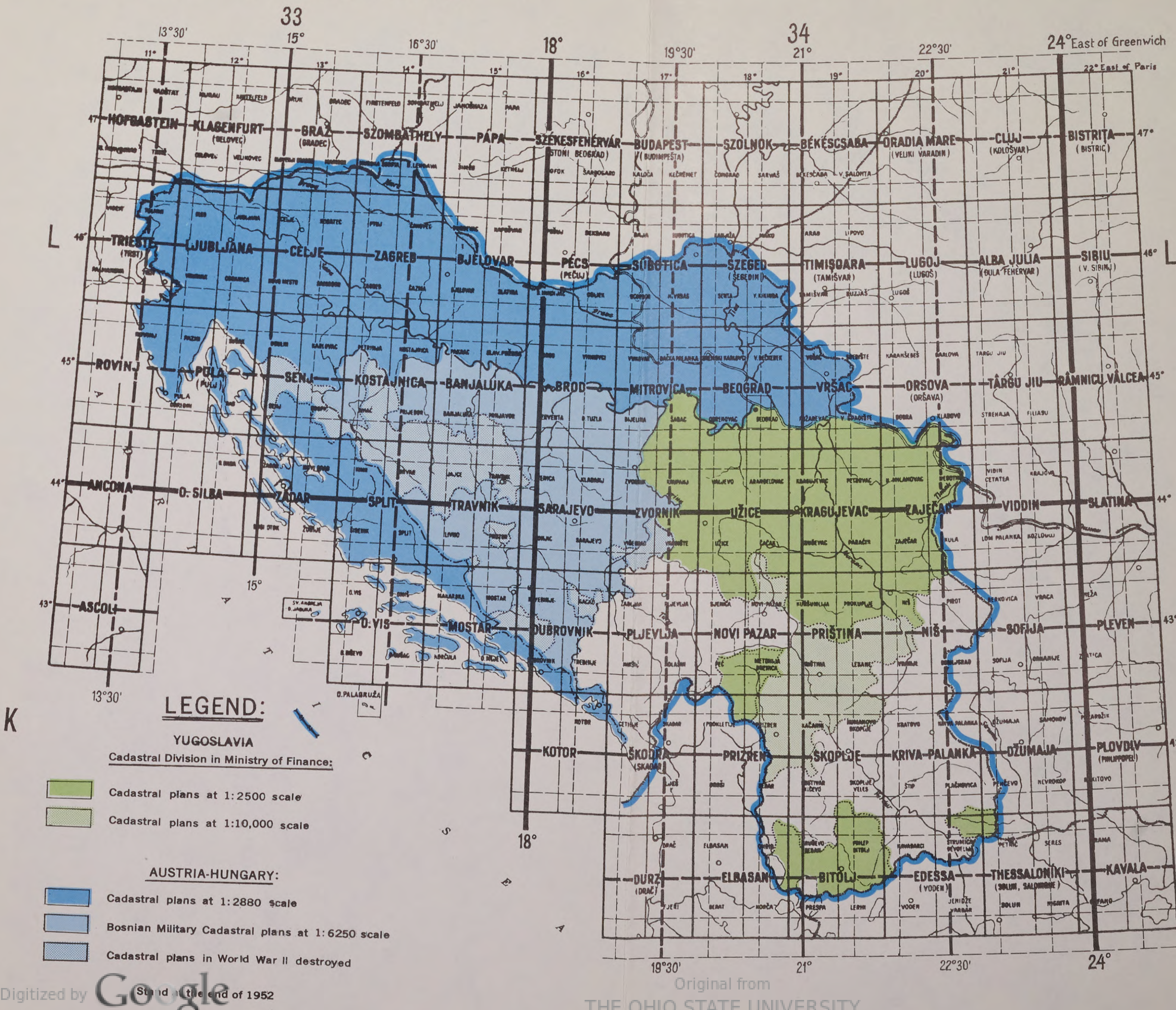
- the utilisation of 640 manuscripts at 1:25,000 scale covering areas of Serbia and Macedonia for the compilation of 1:25,000 topographical map. (The SGU published some of this planimetric sheets). Since these manuscripts obtained by means of pantographical reduction at 1:20,000 scale include only planimetry they should be photo-reduced to 1:25,000, mounted upon aluminum plates and the relief included by means of plane table tachymetry; or the vertical survey in the field according contemporary cadastral instructions should be completed, the expression of the relief included into 1:2500 cadastral planes and than 1:25,000 manuscripts supplemented with contours by means of pantographic reduction and generalization. The generalization of the relief should be carried out by experienced topographers and cartographers having a thorough knowledge of geomorphology. (See Inclosure 46).

The recommendation of the commission was approved by GIJNA and SGU but progress in the relization of this project is unknown.

With the introduction of the relief in the cadastral plans and its utilization in the compilation of topographical maps the Yugoslav surveying and mapping agencies GIJNA and SGU initiated a long desired collaboration by which all records of surveys (topographical and cadastral) will be utilized in a most rational manner eliminating entirely the duplications of field work. Evidently the combined efforts will result in increased production and higher accuracy of Yugoslav topographical maps.

Inclosure 46

YUGOSLAV CADASTRAL SURVEY



SECTION E

CONCLUSIONS

E. CONCLUSIONS

The topographical map is not merely a military necessity but also a cultural document of primary importance; it is a visiting card of a country to be shown for admittance to the cultural World. Therefore the creation of a topographic map requires profound study in which the application of methods and technics in the compilation, expression and reproduction have to be observed from various points of view. Since the map is a combination of geometry and art, its planning and shaping (also if the geodetic part is ignored), represents a highly complex problem.

A successful map-project is tougher than any mathematical problem, because in its solving there is nothing clearly defined, limited, right or wrong, but there is only a good or a poor solution.

A good solution should not merely meet the standards of accuracy, completeness and legibility, but should produce through the harmony in expression of all features, selection of symbols and colours upon the map-reader a psychological effect creating in his mind the impression that he is observing the landscape itself and not just reading the map.

In order to produce a good topographical map various test-sheets should be compiled and reproduced and the top scientists and artists, of a country in the field of cartography have to be consulted and their opinions of the tests and their recommendations considered. Since the production of a map is an important, lengthy and expensive undertaking it would be much wiser to spend enough time and money on testing than to produce hastily a poor map which later has to be improved through many additional editions. (The military situation, of course, could dictate the shortest possible procedure.)

In respect to the statements in this short introduction to conclusions it would be much too ambitious to close my study with a draft of a project for the compilation of a new topographical map which would cover the countries of the Danubian and Adriatic basins. Consequently, to the observations and conclusions expressed within the chapters of this study I would rather add some suggestions which could be considered in the final project for the compilation and reproduction of the aforementioned map.

I. SCALE 1:50,000

The cartographic material available for the compilation of a large scale topographical map of the Danubian and Adriatic basins consists of the maps (a few manuscripts) compiled from the topographical survey carried out by successor states in the period between the two World Wars, of the maps compiled from the reambulated manuscripts, of the III and IV Topographical surveys of the Austro-Hungarian Empire and of copies of manuscripts of the III Topographical survey with a coverage as follows:

1. Successor states topographical surveys:

1:20,000 16, 700 km^2 or 2.8%

1:25,000 74, 404 km^2 or 12.4%

1:50,000 135, 530 km^2 or 22.7%

2. Manuscripts of III and IV TS of AHE reambulated by successor states at scales:

1:25,000 IVTS 19,800 km^2 or 3.3%

1:25,000 IIITS 47,170 km^2 or 7.9%

1:50,000 IIITS 110,000 km^2 or 18.8%

3. Manuscripts of III TS of AHE never reambulated after World War I.

1:25,000 IIITS 194,500 km^2 or 32.5%

Since merely 15% of the cartographic material with total coverage 598.100 km^2 could be considered adequate for the compilation of a 1:25,000 topographical map for the new map the 1:50,000 scale should be adopted. Nevertheless the contemporary artillery due to the longer range and greater mobility prefers a 1:50,000 sheet covering an area of four 1:25,000 sheets.

II. GEODETIC FOUNDATION

1. International ellipsoid.

2. Universal Transverse Mercator projection:

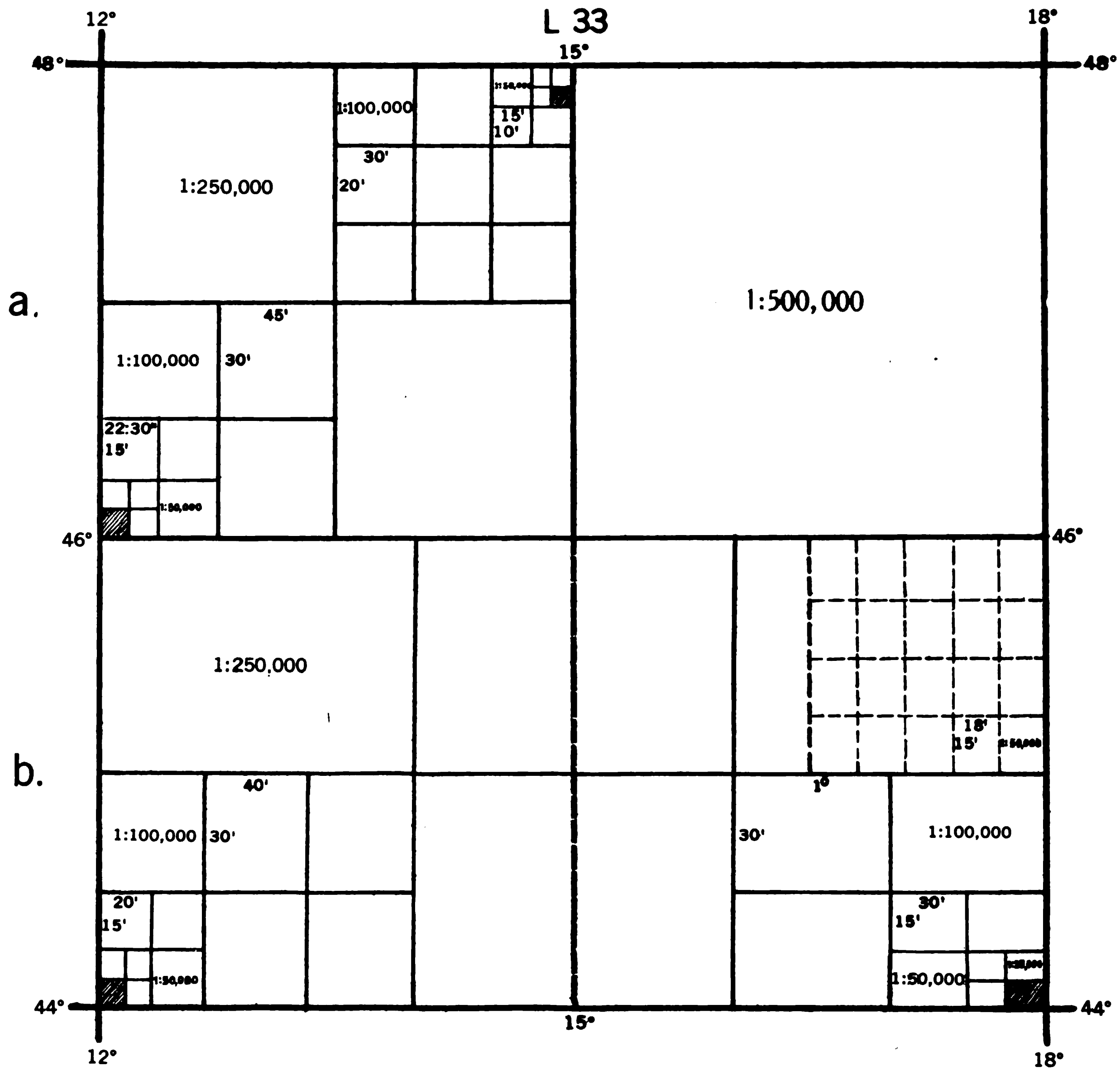
Considering the large area of mapping and the prospective derived maps (1:100,000, 1:250,000, 1:500,000 and 1:1,000 000), in which compilation the new 1:50,000 sheets as basic cartographic material will be utilized, the sheet cut, the size of the sheets and the inclusion of the 1:50,000 sheets into system of the sheet lines of smaller scale maps should be discussed. Since the meridians of the sheet cut of 1:1,000,000 International World Map coincide with the meridians by which the Zones of UTM projection are limited, with the adoption of UTM projection it would be logical to choose the graticule sheet cut in the system of the International World Map. In this case the subdivision, i.e. the size of the sheets of all prospective maps should be considered and in order to obtain a harmonic relation between the sheets of various scales the following principles insofar as possible have to be satisfied:

- quadripartite subdivision
- congruency of sheet lines
- the same size of sheets, which should be within limits of the field reproduction facilities
- the size of the 1:25,000 and 1:50,000 scale should correspond to the size of plane table used in the artillery
- the size of operational map should cover an area sufficient to include all elements of a motorized corps dislocated in movable war,
- the sheets of tactical maps used in the field are preferred to be smaller (handy) and the sheets of strategic (operational) maps used in the headquarters (offices) should be larger,
- the quadratic sheets are practical, but transverse rectangular sheets are more aesthetic.

These principles are based upon contradictory requirements; therefore an ideal solution - which would satisfy all of them - is impossible. Evidently this complex problem was solved in different manners in different countries. Some solutions had to satisfy imposed conditions, such as preservation of the size of old plane table sheets, as in West Germany. There are also proposals for a uniform sheet-cut of all maps, which should be adopted in all countries (Prof. Dr. Strzygowski), but up to the present time only the Warsaw pact countries adopted a uniform sheet-cut in the system of the International map, i.e. that used in USSR since 1931, which differ from Dr. Strzygowski's proposal. (USSR sheet cut is based upon 1:1,000 000 sheet of International World Map with dimensions 4° in latitude and 6° in longitude; meanwhile Dr. Strzygowski proposes as the basis a new $4^{\circ} \times 8^{\circ}$ sheet of IWM.)

Considering that in our case the following scales 1,000 000, 1:500,000, 1:250,000, 1:50,000 and 1:25,000 (?) were adopted, the consecutive scale relation between the sheets of these maps is 1:2 with one exception 1:2.5 between 1:100,000 and 1:250,000 scales. Since at a constant subdivision (1:4, 1:9 etc) the size of the sheet is tied with the scale in a free solution there would be only two sizes of sheets. (USSR and West Germany each has 3 sheet sizes.) In case the present 1:250,000 sheet with dimensions $1^\circ_\varphi \times 2^\circ_\lambda$ has to be preserved there will be three sheet-sizes. The suitable combinations in both cases are evident from the following diagram and explanations:

SHEET-CUT
IN THE SYSTEM OF INTERNATIONAL MAP



a. First case:

Scale relation: 1:2 1:2 1:2.5 1:2 1:2

Sheet subdivision: 4 4 9 4 4

Sheet sizes:

1:1,000 000	4° x 6°	
1: 500 000	2° x 3°	= 44.46 x 45.62 cm
1: 250 000	1° x 1°30'	
1: 100 000	20" x 30'	
1: 50 000	10' x 15'	= 37.05 x 38.02 cm
1: 25 000	5' x 7'30"	

There is only one break in the scale and in the subdivision and consequently two sheet sizes. With exception of unaesthetic quadratic sheets all other principles are satisfied.

Scale relation: 1:2 1:2 1:2.5 1:2 1:2

Sheet subdivision: 4 4 4 4 4

1:1,000 000, 1:500,000 and 1:250,000 as above.

1: 100 000	30' x 45'	
1: 50 000	15' x 22'30"	= 55.57 x 57.03 cm
1: 25 000	7'30" x 11'15"	

One break in the scale, consistent subdivision and two sheet-sizes. The sheets are quadratic and the size of the sheets of the tactical maps contrary to principles are larger than the sheet size of strategical maps.

b. Second case:

Since the 1:250,000 is obtained by subdivision of 1:1,000 000 sheet into 12 parts the sheet lines are not in sympathy with the 1:500,000 sheet.

Scale relation:	1:2	1:2	1:2.5	1:2	1:2
Sheet subdivision:	4	—	6	4	4

1:1,000 000 and 1:500,000 as in the first case.

1: 250 000 $1^\circ \times 2^\circ$ = 44.46 x 60.83 cm

$$\left.\begin{array}{lll} 1: & 100\,000 & 30' \times 40' \\ 1: & 50\,000 & 15' \times 20' \\ 1: & 25\,000 & 7'30'' \times 10' \end{array}\right\} = 55.57 \times 50.69 \text{ cm}$$

One break in scale relation and two breaks in subdivision, consequently three sheet sizes. The sheets of tactical maps still have adequate size and shape to be mounted upon the 60 x 60 cm planetable.

Scale relation:	1:2	1:2	1:2.5	1:2	1:2
Sheet subdivision:	4	—	4	4	4

1:1,000 000 and 1:500,000 as in the first case.

1: 250 000 $1^\circ \times 2^\circ$ = 44.46 x 60.83 cm

$$\left.\begin{array}{lll} 1: & 100\,000 & 30' \times 1^\circ \\ 1: & 50\,000 & 15' \times 30' \\ 1: & 25\,000 & 7'30'' \times 15' \end{array}\right\} = 55.57 \times 76.04 \text{ cm.}$$

In this case aesthetical but impractical sheets of three various sizes are obtained; particularly the sheets of tactical maps are not handy and could not be mounted upon the plane tables regularly used in artilleries (40 x 50 cm and 60 x 60 cm). Otherwise these 1:250,000 - 25,000 sheets have the same size as proposed by Dr. Strzygowski for the new international sheet cut in which the 1:1,000 000 sheet would have dimensions $4^\circ \times 8^\circ$ and would be subdivided into 16 ($1^\circ \times 2^\circ$) sheets at 1:250,000 scale. Consequently, in this case, in order to remain within 6° zones UTM projection the present 1:1,000 000 ($4^\circ \times 6^\circ$) and 1:500,000 ($2^\circ \times 3^\circ$) sheets were combined with the 1:250,000-25,000 sheets having sizes as proposed by Dr. Strzygowski. (All linear dimensions of sheets refer to the latitude of central parallel of the area concerned $\phi = 47^\circ$.)

The present 1:50,000 $13'_\phi \times 18'_\lambda$ sheet represents 1/80 part of the 1:500,000 $2^\circ_\phi \times 3^\circ_\lambda$ sheet. Its sheet-cut is neither in sympathy with the 1:250,000 $1^\circ \times 2^\circ$ sheet nor with 1:100,000 sheet of any combination. (20 of 15' x 18' sheets would compose one 1:250,000 sheet with dimensions $1^\circ \times 1^\circ 30'$.) Since in the composing of large scale maps the congruency of sheet lines is required and a quadripartite subdivision in the scales 1:100,000, 1:50,000 and 1:25,000 is preferred this question should be carefully considered.

Grid: UTM 2km (4 cm) grid. The 1km (2 cm) grid with which the present 1:50,000 sheets are provided appears too dense in respect to scale, having large and solid numbers showing kilometers printed within the sheets. Since the grid with the figures designating kilometers placed within the sheets represents a considerable cartographic burden damaging the appearence of the map, the density of the grid in respect to scale should be 4 or 5 cm and the kilometer figures placed only along the neat lines. Such a grid will completely satisfy artillery needs and would be in much better harmony with the contents of the map.

3. Triangulation:

Adjusted First Order Net of the European Triangulations into which all national triangulations (1st - 5th order nets) are, or have still to be incorporated.

4. Elevations:

Uniform European Leveling Net referring to the leveling datum Normal Amsterdam Peil (NAP). The relationships of the reference surfaces of the national vertical control in respect to NAP are as follows:

Austria	- 267 mm
Czechoslovakia (Lišov)	- 252 mm
Hungary (Nadap)	- 338 mm
Italy (old net)	- 116 mm
Italy (new net)	- 273 mm
Yugoslavia	- 253 mm

These values, resulting from preliminary adjustment of the Uniform European Leveling Net, should be used as blanket corrections in order to bring the elevations of the national vertical control based upon the precise leveling net into sympathy (such as to meet cartographic requirements) with the NAP. In cases where the elevations used in topographical surveys are not based upon the national leveling nets in adjustment of map elevations (benchmark, trig point and spot elevations) to the reference surface of NAP, in addition to blanket corrections, the local disparities in respect to the leveling net must be considered. Evidently these changes in elevations in a few cases (in plains, some summits, particularly in Czechoslovakia and Carpatho-Ukraine) would require small corrections of contours.

The elevations in the map should be shown as follows:

- Benchmarks of precise leveling in meters with two decimal places (centimeters).

- Trig points with elevations determined by means of trigonometrical leveling in meters with one decimal place (decimeters).

- Spot elevations in even meters.

III. CARTOGRAPHIC MATERIAL

The basic cartographic material which should be used in the compilation of the 1:50,000 map covering the countries of the Danubian and Adriatic basins has to be grouped into two parts, i.e. consistent and inconsistent cartographic material.

1. Consistent cartographic material.

Under consistent cartographic material should be considered the manuscripts and maps of successor states compiled from topographical surveys based upon a homogeneous geodetic foundation. The sheets of the following maps are considered consistent (See Inclosures 12 & 50):

AUSTRIA

1:25,000 Austrian map
1:50,000 Austrian map
1:25,000 AMS 871 (GSGS 4528) sheets (Multiplex).

CZECHOSLOVAKIA

1:5000 map of Prague and environs
1:20,000 topographical map
1:50,000 topographical map
1:25,000 topographical map of Protectorate

HUNGARY

1:25,000 topographical map (new survey and reambulation).
1:50,000 topographical map (1941-43 Topographical survey).

ITALY

1:25,000 topographical map (Italian and IV Austro-Hungarian Topo-surveys).

YUGOSLAVIA

1:10,000 topographical map (Boka Kotorska)
1:25,000 topographical map.

The sheets of the above-mentioned maps are positioned upon the national triangulations, i.e. the sheet lines, sheet corner values and grid are in sympathy with the triangulation as discussed for each map in the corresponding chapter of this study. The interior inconsistency of these sheets would be expressed by a mean square error $E_2 = \pm 10m$, hence the sheets could be positioned into the sheet line system of the new map by means of sheet corners. For this purpose the sheet corner values (geographic or rectangular) have to be transformed to UTM (ED, International Ellipsoid) coordinates by means of formulae used in the transformation of the coordinates of trig points of the corresponding national net. There is one exception, i.e. the sheets of 1:50,000 topographical map covering Transylvania (Hungarian 1941-43 topographical survey) have inconsistent sheet lines, but a consistent grid, therefore they have to be positioned by means of the grid intersections nearest to the sheet corners.

Consistent cartographic material covers merely 25% of the area concerned.

2. Inconsistent cartographic material

Into inconsistent cartographic material there have to be included manuscripts of the III Topographical survey of the Austro-Hungarian Empire and by means of their reambulation produced maps of successor states. Furthermore the larger part of the 1:50,000 sheets of the topographical map of Yugoslavia, compiled from the manuscripts of the topographical survey of Serbia, Macedonia and Montenegro, due to the poor composition of sheets, has to be considered inconsistent.

Since the displacement of sheet corner positions increases up to ± 85m and the mean interior inconsistency is ± 75m (maximal 320m), each of these sheets can not be positioned as a whole by means of sheet corners, but the parts have to be panelled by means of positions of identical trig points.

The sheets of the following maps are considered inconsistent:

AUSTRIA

1:25,000 copies of the III TS manuscripts

CZECHOSLOVAKIA

1:25,000 reambulated plane table sections
1:25,000 copies of the III TS manuscripts

HUNGARY

1:25,000 copies of the III TS manuscripts

YUGOSLAVIA

1:50,000 topographical map
1:50,000 AMS M702 (GSGS 4734) sheets.

Since the 1:75,000 sheets of the Austro-Hungarian special map are poorly composed, show the relief expressed only by generalized 100m contour lines, and in many cases do not entirely include the information obtained in the reambulation of the 1:25,000 manuscripts, the 1:50,000 sheets of the provisional Austrian map, the Hungarian topographical map, and the various German War maps obtained by the enlargement of the 1:75,000 sheets can not be utilized as basic cartographic material. Ofcourse, the basic cartographic material - copies of 1:25,000 topographic manuscripts - have to be supplemented with the information included into 1:75,000 and 1:50,000 sheets by field or photo revision.

IV. COMPILATION

The compilation should be carried out at 1:40,000 scale. To this scale the basic cartographic material has to be photo-reduced or enlarged.

The compilation of the map from the consistent cartographic material represents a routine procedure and therefore need not be discussed. Meanwhile the utilization of inconsistent material in the compilation of the map in order to obtain a satisfactory result with a reasonable effort, has to be carefully studied. One of the shortest procedures would be as follows:

1. The sheet lines and the grid have to be constructed and all available control plotted at the scale of compilation (1:40,000) by means of the coordinatograph. The sheet lines, grid and control have to be inked in red.

2. The black positive prints at exact scale of compilation (1:40,000) from the photography of cartographic material (1:25,000 copies of manuscripts and 1:50,000 map sheets) have to be produced upon stable transparent material such as astralon, ultraphan, Kodak-Klarzell.

3. The prints have to be fitted into constructed sheet lines be means of the best matching of horizontal control (identical trig points). The matching should be within limits of ± 0.3 mm, i.e. the positions of trig points on the prints in respect to the plotted positions would be matched with an accuracy expressed by mean square error E_2 = ± 0.1 mm. Since the matching of trig points with this accuracy hardly would succed over all print, the sizes and directions of displacements have to be studied in order to divide the print into the parts which then are individually matched. After matching, the prints are fixed and the gaps among the parts cartographically tied.

Evidently, in this positioning, where the sheet lines of the basic cartographic material are ignored and topography based upon heterogeneous geodetic foundation (unadjusted triangulation, different datum, ellipsoid, projection) is fitted into a new uniform system of sheet lines by matching the plotted positions of present homogeneous control, the success of this operation largely depends upon a sufficiant number of identical points. The dense cadastral and military triangulations largely carried out after the topographical surveys (III Topo-survey of AHE and Topo-survey of Serbia, Macedonia and Montenegro) would provide a sufficient number of identical points (cadastral trig points used in topo-survey and churches, towers, smokestacks, monuments and other landmarks determined by plane table triangulation) which would facilitate the positioning of inconsistent cartographic material by the method of panelling. The use of transparent prints in the positioning would reduce the slow and expensive scaling process to the minimum needed in a random test of positional accuracy and in proof of identity of those trig points in areas with sparse control for which other identity records are not available.

In areas not covered with available geodetic control of sufficient density (Croatia, Area A-1, See Inclosures 30 and 38) the Dr. Ledersteger's sheet corner corrections (See pp. 317-321 and Enclosure 38) have to be applied to the sheet corner values of 1:50,000 sheets of the topographical map of Yugoslavia as well as the northings of the sheet corners along the meridians $n^{\circ}15'$ and $n^{\circ}45'$ increased by 30m ($0''.994$). (See pp. 313-315). The corrected values of sheet corners have to be transformed to UTM (ED, International ellipsoid) and plotted into new sheets. The positional accuracy of sheet corner values of the Yugoslav 1:50,000 sheets in this area (area of Bosnian adjustment) is within ± 15 m (0.3mm), therefore a greater accuracy than 0.4 mm/1:40,000 in positioning of the sheet corners of prints should not be required, but the sparse control (some 1st and 2nd order points) have to be matched exactly and positions of the surrounding prints panelled by control held fixed. Evidently, in this area the interior inconsistency would be reduced only in those sheets having, together with the positions of sheet corners and identical trig points, a sufficient number of points to form a criterion for their decomposing and panelling.

The leading principle in this recasting operation is to make the basic cartographic material consistent, i.e. to fit graphically expressed contents of the map to the numerical data of the homogeneous geodetic foundation.

4. The composed prints fitted into sheet lines and tied to the control and grid, i.e. planimetrically brought into sympathy with the horizontal control in certain areas would need some corrections of the relief. Since the elevations have to be adjusted to the common leveling datum (NAP) and a large number of trigonometrical points with elevations determined after the topographical survey in this compilation will be included into new sheets, the contours have to be brought into sympathy with additional elevations without changes in general shape of the relief. With this correction of contours the production of consistent basic cartographic material is completed. The sheets, composed in this manner in order to produce a final, up to date, cartographic manuscripts, have to be supplemented with the additional information taken from supplementary and auxiliary cartographic material - various maps, photography, reports etc.

Despite the fact that selection of cartographic material to be utilized in the compilation and the assignment of its priority is a part of the technological project, (which evidently should be made after a careful evaluation of all available material for each individual sheet,) the following line of priority in general has to be kept:

- consistent basic cartographic material at 1:50,000 scale, such as 1:50,000 Austrian map, 1:50,000 topographical map of Czechoslovakia and 1:50,000 topographical map of Hungary, (reduction and generalization already completed);

- consistent cartographic material at 1:25,000 and larger scale,

- inconsistent cartographic material at 1:50,000 scale if compiled from 1:25,000 topo-manuscripts reambulated at 1:25,000 or 1:50,000 scale,

- inconsistent cartographic material at 1:25,000 reambulated, and

- inconsistent cartographic material at 1:25,000 scale not reambulated.

In cases where sheets of basic cartographic material include areas or topographic features not properly expressed, such parts should be copied or corrected from supplementary cartographic material if expressed with greater skill or realibility. For instance: The 1:25,000 AMS M871 multiplex sheets covering regions of Western Austria include the rocky areas of Alps with cliffs inadequately expressed; meanwhile the expression of the same cliffs in the inconsistent 1:25,000 manuscripts (copies) of the III Topographical survey based partly upon perspective appearence has high artistic value. On the basis of photogrammetric contours and expression of cliffs in old manuscripts a skilled topographer or cartographer would be able to provide the new sheets with the expression of the cliffs which would satisfy topographic and artistic aspects. The inconsistent sheets of 1:50,000 topographical map of Yugoslavia covering the Adriatic islands and coast in some places have an insufficiently accurate shore line which is better expressed on the AMS M702 multiplex sheets; therefore in the Yugoslav sheets the shore line and relief along it have to be corrected according to the AMS M702 sheets.

V. CARTOGRAPHIC REPRESENTATION

The original topographical map is a geometrical design of the landscape representing its outward appearence, i.e. the shape of of surface, hydrography, vegetations, settlements and communications, by means of orthogonal projectioning in the horizontal plane. The contents of topographical maps obtained by plane table survey or by photogrammetric compilation have to be graphically expressed in a manner which would preserve the accurate position and planimetric shape (if scale permits) of the features and thus provide the opportunity for cartometric use of the map and also produce the best legibility.

Since the three dimensional relief and solid objects in the plane can not be correctly expressed, and because a large number of features in respect to the scale of maps can not even be expressed planimetrically, conventional symbols (topographic, cartographic symbols) are used in the cartographic expression. Despite the fact that these symbols developed through the centuries from the perspective drawings of features to intuitive (stylized) and abstract symbols used in contemporary mapping, the topographical map still remains a portrait of the landscape, though in a form which is not only stylized but even abstract, and preserves the same gradation in the representing of features as it exists in nature.

The military map is a topographical map and not a special (thematic) map, as it is often incorrectly considered to be; hence the principles applied in the compilation of topographical maps are valid for compilation of military maps. Certain emphasis (cartographic weight) usually given to the expression of orientation points (landmarks) and communications is not a sufficient reason to consider the military map to be a special map. Since the cartographic representation applied in the compilation of military maps is an established procedure regulated by specific instructions, standard topographical symbols, and master sheets of each particular country it is appropriate here to include only such suggestions as would be conducive to improvement of aesthetic appearence, legibility, accuracy and completeness of the 1:50,000 topographical map covering the considered area.

1. Topographical symbols.

The development and topography of a country have considerable influence upon the selection of the topographical symbols and their variances in number, size and shape. For instance, it is easy to understand that the churches, chaples, castles, towers and ruins are characteristic of European landscape and are the most important landmarks (orientation points) of which a large number are trigonometrically determined. Considering the American landscape, with sky-scrapers and scores of smokestacks, the importance of those objects as landmarks is minimal. Such examples could be cited in respect to other objects, features, and countries; therefore in any attempt to obtain a successful representation of another country it is possible neither to create universal topographical symbols (there would be too many) nor to apply topographical symbols unique to a country having different characteristics in development and topography. Consequently in the mapping of foreign countries some native symbols have to be adopted or equivalent symbols added to the domestic standard symbols. In the case of the compilation of the 1:50,000 topographical map of Danubian and Adriatic basins the following symbols should be added to the domestic standard symbols, or native symbols adopted and explained within the marginal information.

Church with two belfries
Church as trigonometric point
Castle which could not be shown planimetrically
Ruins
Monument
Tower
Water tower (reservoir)
Alpine hotel (shelter)
Smokestack
Hops
Hedge

The symbols of trigonometrically determined objects (landmarks) should be combined with the symbol of the trig point which indicates the exact position.

The symbols of the most prominent landmarks, such as churches, towers and smokestacks, which serve in the orientation of the map and in determination of position by means of resection, should be somewhat emphasized (made larger) and oriented to the north (except smokestacks if shown by circle); they should have the same distinctive appearence on the map as in nature.

Hops as vegetation substantially differ from vineyards (as a barrier and as camouflage) and should not be shown by the same symbols. Vineyards are much more permanent as vegetation than hops.

Hedges should be shown by rows of small green circles or dots, but not by black lines which do not differ from symbols of walls and fences.

2. Populated places:

The representation of the built-up areas (settlements) is not only one of the oldest, most interesting and most discussed parts of cartography, but also the most important part with the exception of expression of relief. The military importance of populated places, cities particularly as centers of defense and communication and as places of living and recreation was reamphasized by experiences in World War II. Consequently it is an essential requirement of any contemporary topographical map that populated places be represented in such manner that all characteristics in respect to the extent of urban area, type, structure and connections with relief, drainage and communication are clearly expressed. Careful study of this cartographic element is most important because the beauty and legibility of the map and the satisfaction of military requirements depend upon proper representation of populated areas.

The topographical map at 1:50,000 scale usually is compiled from the 1:25,000 topographical map or manuscripts; therefore in the process of compilation the contents included into the 1:25,000 map have to be reduced and generalized. The generalization has to be carried out in such a manner that all characteristics of a settlement are preserved and the original expression is not distorted. The process of generalization is one of the most complicated parts of compilation and requires careful study of each individual settlement by an experienced cartographer or compiler who is able to reduce the number of buildings and small blocks without change of the general form of the entire design. Since in this case the 1:50,000 topographical map will be our largest scale tactical map of the area concerned and has to be used by company commanders, platoon and even patrol leaders the generalization should be done even more carefully.

In the representation of a populated place at 1:50,000 scale the following rules have to be observed:

- Outline (external edge) of a compact settlement, consisting of walls, fences around gardens and orchards, important for defense, has to be preserved.

- Thoroughfares should be filled with colour as are all weather roads, other main streets should be emphasized (0.7mm); streets should be shown with 0.5mm or in natural width to scale, if larger; all enlargements, places and squares have to be preserved, but some narrow streets not practicable for driving, and streets with stairs, omitted.

- The landmarks and main buildings significant to the administrative (Public buildings), cultural (churches, museums, castles, monuments), and economical (factories, power plants, mills etc) character of the populated place, have to be shown planimetrically sometimes even slightly emphasized.

- The trig points, landmarks, street intersections, outline of the settlement, and all isolated objects have to be positioned exactly; meanwhile, since the width of many streets is less than 25m, the representation of blocks at 1:50,000 scale will require some slight positional shifts. The distinction between positions of buildings at the edge of the streets and of those located somewhat inside has to be respected. Smokestacks of factories should be shown always in exact position.

- In order to provide the best possible legibility in populated places, landmarks, public, cultural, industrial, and other important buildings should be shown in solid black planimetric form (or with standard symbols) if the red screen is used in the expression of blocks in built-up areas. The symbols, streets, and roads should be cleared of any tints or screen, such as shading, vegetation and fill of blocks and water. The lettering inside the settlements should be reduced to a minimum.

3. Drainage:

Due to their vital importance special care should be taken to include all springs, wells, cisterns (water tanks) and water supply lines in karstic regions. Shore lines of the cartographic material produced by method of plane table survey should be revised by aerial photography. The bridges and culverts (many of them are checked spot elevations) along roads and railroads should not be omitted.

4. Relief:

In respect to the expression of the most important element of the map - the relief - it should be stated that the 1:50,000 sheets of series M705 and M709 (there are only two sheets covering hilly land) would satisfy military needs. The standard contour interval of 20m with auxiliary 10m and 5m contours should be retained in the mapping of the countries in the Danubian and Adriatic basins. (See pp. 210-212). The contours in contrast to finely drawn communications, drainage and undersized lettering of the names of populated places appear too heavy; therefore finer engraving is desirable. The fills, cuts, levees and ravines are too much exaggerated and require much finer representation.

Cartographic representation of cliffs and large rocky areas is the most difficult part of the expression of relief. Since the topography of large rocky areas can not be expressed by standard symbols or merely by the inscription "Rocky" various techniques of expression of cliffs were developed, among them:

- Method of cliff-hachuring (Swiss manner) by which the topographer observing the landscape at an oblique illumination produces a plastic intuitive drawing of cliffs based upon measured salient points. (Similar to this method are Austro-Hungarian and Italian method of expression of cliffs. See page 192).

- Method of combination of photogrammetric cliff-contours and hachuring or shading. This method, first applied after World War I in Switzerland and Austria, gives in respect to position and elevation a geometrically correct design of the rocky areas with their characteristic shape, structure, stratas and folds emphasized by means a supplementary hachuring at oblique illumination: (The method is applied in the 1:25,000 and 1:50,000 maps of Switzerland and in the Austrian 1:25,000 and 1:50,000 maps).

The first method of cliff-hachuring (Swiss manner) produces a great similarity of drawing in respect to the landscape and an artistic expression of the cliffs but does not provide cartometric accuracy and elevations. Meanwhile the second method of expression of cliffs by means of combination of photogrammetric contours and hachuring or shading produce exact geometrical expression, and provide cartometric accuracy and elevations, with a lower degree of plastic effect. Consequently in the expression of the cliffs in contemporary large scale mapping os Switzerland, Germany and Yugoslavia a combination of both methods is applied. The cliffs are constructed on the basis of photogrammetric contours with old plastic hachured drawing as the dominating element, connected and supplemented with 20m contours in flat and 100m index contours in steep parts of the rocky regions.

Consideration should be given to the manner of expression of cliffs by a cliff-skeleton outline consisting of photogrammetrically-compiled contours tied together with lines showing the drainage lines, i.e. the edges of crests, ridges, spurs and ribs. The degree of plastic shown by such a skeleton-outline should be corroborated by cliff-hachuring or shading at oblique illumination shown on the map with a color which differs from the color of the skeleton. Since the photogrammetrically compiled (mechanically obtained) skeleton composed of geometric lines is the carrier of the shape and characteristic of the cliffs, the subordinated hachuring and shading could be carried out also by cartographers who lack the highest artistic imagination required for the expression of cliffs in the Swiss manner. Due to this advantage the proposal of Dr. Rabensteiner (See [145]) should be considered. The application of this manner evidently is possible in a new photogrammetric compilation, but in respect to our project it could be applied in to expression of cliffs compiled from AMS M871 multiplex sheets. In this case the drainage lines have to be constructed upon photogrammetric contours.

Considering the cartographic material available in this project, the variety in manner of expression of cliffs and elements included into maps upon which the expressions are based and the manner in which a common and uniform expression could be produced, the method of combination of cliff hachuring at oblique illumination and index contours shown in the cliffs is recommanded:

The expression of large karstic regions also represents a cartographic problem in which solution two requirements, insofar as possible, have to be satisfied, i.e. the organic tie of numerous details has to be shown by means of auxiliary contours and the prominence of the remainder of primary ridges and valleys distorted by karstic erosion should be preserved. These parts of remaining ridges and valleys in otherwise chaotic configuration of Karst, are of primary importance for the orientation in the field.

Though the expression of relief by means of contours in the present M705 and M709 1:50,000 sheets satisfies military requirements, there is no doubt that the relief expressed by the combination of contours and shading would make the map more picturesque, and even of greater importance, more legible to inexperienced map readers.

In large scale mapping of some countries experiments were made in order to improve the legibility of relief by introduction of hypsometric tints. All these tests pointed to a conclusion that the hypsometric tints are an element which should be used in the expression of relief in maps smaller than 1:200,000 scale.

5. Vegetation.

Vegetation is not merely important as a characteristic part of the landscape to be shown on the map but also as an element of camuoflage. Consequently the orchards around the settlements, the tree lines along the roads, areas sparsely covered with trees and bushes should not be omitted from a 1:50,000 scale map and parks in cities, towns and around the castles shown as forests.

6. Nomenclature.

Determination of the quantity of names and adequate selection of. type, size and graduation of lettering are the principal factors in producing legibility and aesthetic appearence of any map. At first glance the attention of the average map reader is attracted by the names on the map, therefore many map readers are inclined to judge the reliability of a map by the lettering and its harmony with the entire contents of the map. The AMS sheets of M705 and M709 series in general have a pleasing appearence, particularly sheet 7433-IV of M709 series. The harmony of colours and drawing would satisfy the average, but not the artistic-minded map reader; the reproduction in respect to sharpness and color register is excellent; consequently if consideration is given to the remarks and suggestions of this chapter, these sheets could serve as a test in the mapping project of the area concerned. In respect to the nomenclature the general appearence gives the impression of certain monotony. The area names, the names pertaining to relief and hydrography, and spot elevations are adequate in style and size. Meanwhile the place names are undersized and should have a richer graduation in size which would grant that the places of greater importance attract at first glance the attention of map readers. The graduation of place names is based upon two principles; i.e. population and the administrative importance of places. In the countries with old populated places having a long history of development during which the type and character of a settlement was formed, the administrative importance of a populated place is closely tied with general living conditions which are important also from the military aspect; therefore a certain degree of consideration should be given to this factor and the graduation should not be based strictly upon population. The place name of a small town which is the center of a community or even of a district with offices, school, shops, pharmacy, hotels etc. should by size or type of letters distinctively differ from the place name of a village having an even larger population.

Considering these general statements about the nomenclature in respect to the sheets of series M705 and M709 the following remarks could be made:

- The average size of letters used in the place names is less than 1.5mm (it would be appropriate for the map at 1:100,000 scale); meanwhile the average size of corresponding letters in European 1:50,000 scale maps is 2.5-2.8mm. The place name of the town (Reghin) shown with 1.5mm letters is not in harmony with the surface of its planimetry covering 18 cm^2; moreover, in respect to the planimetry it is not visible at first glance.

- The lettering of names of villages in comparison with the lettering of objects is too small and should be two points larger.

- The type of letters used for the names of dispersed villages should not differ from that used in the names of compact villages. Since the names of small areas (usually parts of forests, meadows or fields) in respect to the names of populated places are secondary in significance, the use of the area type of lettering in names of dispersed settlements is not a successful solution.

- Names such as: Church, Cemetery, Monument, Factory, Sawmill and Brickworks within settlements should be omitted; such objects are sufficiently expressed by appropriate symbols. In case the objects are isolated or have a particular significance and have proper names as: National Cathedral, Gun Factory, Citadel or name of Saint of an isolated church, these names should be included.

- The abbreviations BM, VABM for benchmarks are superfluous, symbol and elevation shown with two decimals are sufficient.

By the combined factors of shape, size and graduation of the lettering the grade of importance of places and objects has to be emphasized without a substantial disturbance of the relief and cultural features.

VI. ACCURACY

Considering the variety of the basic cartographic material which has to be utilized in the compilation of the sheets of 1:50,000 map of Danubian and Adriatic basins, the mean values of positional and vertical accuracy of prospective sheets, if computed, would have rather a theoretical signifiance and would not clearly express the accuracy which should be expected. Since the expected accuracy will vary within the limits expressed by accuracy of consistent cartographic material and the accuracy by which we succeed to position and to correct the inconsistent cartographic material, these accuracies have to be determined.

The horizontal (positional) accuracy. The accuracy of the sheets of 1:25,000 topographical map of Yugoslavia represents a mean value among the slightly varying accuracies of the sheets of

1:20,000 - 1:25,000 topographical maps of successor states (See Inclosure 49), compiled from the topographical surveys carried out at the same scale between the two World Wars, which constitute the consistent cartographic material. Since only for the Yugoslav 1:25,000 sheets the numerical data of a check survey were available to make possible an analytical determination of the horizontal and vertical accuracy of these sheets, results of this analysis were considered as an expression of the accuracy of consistent cartographic material. (See pp. 338-345).

a. The positional accuracy of the planimetry of these sheets is expressed by the mean square error

$$E_2 = \pm 12.92 \text{ m} = \pm 0.517\text{mm}/1{:}25{,}000,$$

hence the positional accuracy of the planimetry of the newly-compiled sheets reproduced at 1:50,000 scale would be as follows:

mean square error of planimetry of the 2:1 reduced blue lines of the sheet	± 0.258mm/1:50,000
mean square error of drafting	± 0.062mm
mean square error of reproduction	± 0.2mm

$$E_2 = \pm\sqrt{0.258^2 + 0.062^2 + 0.2^2} = \pm 0.33\text{mm}$$

$$E = \pm 0.22\text{mm}$$

Since the positional accuracy of the planimetry of these sheets is expressed by the mean square error

$$E_2 = \pm 16.50 \text{ m} = \pm 0.33\text{mm}/1{:}50{,}000$$

87% of points would be positioned with an accuracy within limits of 0.5mm, or 99.7% within limits of 1 mm.

These values, expressing the mean positional accuracy of the planimetry of the consistent cartographic material, should be considered the upper limit of positional accuracy by which the planimetry would be plotted in the newly-compiled sheets.

b. Considering that the panelling of the inconsistent cartographic material by means of identical trig points would succeed within limits of ± 0.3 mm (at 1:40,000 scale actually 0.375 mm) and the positions of the detail points in the topographical survey were determined with and accuracy expressed by mean square error ± 0.45 mm (probable error ± 0.3 mm) the detail points of planimetry in the newly compiled sheets would be positioned with an accuracy expressed as follows:

mean square error of planimetry in manuscript $E_2 = \pm\sqrt{0.1^2 - 0.45^2} = \pm 0.46$mm
mean square error of drafting.................................. $= \pm 0.062$mm
mean square error of reproduction............................. $= \pm 0.2$mm,

hence

$$E_2 = \pm\sqrt{0.46^2 + 0.062^2 + 0.2^2} = \pm 0.51 \text{ mm}/1{:}50{,}000$$
$$E = \pm 0.34 \text{ mm.}$$

Because the positional accuracy of the planimetry in the sheets compiled by means of panelling is expressed by mean square error

$$E_2 = \pm 25.50 \text{ m} = \pm 0.51 \text{ mm}/1{:}50{,}000$$

68% of points of planimetry would be positioned with an accuracy within limits ± 0.5 mm, or 95% within limits of ± 1 mm. These values represent the lower limit of positional accuracy by which the planimetry would be plotted in the newly compiled sheets.

Since the requirement that the panelling should be done with an accuracy of position of trig points expressed by a maximal error ± 0.3 mm (actually nearly 0.4 mm/1:40,000), may be considered too rigorous (though practically possible) it should be stated that, if the procedure of panelling is carried out with an accuracy within limits of ± 1 mm ($E_2 = \pm 0.33$ mm) the planimetry would be positioned with an accuracy expressed with the mean square error $E_2 = \pm 0.60$ mm or probable error $E = \pm 0.40$ mm; hence 59% of planimetric points would be positioned with an accuracy within ± 0.5 mm and 90% within ± 1 mm.

Consequently, the sheets compiled from inconsistent cartographic material by method of panelling will have a positional accuracy of planimetry ranging within 90-95% of points plotted with an error smaller than 1 mm ($E_2 = \pm 0.5$-0.6 mm), and would represent a good B class map. In respect to the magnitude of probable error ranging between ± 0.34-0.40mm (orientation points ± 0.3mm and detail points up to ± 0.4 mm) it could be concluded that these sheets would meet artillery requirement for positional accuracy. Meanwhile, the sheets compiled of consistent cartographic material, among which the Yugoslav sheets having planimetry positioned with an accuracy expressed by the mean square error $E_2 = \pm 0.33$ mm and probable error $E = \pm 0.22$ mm, i.e. 87% of points positioned with an error within limits of 0.5 mm, or 99.7% of points within limits of 1 mm represent the mean accurate sheets, certainly would meet the artillery requirements and would represent an excellent B class map with an considerable number of sheets in A class, i.e. having more than 90% of points positioned with an error limited by 0.5 mm.

2. Vertical accuracy.

The best result of the analysis of vertical accuracy of contours in the Yugoslav 1:25,000 sheets is expressed as follows:

$$Eh_2 = \pm 2.01 \text{ m} = 98.7\% \text{ within } \frac{CI}{2} (5m), \text{ or}$$

by formula of Prof. Koppe

$$Eh_2 = \pm (0.32 + 6.1 tg\, \alpha) \text{meters.}$$

Considering the 2:1 reduction of scale, change of contour interval from 10 to 20 meters and redrafting of the relief the accuracy with which the contours in the newly compiled 1:50,000 sheets would be drawn or the accuracy of the elevations which for the purpose of artillery from contours of these sheets could be interpolated would be expressed as follows:

$$Eh_2 = \pm 2.84 \text{ m} = 92.4\% \text{ within } \frac{CI}{2} (10m), \text{ or}$$

by Koppe formula

$$Eh_2 = \pm (0.45 + 8.6 tg\, \alpha) \text{meters.}$$

Meanwhile the lowest vertical accuracy with which the contours in the 1:50,000 sheets of topographical map of Yugoslavia, compiled from 1:25,000 manuscripts of the III Topographical survey of the Austro-Hungarian Empire and reambulated by Yugoslavs at 1:50,000 scale, are drawn is of the following magnitude:

$$Eh_2 = \pm 8.75 \text{ m} = 74.5\% \text{ within } \frac{CI}{2} (10m), \text{ or}$$

by Koppe formula

$$Eh_2 = \pm (4.2 + 20 tg\, \alpha) \text{meters.}$$

Consequently, the vertical accuracy of contours in the newly compiled sheets would range between

$$Eh_2 = \pm 2.84 - 8.75 \text{ m} = 92.4\text{-}74.5\% \text{ within } \frac{CI}{2} (10m), \text{ or}$$

by Koppe formula

$$Eh_2 = \pm (0.45 + 8.6 tg\, \alpha) \text{ to } \pm (4.2 + 20 tg\, \alpha) \text{ meters;}$$

hence, there will be a certain number of sheets compiled from the inconsistent cartographic material having contours drawn with an accuracy which would not meet the artillery requirements prescribed for the 1:50,000 sheets $Eh_2 = \pm (1.5 + 15. tg\, \alpha)$meters.

3. The accuracy standards and the maps.

The accuracy standards for the horizontal (positional) and vertical accuracy of the maps are based upon the Gaussian law of errors. The accuracy standards prescribed in different countries vary in rigorousness and in manner of expression.

a. The horizontal (positional) accuracy, with which planimetry is plotted into maps, in European countries expressed by the mean square error

$$E_2 = \pm\sqrt{\frac{[\varepsilon\varepsilon]}{n}}$$

meanwhile the vertical error with which contours are drawn usually is expressed by formula of Prof. Koppe

$$Eh_2 = \pm\ (c + k{\cdot}tg\ \alpha)\text{meters.}$$

b. The USA National standards of map accuracy are expressed by counting of errors lying below a fixed limit i.e.

- the requirements for horizontal accuracy are such that 90% of the points have to be plotted with an error smaller than 0.5 mm (Class A) or smaller than 1.0mm (Class B). This expression corresponds to the mean square error $E_2 = \pm\ 0.3$ mm ($1.66\ E_2 = 0.5$mm) or probable error $E = \pm\ 0.2$ mm used in artillery (Class B: $E_2 = \pm\ 0.6$ mm and $E = \pm\ 0.4$ mm).

- the requirements for vertical accuracy are such that 90% of the errors with which contours are drawn should be of a smaller magnitude than one half of the contour interval (Class A) or smaller than one contour interval (Class B.) Evidently, the relation between these requirements is similar to the above expressed, i.e. $1.66\ E_2 = \frac{CI}{2}$ in class A or $1.66\ E_2 = CI$ in class B.

The percentage of errors for each value of n times mean square error ($0.1E_2$, $0.2E_2$.....$3.3E_2$) could be computed by formula.

$$N\% = 100\sqrt{\frac{2}{\pi}}\ \left(n - \frac{n^3}{6} + \frac{n^5}{40} - \frac{n^7}{336} + \frac{n^9}{3456} \ldots\ldots\right) \text{*} \qquad [39]$$

c. The USA National standards of map accuracy and the results of the accuracy tests of the topographical manuscripts of the surveys carried out in European countries in the period between the two World Wars: The horizontal (positional) accuracy resulting from the tests of the manuscripts of the topographical surveys carried out in Europe between the two World Wars is expressed by mean square error

$$E_2 = \pm\ 0.45 \text{ mm } (E = \pm\ 0.3 \text{ mm});$$

hence only 73% of planimetric points are plotted with the error smaller than 0.5 mm (97.5% with the error smaller than 1 mm). Such accuracy satisfies the artillery requirements.

The accuracy of the maps reproduced at the same scale would be expressed as follows:

* Jordan-Eggert: Handbuch der Vermessungskunde Bd. I Ausgeichungsrechnung, p. 599; Stuttgart 1920, (7 edition).

$$E_2 = \pm\sqrt{45^2 + 0.062^2 + 0.2^2} = \pm\ 0.50\ mm;$$

therefore 68% of planimetric points will have a positional error smaller than 0.5 mm and 95% smaller than 1.0 mm.

Since the USA requirements for horizontal (positional) accuracy of the maps if expressed in terms of probable, mean square, and maximal error areof the following magnitudes

$$E = \pm\ 0.2\ mm;\ E_2 = \pm\ 0.3\ mm \text{ and } E_3 = \pm\ 0.9\ mm;$$

the planimetric points have to be plotted with an error smaller than 1.0 mm. These requirements hardly will be satisfied in any topographical survey. The instructions in European countries permit a tolerance that planimetric points in forest regions could be plotted with an error within limits of 1 mm or even more (German instructions for 1:5000 map permit an $E_3 = \pm\ 7\ m = \pm\ 1.4\ mm$). The USA requirements can be satisfied only in the photogrammetric compilation by 1st order instruments such as stereoplanigraph and autograph providing a plotting accuracy expressed by $E_2 = \pm\ 0.2\ mm$, but not by multiplex having a plotting accuracy ± 0.5-0.6 mm.

Considering the errors made in composition of cartographic manuscripts (caused by shrinkage of paper), error of drawing $E_2 = \pm\ 0.062\ mm$) and error of reproduction $E_2 = \pm\ 0.2\ mm$, the maps reproduced at the scale of topographical survey could even less than the manuscripts meet the USA standards for horizontal accuracy.

Consequently, it is evident that such maps as would meet the USA standards for positional accuracy can be produced only by the reduction of scale of basic cartographic material (manuscripts or maps) at a ratio 2:1 or larger, using in the compilation the stable material as a plotting and drawing base. Such maps are the new German 1:25,000 and 1:50,000 sheets obtained by reduction of the 1:5000 topographical basic map and 1:25,000 and 1:50,000 sheets of the topographical map of Switzerland compiled by means of reduction of cadastral 1:5000 and 1:10,000 manuscripts.

The USA standards prescribed for the vertical accuracy of maps are designed for the maps with the contour intervals changing with the steepness of slope. Although not too rigorous they are not appropriate for application in evaluation of maps with standard basic contour intervals. The tolerance of one half contour interval, if a standard basic contour interval, for instance 20 m is used, corresponds to $E_2 = \pm\ 6$ m and is applicable to a slope between 20°-30°, above 30° it is too rigorous and in flat land four times too liberal.

The Koppe formula still used in the evaluation of the vertical accuracy of the maps of European countries

$$Eh_2 = \pm\ (c + k \cdot tg\ \alpha) \text{meters}$$

with the constant c takes care of the accuracy in the plains and with its second term $k \cdot tg\alpha$ along with growing steepness gradually increases the magnitude of tolerance.

The following standards for vertical accuracy of contours in European maps, prescribed by instructions, for comparative purposes should be mentioned:

1:5000 basic topographical maps of Germany, Hungary and Yugoslavia

$$Eh_2 = + (0.4 + 5tg\,\alpha)\text{meters}; \qquad [35]\ [4]$$

1:5000 and 1:10,000 plans of Switzerland

$$Eh_2 = + (1 + 3tg\,\alpha)\text{meters}; \qquad [11]$$

1:25,000 topographical map of Switzerland

$$Eh_2 = + (1 + 7tg\,\alpha)\text{meters, and} \qquad [11]$$

1:50,000 topographical map of Switzerland

$$Eh_2 = + (1.5 + 10tg\,\alpha)\text{meters.} \qquad [11]$$

In the recent German professional literature new expressions for evaluation of the vertical accuracy of contours are discussed. The vertical error as expressed in Koppe formula is absorbed by the horizontal error $(c \cdot \cot\alpha + k)m$ because of their functional relation, therefore the horizontal error into which have to be included positional errors caused by error of direction and error of curvature of contours is proposed to be used in the evaluation of accuracy of contours.[40][64][113]

TABLES

Inclosure 47

ACCURACY OF OBSERVATIONS
OF 1ST ORDER TRIANGULATIONS OF EUROPEAN COUNTRIES

No.	Country	Date	No. of triangles	Instruments used	m_a	Δmax
1	Albania	1931–32	71	Starke-Salmoiraghi	±1″.57	5″.49
2	Austro-Hung. Empire	1862–96	1250	Ertl, Reichenbach Starke & Kammerer	0.916	8.159
3	Austria	1920–38	65	Starke & Kammerer, Wild T3	0.294	1.248
4	Belgium	1853–73 1945–53	219	Gambey, Beaulieu, Wanschaff Wild T3	0.892	4.096 <1.0
5	Bulgaria	1922–37	114	Hildebrand, Bamberg, Wild T3	0.40	2.88
6	Czechoslovakia	1920–27 1940–55	411 227	Fennel, Breithaupt, Frič Chasselon, Hildebrand, Fennel Wild T3	0.894 0.382	5.213 2.0
7	Denmark	1926–33	64	Hildebrand	0.43	1.823
8	England	1783–1853 1935–38	 208	Ramdsen, Troughton & Simms Tavistock	1.83 0.79	
9	Finland	1920–31	168	Hildebrand	0.32	1.46
10	France	1870–92 1899–1937		Brunner, Chasselon Brunner, Chasselon	0.97 0.59	
11	Germany	1870–1937		Ertl, Pistor, Martin, Wanschaff Reichenbach, Bamberg etc.	 0.35	
12	Greece	1920–35		Hildebrand, Wild T3	0.57	<3.0
13	Hungary	1933–38 1948–53	89 132	Starke & Kammerer, Wild T3 Wild T3	0.40 0.462	 <2.0
14	Italy	1862–1932 1932–43	 59	Repsold, Starke & Kammerer Pistor, Reichenbach-Brunner Wild T3	 0.93 0.46	
15	Latvia	1923–37	41	Hildebrand, Bamberg, Fennel	0.28	1.66
16	Lithuania	1927–37	71	Hildebrand	0″.40	1″.80
17	Netherlands	1920–37	119	Wanschaff	0.42	
18	Norway	1906–36 1937–49	 56	Olsen, Bamberg, Repsold Wild T3	1.20 0.57	 2.395
19	Poland	1927–35 1945–56	122	Bamberg, Fennel, Wild Wild T3, Aerogeopribor TT″/6″	0.56 0.46	2.682 1.86
20	Portugal	1864–86	139	Repsold, Pistor, Brunner	1.295	
21	Romania	1920–37	71	Brunner, Gautier, Cooke Starke & Kammerer, Wild T3	 0.80	 4.514
22	Spain	1861–84 1930–33	235 34	Repsold, Pistor, Brunner, Kern Wild T3	1.059 0.57	 2.60
23	Sweden	1903–38 1939–53	170 222	Wanschaff, Hildebrand Wild T3	0.41 0.40	
24	Switzerland	1861–67 1910–22	40 59	Kern Kern, Hildebrand	0.86 0.23	
25	Turkey	1940–53	981	Wild T4, Hildebrand	0.67	4.064
26	USSR	1936	348	Hildebrand, Bamberg	0.62	3.02
27	Yugoslavia	1902–48 1948–57	595 45	Kern, Starke & Kammerer, Fennel Wild T3	0.89 0.45	4.980 1.340

REMARKS:

Mean square error of an angle by formula of Ferrero $m_a = \pm \sqrt{\frac{[\Delta\Delta]}{3n}}$

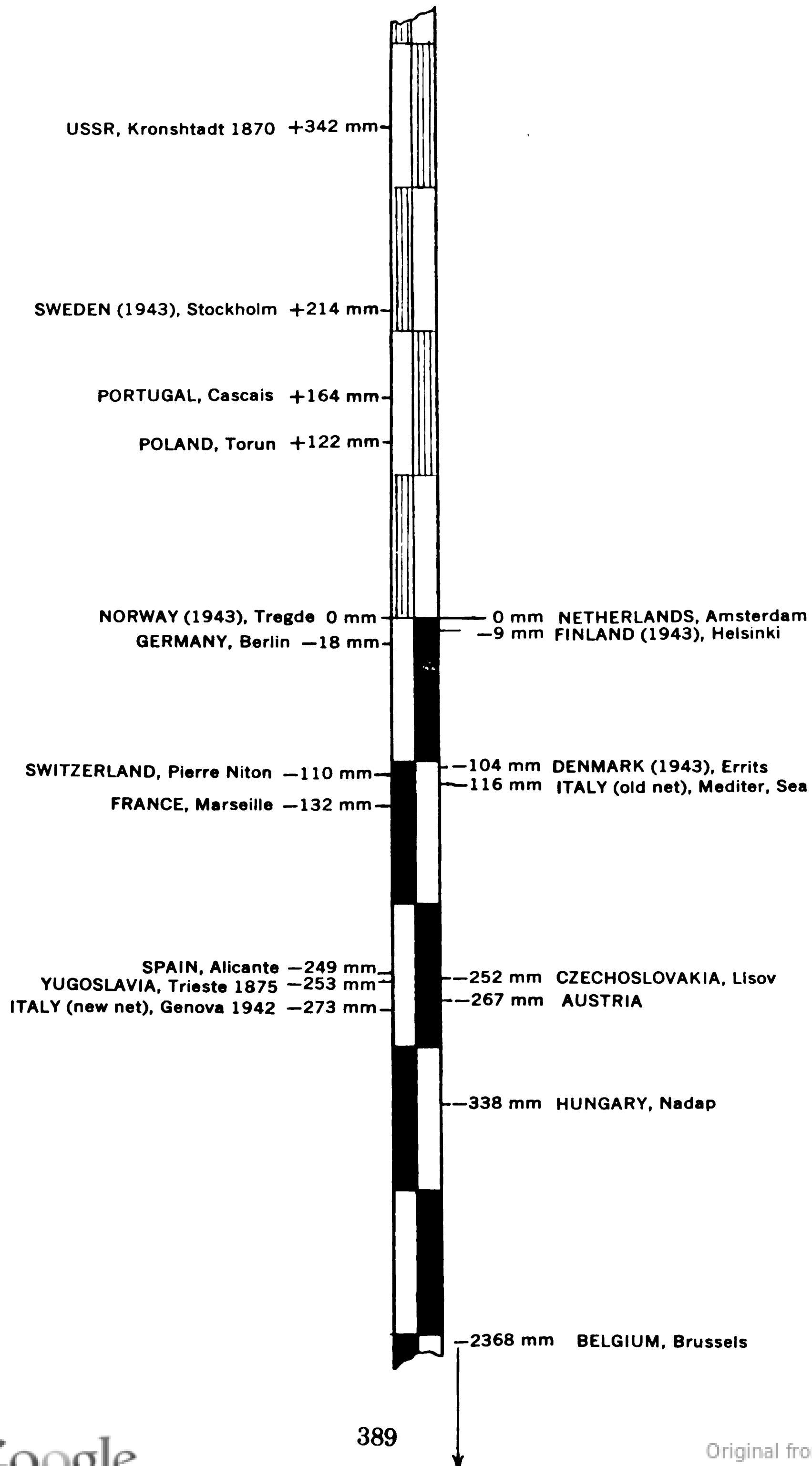
Maximal error of triangle closure Δ max.

Inclosure 48

EUROPEAN LEVELING DATUMS

AND THEIR RELATIONSHIPS TO THE NORMAL AMSTERDAM PEIL

(NAP).



Inclosure 49

SOME SIGNIFICANT RECORDS

OF THE PRE-WORLD WAR II TOPOGRAPHICAL SURVEYS IN THE CENTRAL EUROPEAN COUNTRIES

No.	Country	Scale	1 TP per km2	Detail pts. per km2	Elevs. per km2	Cadastral plans used	Average norm in 6 months
1	Austro-Hungarian Empire	III Top. s. 1:25,000	25	7–9	1–6	60% of surface	256 km2 no Cad. 405 km2 w/Cad.
		IV Top. s. 1:25,000	4–8	16–30	4–22	100%+Terrest Photo	75 km2
2	Austria	1:25,000	6.5	Ter. ster. photogram.	75–100	100%	70 km2
3	Czechoslovakia	1:10,000	1	45–300	50–300	100%	32 km2
		1:20,000	3–4	15–100	15–100	100%	80 km2
4	Germany	1:5,000	0.5–1	500–1400	500–1400	100%+Aerial photo	12 km2
		1:25,000	1–5	100– 400	80– 350	100%	85 km2
5	Hungary	1:25,000	2	80–160	5–70	75%+Aerial photo.	65 km2 no Cad. 260 km2
		1:40,000	8–30	Aerial phot.	Aerial phot	none	266 km2
6	Italy	1:20,000	9	average 50	average 50	none	50 km2
		1:25,000	9	33	33	none	70 km2
7	Yugoslavia	1:10,000	1.5	200–500	50–300	none	26 km2
		1:25,000	6–10	100–250	20–150	none	87 km2
		1:50,000	25–40	20– 50	5– 30	none	275 km2

BIBLIOGRAPHY

BIBLIOGRAPHY

[1] Adamik Emil: Osvrt na radove trigonometrijske mreže I. reda na području Jugoslavije. Geodetski list 1949, Vol III, No. 8-12 pp. 207-244.

[2] AFTH: Az Állami Földmerési és Terképészeti Hivatal Elnökenek 106 és 107/1957 utasutasai Geodézia és Kartográfia, 1957, Vol IX, No. 1-2, pp 107-108

[3] AFTH: Ideiglenes utasitás az 1:5000 méretarányú topográfiai felvételek végrehajtására. Budapest, Kartografiai Vállalat.

[4] AFTH: Minták és mellékletek az 5000-es ideiglenes felmérési utasitáshoz Budapest, 1956.

[5] Benedetti Alfredo Gen: Relazione sull' attivita geotopografica dell' I.G.M. nel 1952 e sui programmi dei lavori da eseguire nel 1953. Bollettino di geodesia 1953, Vol XII, No. 2, pp. 167-180.

[6] Benedetti Alfredo Gen: Relazione sull' attivita geotopografica dell' I.G.M. nel 1953 e sui programmi dei lavori da eseguire nel 1954. Bollettino di geodesia 1954, Vol XIII, No. 2 pp. 109-122.

[7] Benedetti Alfredo Gen: Relazione sull' attivita geotopografica dell' I.G.M. nel 1954 e sui programmi dei lavori da eseguire nel 1955. Bollettino di geodesia 1955, Vol XIV No. 2, pp. 175-189

[8] Bendefy Laszlo Dr.: A magyar országos felsőrendú szintezés uj főalappontjai Földmeréstani Közlemények 1952, Vol IV, No. 1, pp. 36-42

[9] Bendefy Laszlo Dr.: Felsőrendu szintezési hálózatunk az 1949 évi kjégyenlités tükrében. Földmeréstani Közlemények 1952, Vol IV, No. 2, pp. 84-90.

[10] Benes Ladislav Dr. Col: O volbě základniho bodu pro trigonometrickou sit Československe republiky. Výročni zpráva 1929, Vol II, pp. 155-171.

[11] Bertschmann S. Dr.: Die Genauigkeit der neuen Landeskarten der Schweiz Festschrift C. F. Baeschlin pp. 9-18 Zürich, 1957.

[12] Bertschmann S. Dr.: Neues von dem Landeskarten der Schweiz Schweizerische Zeitschrift fur Vermessung, Kulturtechnik und Photogrammetrie 1955, Vol III, No. 7, pp. 189-193.

[13] Boaga Giovanni, Dr.: Sguardo ai lavori di rilevemento effetuati in Italia con la Fotogrammetria Bollettino della Societa Italiana di Fotogrammetria e Topografia Vol 1956, No. 1-2 pp. 3-9.

[14] Boaga Giovanni Dr.: Sugli errori di chiusura dei triangoli nelle moderne triangolazioni Europee. L' Universo, Vol XXIV, No. 7, 1943, pp. 1-4.

[15] Boaga Giovanni, Dr.: Sviluppo dei lavori trigonometrici Italiani attraverso i secoli e stato attuale della Rete Geodetica Fondamentale. Rivista dell Catasto e dei Servizi Tecnici Erariali 1950, Vol 5, No. 1, pp. 5-29.

[16] Boguszak F. Dr. Capt: Kapitolu o novém měřeni topografickém. Zeměměřicaký Věstník 1929, Vol XVIII, pp. 6-13.

[17] Boguszak F. Dr. Capt: Vojenska mapování na uzemi našeho statu. Zeměřičaký Věstnik 1936, No. 3-4. pp. 68-69.

[18] Bojković Cvetko, Lt Col: Uporedjenje numeričkog i grafičkog odredjivanja tačaka. Geodetski list 1957, Vol XI (34), No. 5-8 pp. 188-200.

[19] Borčić Branko: Kloštar-Ivanički sistem Geodetski list 1954, Vol VIII, No. 1-4, pp. 41-48.

[20] Bosanac Dušan, Col: Razvoj i rad naše Vojno-geodetske službe od njenog osnivanja do danas. Beograd 1953.

[21] Bošković Dragmio M: Srednje odstupanje pri trigonometriskom odredjivanju visina. Geodetski list 1953, Vol VII (30), No. 9-10, pp. 293-298.

[22] Bošković Stevan P. Gen: Bases Paračin, Negotin, Vranje, Loznica, Prizren, Strumica, Prilep et Sjenica. Travaux del' Association de Géodésie de l'Union Géodésique et Géophysique Internationale, Raport general sur les bases 1912-1932, Vol 9, No. 27, pp. 371-381

[23] Bošković Stevan P. Gen: Les travaux géodésiques et cartographiques de l'Institute Geographique Militaire 1878-1931 Beograd 1931.

[24] Bošković Steven P. Gen: Les travaux géodésiques de l'Institute Geographique Militaire 1899-1922, 1922-1924, 1924-1927, 1927-1930, 1930-1933, 1933-1936.

[25] Bošković Stevan P. Gen: Les travaux topographiques et cartographiques de l'Institute Geographique Militaire 1931-1934, 1934-1938.

[26] Byelugin D.A. Col: Artileriiskaya Topograficheskaya Sluzhba Moskva, 1948.

[27] Cavicchi Carlo Col: La Carta Topografica in Tipo Italiano per le Venezia Giulia e Tridentina. L'Universo 1924, Vol V, No. 4, pp. 340-344.

[28] Comite National de Geodesy et de Geophysique de la R.P.F. de Yougoslavie: Rapport national de la R.P.F. de Yougoslavie. Travaux géodésiques exécutés en 1939-1953, pp. 1-4. Beograd 1954.

[29] Comite National de Geodesy et de Geophysique de la R.P.F. de Yougoslavie: Raport national de la R.P.F. de Yougoslavie. Travaux de triangulation et des bases exécutés en 1954-1956. Beograd, 1957.

[30] Csatkai Dénes: Elsőrendű szintezési hálózatunk ortométeres javításainak számitása. Geodézia és Kartográfia, 1957, Vol IX, No. 3, pp. 159-169.

[31] Cueni B: Kartengenauigkeit Schweizerische Zeitschrift für Vermessungswesen und Kulturtechnik 1927 Vol XXV, pp. 283-289, 307-315.

[32] Cvetković Jovan: Fotogrametriski instrumenti Zavoda za fotogrametriju u praktickoj upotrebi Geodetski list 1956, Vol. X (33), No. 9-10, pp. 272-279.

[33] Černe Jože Lt Col: Numerički rad na autografu Geodetski list 1956, Vol X (33), No. 9-10, pp. 280-284.

[34] Č.S.R. Academie Tchecoslovake des Sciences: Rapport présenté a la XI assemblée générale del' Union Géodésique et Géophysique Internationale. Praha 1957

[35] Dahl: Vergleichsmessung an der unteren Oder, ausgeführt im März 1928 zur Prüfung der Genauigkeit der topographischen Grundkarte 1:5000. Mitteilungen des Reichsamts für Landesaufnahme 1929, Sonderheft 8.

[36] Djordjević Momčilo P.: Analiza kartografskog ključa za osnovnu državnu kartu u razmeri 1:5000. Geodetski list 1953, Vol VII (30), No. 9-10, pp. 307-323.

[37] Fasching Antal Dr.: A Magyar Országos Háromszögelések és részletes felmerések uj vetületi rendszerei. Pp. 14 and 69. Budapest 1909.

[38] Fedl Ferenc: Beszámoló az 1:5000 méretarányú topográfiai felmérésekröl. Geodézia és Kartográfia 1955, Vol VII, No. 1, pp. 30-31.

[39] Finsterwalder R. Dr.: Photogrammetric measures of accuracy in the United States and Europe. Photogrammetric Engineering 1954, Vol XX, No. 3, pp. 567-570.

[40] Finsterwalder R. Dr.: Photogrammetrische Höhenschichtlinien Zeitschrift für Vermessungswesen 1957, Vol 82, No. 7, pp. 203-209.

[41] Forman Vladimir: Geodetické systémy a pričiny jejich vzniku Geodetický a Kartografický Obzor 1957, Vol 3/45 No. 11, pp. 212-216.

[42] Forman Vladimir: Geodetické zaklade specialni mapy 1:75,000 a poučeni pro nové topografické mapovani 1:10,000 a 1:5000. Geodetický a Kartografický Obzor 1956, Vol 2/44, No. 4, pp. 65-68.

[43] Förstner Rudolf: Schichtlinienfehler Zeitschrift für Vermessungswesen 1957, Vol 82, No. 12, pp. 445-448.

[44] Frank Otto, Gen: Landesufnahme und Kartographie. Mitteilungen des K.u.k. M.G.I. 1904, Vol XXIV, pp. 49-75.

[45] Generalstab des Heeres Planheft Tschechoslowakei, 1936 and 1938. Berlin 1938.

[46] Geodetska Uprava Sastanak stručnog savjeta Geodetske Uprave N.R. Hrvatske. Geodetski list 1953, Vol VII (30), No. 5-8, pp. 210-233.

[47] Germershausen Augustin: Die topographische Landesaufnahme im neuen Österreich. Die Zentralisierung des Vermessungswesens in ihrer Bedeutung für die topographische Landesaufnahme pp. 26-28 Wien 1935.

[48] Gianni Giuseppe Gen: La Cartografia Officiale Italiana negli ultimi due secoli. L'Universo 1949, Vol XXIX, No. 6, pp. 683-701 and Vol XXX, No. pp. 33-63.

[49] Gianni Giuseppe Gen: Sintesi storica dei principali lavori geodetici in Italia Il Bollettino di Geodesia e Scienze Affini 1950, Vol IX, No. 2, pp 91-120.

[50] Glavna Geodetska Uprava: Instrukcija za izradu osnovne državne karte u razmeri 1:5000; I deo; Terenski radovi. Beograd 1948.

[51] Glavna Geodetska Uprava: Instrukcija za izradu osnovne državne karte u razmeri 1:5000; IIdeo: Izrada terenskog originala. Beograd 1950.

[52] Glavna Geodetska Uprava pri vladi F.N.R.J.: Pravilnik za državni premer I deo Triangulacija. Beograd 1951

[53] Glušič Andrej M.: Adjustment of M.G.I. triangulation in Southern Serbia and Macedonia. Geodetic Memo No. 1026 (1952).

[54] Glušič Andrej M.: Triangulation in Montenegro and Boka Kotorska. Geodetic Memo No. 1032 (1953).

[55] Graeser M.: Prüfung der Genauigkeit der topographischen Grundkarte 1:5000. Mitteilungen des Reichsamts für Landesaufnahme 1926, Sonderheft 4.

[56] Gromann Alfred: Der bundesstaatliche Vermessungsdienst in Österreich und seine Arbeiten seit der Reform. Wien 1931.

[57] Günther Hinghofer-Szalkay: Mérettartás a térkép elöállitásnál Magyar Katonai Szemle 1940, No. 2, pp. 443-453. (Translation, Oberkommando des Heeres).

[58] Györgeyényi Istvan & Szendy Béla: Az 1:5000 méretáranyú állami alaptérképekröl. Földméréstani Közlemények, 1954, Vol VI, No. 4, pp. 231-240.

[59] Haardt v. Vinzenz: Die militärisch wichtigsten Kartenwerke der europäischen Staaten. Mitteilungen des K.u.k. M.G.I. 1907, Vol XXVII, pp. 98-238.

[60] Hartl Heinrich, Maj: Die Projectionen der wichtigsten vom K.k. General-quartiermeisterstabe und vom K.k. M.G.I. herausgegebenen Kartenwerke. Mitteilungen des K.u.k. M.G.I. 1886, Vol VI, pp. 120-312.

[61] Hartl Heinnich, Maj: Materialien zur Geschichte der astronomisch-trigonometrischen Vermessung der österreichisch-ungarische Monarchie. Mitteilungen des K.u.k. M.G.I. 1887, Vol VII,

[62] Hartl Heinrich Col: Studien über flachentreue Kegelprojektionen. Mitteilungen des K.u.k. M.G.I. 1895, Vol XV, pp. 203-249

[63] Hartner—Doležal: Katastralaufnahme.
Niedere Geodäsie, Vol 1, Part 2, pp. 703-706.

[64] Hoitz H.: Ein Vorschlag für die einheitliche Deutung der Schichtlinienfehler
Zeitschrift für Vermessungswesen 1957, Vol 82, No. 6, pp. 188-191.

[65] Homoródi Lajos Dr.: Negyendrendü háromszögelési hálózatunk felújitása Geodézia es Kartográfia 1957, Vol IX, No. 4, pp. 218-239.

[66] Homoródi Lajos Dr.: Régi háromszögelési hálózataink elhelyezése és tájékozása.
Földméréstani Közlemények 1953, Vol V, No. 1, pp. 1-18.

[67] Homoródi Lajos Dr.: Vizsgálatok új háromszögelési hálózatunk elhelyezésére es tájékozására.
Földméréstani Közlemények 1952, Vol IV, No. 2, page 63.

[68] Hónyi Ede Dr.: A dunántúli új kitöltöhálózat szögméréseinek pontossága.
Geodézia es Kartográfia, 1958, Vol X, No. 1, pp. 16-21

[69] Idler R. Dr.: Beitrag zur Genauigkeit topographischer Karten 1:25,000 und von Luftbildplanen 1:25,000.
Zeitschrift für Vermessungswesen 1942, Vol LXXI, No. 5, pp. 140-150.

[70] Imhof Ed. Dr.: Der heutige Stand der neuen schweizerischen Landeskartierung.
Schweizerische Zeitschrift für Vermessung Kulturtechnik und Photogrammetrie 1953, Vol LI, No. 6, pp. 156-160.

[71] Imhof Ed. Dr.: Die Vertikalabstände der Höhenkurven
Festschrift C.F. Baeschlin pp. 77-104.

[72] Imhof Ed. Dr.: Les cartes de Suisse et leur developpement ulterier.
Schweizerische Zeitschrift für Vermessungswesen und Kulturtechnik 1927, Vol XXV, pp. 81-180.

[73] Istituto Geografico Militare: Catalogo Generale della Triangolazione Ausiliaria in Venezia Giulia

[74] Istituto Geografico Militare: Catalogo Generale degli Elementi trigonometrici di alcuni punti compresi nel Foglio:
40A, 40B, 53B, 65A, 65B, 77A, 77B, 77C della Carta di Italia.

[75] Ján László: Amagyar felsörendü háromszögelés alapvonalai és alapvonalfejlesztö hálózatai.
Földméréstani Közlemények 1954 Vol VI, No. 3, pp. 159-171.

[76] Karda Jan: Kotázce využiti topografickych map v projektovani staveb. Geodetický a Kartografický Obzor 1958 Vol 4/46, No. 2, pp. 32-35.

[77] Kartograph. früh. M.G.I. in Wien: Entwicklung des Kartographischen Institutes und der staatlichen Kartenherstellung nach dem Umsturz. Wien 1933.

[78] Kasumović Marijan: Srednja razina Jadranskog mora i geodetska normalna nula Trst. Geodetski list 1950, Vol IV, (27), No. 10-12, pp. 243-256.

[79] Klak Stjepan: Precizni nivelman na području N.R. Hrvatske. Geodetski list 1953, Vol VII (30), No. 1-4, pp. 22-31.

[80] Klobouček Josef Dr.: Současny stav fotogrametrie v Československo a smeru jejiho dalšiho ekonomického razvoje. Geodetický a Kartografický Obzor 1957, Vol 3/45, No. 11 pp. 204-208.

[81] Korzer Karl, Col: Die Stereoautogrammetrie im Dienste der Landesaufnahme. Mitteilungen der K.u.k. M.G.I. 1913, Vol XXXIII, pp. 103-166.

[82] Korzer Karl, Gen: Kartographie, Politik und Krieg im Südosten Europas. Nachrichten aus dem Reichsvermessungsdienst 1941, Vol XVII, No. 6, pp. 368-385.

[83] Kost R.W. Dr.: Die Entwicklung der Geländedarstellung in Karten. Mitteilungen des Reichsamts für Landesaufnahme 1937, Sonderheft 14.

[84] Kraljevina Jugoslavija Min. Vojske i Mornarice: Podaci Topografske Organizacije Zemljišta na Kartama Bled, Cerknica, Vrhnika, Sušak 1:25,000. Str. Pov. Dj. Br. 1542 od 30. Augusta 1934.

[85] Kraljevina Jugoslavija Vojni Geografski Institut: Privremena tehnička Instrukcija o radu sekcija Kartografskog otseka.

[86] Krauland Richard: Die Gauss'sche konforme Abbildung als einheitliche Grundalage für die neuen topographischen Karten und die neuen Katastralmappen. Die Zentralisierung des Vermessungswesens in ihrer Bedeutung für die topographische Landesaufnahme. pp. 26-28 Wien 1935.

[87] Křovák Josef: Československá základni sit trigonometrickýh bodu, jeji geodetické základy a zobrazeni. Zeměměřický Věstník 1928, Vol XVI, pp. 149-167.

[88] Křovák Josef: Geodetické základy polohopisné a jednotný zobrazovací způsob Československé republiky. Zeměměřicský věstník 1938, Vol XXVI, No. 4, pp. 54-58.

[89] Kruis Bedrich: Srovnáci studium nivelačnich horizontu ČSR a okolnich státu. Geodetický a Kartograficki Sbornik Praha 1957, pp. 29-33.

[90] Kuhlman H. Dr.: Der gegenwärtige Stand der Landes-und Katastervermessung in Böhmen und Mähren. Nachrichten aus dem Reichsvermessungsdienst 1944, Vol XX, No. 1-2, pp. 3-24

[91] K.u.k. M.G.I. Official Report: Bericht über die Leistungen des K.u.k. militär-geographischen Institutes Mitteilungen des K.u.k. M.G.I. 1881. Vol 1, pp. 22-24.

[92] K.u.k. M.G.I. Das Präcisions-Nivellement in der öster-ungar. Monarchie. Die astronomisch-geodätischen Arbeiten des K.u.k. M.G.I. Vol VII, VIII, X and XIV.

[93] K. und k. M.G.I.: Die Ergebnisse der Triangulierungen Vol I, Wien 1901.

[94] K. und k. M.G.I.: Die Ergebnisse der Triangulierungen Vol II, Wien 1902

[95] K. und k. M.G.I.: Die Ergebnisse der Triangulierungen Vol. IV, Wien 1906.

[96] K.u.k. M.G.I.: Die Fortsetzung des Präcisions-Nivellements ausgeführt in den Jahren 1900-1913. Metteilungen des K.u.k. M.G.I. 1900-1913, Vol XX, XXI, XXII, XXV, XXVII, XXIX, XXXII.

[97] K.u.k. M.G.I.: Grundlinienmessungen. Die astronomisch-geodätischen Arbeiten des K.u.k. M.G.I. Vol XXIII, Ch. 20, pp. 84.

[98] K.u.k. M.G.I.: Instruction für die militärische Landesaufnahnne (Militär-Mappirung und Reambulirung)II Technischer Teil Wien 1887.

[99] K.u.k. M.G.I.: Instruction fur die militerische Landesaufnahme II, Technischer Teil. Wien 1903.

[100] K.u.k. M.G.I.: Mitteilungen des K. und k. Militärgeographischen Institutes 1881-1913, Vol I, III, IV, V, VI, VII, VIII, IX, X, XI, XII, XIII, XIV, XVI, XXII, XXIII, XXIV, XXV, XXVI, XXVII, XXVIII, XXIX, XXX, XXXIII, Offizieller Teil.

[101] K.u.k. M.G.I.: Positions-Rechnungen für die neue Specialkarte der östlichen Monarchie 1887. Vol 1, Part I. (Vienna University system for provinces Lower Austria, Moravia, Silesia and Hungary; Part II. (Arad, St. Anna system for provinces Hungary, Galicia, Bucovina, Moravia and Silesia).

[102] K.u.k. M.G.I.: Positions-Rechnungen für die neue Specialkarte der westlichen und südlichen Monarchie-Theile 1889. Vol II. (Vienna University system for provinces Bohemia, Upper Austria, Salzburg, Tyrol, Vorarlberg, Carinthia, Styria, Carniola, Littoral, Croatia and Dalmatia).

[103] K. und k. M.G.I.: Triangulierung II. u. III. Ordnung in Dalmatien 1906 M.G.I. Protokoll No. 346 A.

[104] Ledersteger Karl, Dr.: Die Beziehungen der jugoslawischen Kartenwerke zur öster.-ungar. Militärtriangulierung und zum deutschen Koordinaten-system. Verm. Auswertebatterie 762. 1944.

[105] Ledersteger Karl, Dr.: Die Einbeziehung der Neuen italienisch-dalmatinischen Kette in das Europäische Einheitssystem Potsdam und in die Jugoslawische Landesvermessung. Verm.-Ausw. Battr. 762

[106] Ledersteger Karl, Dr.: Die Einrechnung des Italienischen Netzes auf der Insel Krk (I. Veglia) in die Jugoslawische Landesvermessung Verm. und Kart. Abt. (mot.) 501, 1944.

[107] Ledersteger Karl, Dr.: Die gesetzmässigen Beziehungen zwischen den deutschen Heeresgitter und den jugoslawischen und ungarischen Kartenwerken Ey 50 und Eh 75.

[108] Ledersteger Karl, Dr.: Vorwort zur bosnischen Militartriangulierung Verm.-Ausw. Battr. 762.

[109] Lehrl Franz, Col: Das Pracisions-Nivellement in der österr.-ungar. Monarchie Mitteilungen des K.u.k. M.G.I. 1899, Vol XIX, pp. 166-198.

[110] Lego Karl: Die photogrammetrischen Arbeiten in neuen Österreich. Die Zentralisierung des Vermessungswesens in ihrer Bedeutung für die topographische Landesaufnahme pp. 33-37 Wien 1935.

[111] Lerner L.: Die Verwendung der Katastralmappen zur Evidenthaltung der staatlichen Karten. Die Zentralizierung des Vermessungswesens in ihrer Bedeutung für die topographische Landesaufnahme pp. 38-42 Wien 1935.

[112] Levi Moric, Col: Reprodukcija Karte 1:300,000 izdanja Geografskog Instituta JNA. Geodetska Služba 1954, Vol V, No. 2, pp. 207-216.

[113] Lindig G.: Neue Methoden der Schichtlinienprüfung Zeitschrift für Vermessungswesen 1956, Vol 81, No. 7, pp. 224-251 and No. 8, pp. 296-303.

[114] Lukášek Vaclav, Capt: Příspevek k výškovym meřenim na uzemi našeho státu. Vyrocni Zprava 1929, Vol X, pp. 196-208.

[115] L'Universo: L'attivita dell' Istituto Geografico Militare dalla liberazione dell' Italia ad oggi. L'Universo 1948, Vol XXVIII, No. 1, pp. 68-73.

[116] Marussi Antonio Dr.: Le triangolazioni eseguite dall' Italia e dall' Austria in Alto Adige, e la loro reciproca dipendenza. Bollettino Geodetico de l'Universo 1946, Vol XXVI, No. 3,

[117] Marussi Antonio, Dr.: Per l' unificazione geodetica dell Bacino Mediterraneo. Bollettino Geodetico dell I.G.M. 1947, Vol VI, P. 101.

[118] Medvey Aurel, Gen: Das topographische Kartenwesen Ungarns Mitteilungen des Reichsamts für Landesaufnahme 1932/33, Vol 8, No. 2, pp. 99-114.

[119] Mellien H.: Zur Neuherstellung der Topographischen Karte 1:100,000 Zeitschrift für Vermessungswesen 1954, Vol 79, No. 3, pp. 72-75.

[120] Merkl H. Dr.: Beitrag zur Genauigkeitsfrage topographischer Karten. Zeitschrift für Vermessungswesen 1923, Vol LII, No. 7 und 8, pp. 121-131.

[121] Meyr H.F. Hans, Dr.: Bericht über das Kartenwesen Ungarns. (1938) Oberkommando des Heeres.

[122] Milovanović-Zokić-Popeskov: Diskusija na savetovanju o primeni fotogrametrije u našoj zemlji. Geodetski list 1956, Vol X (33), No. 9-10, pp. 285-296.

[123] Ministero della Guerra Ispettorato dell' Artigl.: Elementi geodetico-topografici dei punti della Rete d' Artiglieria

[124] Ministerstvo financi Č.S.R.: Návody pro vykonovani katastrálnich měřickyh prácí. V Praze 1932.

[125] Mitić Miloje: Odredjivanje srednje vrednosti velike i male poluose srednje elipse grešaka za našu do sada izvršenu triangulacija III i IV reda. Geodetski list 1954, Vol VIII, No. 1-4, pp. 26-33.

[126] M. kir. Állami Térképészet: Jahresbericht des Kartographischen Institutes vom Jahre 1931. Térképészeti Közlöny Vol II, (1932), No. 1-2, pp. 2-9.

[127] M. Kir Háromszögelö Hivatal: Átszámitás a budapesti sterographikus vetületi rendszerböl a Gauss-Krüger vetületi rendszerbe. Budapest, 27, Oktober 1944.

[128] Morosini Luigi Gen: Rapport sur l'activité de l' Institut Geographique Militaire Italien dans le domaine de la triangulation et du nivellement de precision pendant les trois annees 1948-1950 Bollettino di geodesia 1951, Vol X, No. 3, pp. 305-310.

[129] Morosini Luigi Gen: Relazione dell' attivita geotopografica dell' I.G.M. nel 1951 e sui programmi dei lavori da eseguire nel 1952. Bollettino di Geodesia 1952, Vol XI, No. 2, pp. 93-108.

[130] Mühlberger Josef: Die Entwicklung der österreichischen Staats-Kartographie Mitteilungen des Reichsamts für Landesaufnahme 1929/30, Vol V No. 3, pp. 193-213.

[131] Nikolić Djordje, Dr.: O orientaciji jedne trigonometriske mreže. Geodetska služba 1954, Vol V, No. 1, pp. 3-13.

[132] Norcen Antonio Gen: I Lavori geodetici e magnetici del l'Istituto Geografico Militare dal 1939 a tutto il 1949. L'Universo 1950, Vol XXX, No. 1, pp. 1-15.

[133] OKH (Headquarters of German Army): Planheft Italien, 19 August 1944. Oberkommando des Heeres.

[134] O.K.H. (Headquarters of German Army: Planheft Südosteuropa Nördlicher Teil, 14, Januar 1944. Oberkommando des Heeres.

[135] O.K.H. (Headquarters of German Army): Planheft Südosteuropa Südlicher Teil, 1, August 1943. Oberkommando des Heeres.

[136] O.K.H. (Headquarters of German Army): Überführung der Vermessungsgrundlagen des ehem. Jugoslw. Raumes in das Europ. Einheitssystem (Potsdam). Arbeiten der Heeresvermessung, Vol 5, Berlin 1944.

[137] Pariani Alberto Col: Delimitazione del Confine Italo-Austriaco Vol I; Istituto Geografico Militare 1928.

[138] Pehnack Max: Prüfung neuer Messtischaufnahmen 1:25,000 auf ihre Genauigkeit. Mitteilungen des Reichsamts für Landesaufnahme 1937, Vol XIII, No. 2, pp. 77-78.

[139] Peroutka, Major Topographische Aufnahme 1:10,000. Mitteilungen des K. u. k. M.G.I. 1908, Vol XXVIII pp. 59-68.

[140] Plachte Leo: The Geodetic Basis of the 1:75,000 Map Series of Austria-Hungary. Geodetic Memo No. 1000.

[141] Popeskov Boško: Primena fotogrametrije u katastru. Geodetski list 1956, Vol X (33), No. 9-10, pp. 250-254.

[142] Potužak Pavel, Dr.: Studie nejvhodnějších formatu map a převodu kresky z map dosavadnich do map v zobrazovaci soustavě Gaussově. Geodetický a Kartografický Obzor 1957 Vol 3/45, No. 9, pp. 161-163.

[143] Pruša Jaroslav: Vytyčeny perspektivy zeměměřickeho odbory a centralisace zeměměřické a kartografické služby. Zeměměřictví 1953, Vol 3 (41), No. 5, pp. 72-80.

[144] Pruša Jaroslav: Vyvoj československe geodesie a kartografie v podminkách budovani socialismu. Geodetický a Kartografický Obzor 1958 Vol 4/46, No. 2, pp. 21-26.

[145] Rabensteiner W. Dr.: Höhenlinien in der Karte 1:25,000. Zeitschrift für Vermessungswesen 1951, Vol 76, No. 3, pp. 83-88.

[146] Radó Sándor: Magyar Térképék Muszaki Élet 1956, Vol II, No. 17, pp. 10-11

[147] R. Commissione Geodetica Italiana: Elementi della Rete Altimetrica Fondamentale (Livellazione Geometrica di Precisione). Firenze 1906.

[148] R. Commissione Geodetica Italiana: Elementi della Rete Geodetica Fondamentale a nord del parallelo di Roma Firenze 1908.

[149] R. Commissione Geodetica Italiana: Elementi della Rete Geodetica Fondamentale a sud del parallelo di Roma Firenze 1919.

[150] Regöczi Emil Dr.: Les Travaux Géodésiques en Hongrie. Acta Technica A.S.H. 1957, Vol XVIII, pp. 104-115.

[151] Regöczi Emil Dr.: Madarske katastrálni vyměřovani Zeměměřicky obzor SIA 1949, Vol 10/37, No. 9, pp. 109-115.

[152] Regöczi Emil Dr.: Takarékos Felsőrendű Háromszögeles. Földméréstani Közlemények 1951, Vol III, No. 4, pp. 173-184.

[153] Reichsministerium: des Innern Planheft Gross-deutsches Reich Gotha, 1944.

[154] Rohrer H. Dr.: Die Ausgestaltung der Dreicknetzes 1. Ordnung. Die Zentralisierung des Vermessungswesens in ihrer Bedeutung für die topographische Landesaufnahme pp. 20-25. Wien 1955.

[155] Rohrer Johann Dr.: Die neuen Österreichischen Kartenwerke und ihre geodetischen Grundlagen. Österreichische Bauzeitschrift 1951, Vol VI, No. 7, pp. 105-110

[156] Salvioni Guido Dr.: Confronto fra i livelli medi del mare a Genova e a Venezia. Bollettino di geodesia Vol XVI, No. 4, 1957, pp. 539-545.

[157] Salvioni Guido Dr.: I movimenti del suolo nell' Italia centro-settentrionale Bollettino di geodesia Vol XVI, No. 3, 1957, pp. 325-344.

[158] Salvioni Guido Dr.: La Sezione italiana della Rete Europea Unificata di livellazione Bollettino di geodesia Vol XVI, No. 2, 1957 pp. 260-263.

[159] Salvioni Guido Dr.: Progetto della nuova rete altimetrica fondamentale; Bollettino di Geodesia, 1951, Vol X, No. 3, pp. 319-330.

[160] Savezna Geodetska Uprava: Osnovni Geodetski Radovi u F.N.R. Jugoslaviji. Beograd 1953.

[161] Savezna Geodetska Uprava: Uputstvo o izvršenju nivelmana visoke tačnosti i preciznog nivelmana. Geodetski list 1955, Vol IX, No. 3, pp. 168-176.

[162] Schneider K.: Die neuen Landes Karten der Schweiz
Vermessung, Grundbuch und Karte.
Zürich 1939, pp. 133-145

[163] Schwidefsky K. Dr.: Einführung in die Luft und
Erdbildmessung.
Leipzig und Berlin 1936.

[164] Schwiegk F.: Die Problem Morphologie in
der Topographie.
Zeitschrift für Vermessungswesen 1941,
Vol LXX, p. 19.

[165] Sendjerdji Janko, Col: Kratak historijski pregled razvitka
kartografiranja Crne Gore u XVIII-XX
stoljeću.
Geodetski list 1955, Vol IX (32), No. 7-10,
pp. 245-270.

[166] Simonović Josip, Lt Col: Prvi topografski premer Kraljevine Srbije.
Ratnik 1896.

[167] Stefanović Milutin, Lt Col: Normalni reper nivelmanske mreže.
Geodetski list 1955, Vol IX (32),
No. 1-2, pp. 3-14.

[168] Stejskal Miloslav: Práce Geodetického a topografického
ustavu v Praze.
Geodetický a Kartografický Obzor 1958,
Vol 4/46, No. 2, pp. 28-30.

[169] Sterneck Robert V. Dr. Gen: Kontrolle des Nivellements durch die
Flutmesserangaben und Schwankungen des
Meeresspiegels der Adria.
Mitteilungen des K.u.k. M.G.I. 1904,
Vol XXIV, pp. 75-141.

[170] Stolfi: I rilievi fototopografici dell' I.G.M. in
Valtelina nel 1935. Published in
L'Universo Jun. 1956.
Rivista del Catasto e dei Servizi Tecnici
Erariali 1937, Vol IV No. 1, pg. 76.

[171] Szabo Béla: Yugoslavia M607-Cartometric
Evaluation-Gridconversion
Geodetic Memo 1106.

[172] Šobić Dobrosav Z. Lt Col: Historiski razvoj naše Kartografije
1878-1953.
Beograd 1953.

[173] Štorkan František: Kartograficke tabulký pro nove mapy
1:100,000. 1:50,000, 1:25,000 a 1:10,000,
Elipsoid Krasovskeho. Praha 1956.

[174] Štorkan František: Mezinarodni uspořadani listu map velkych
měřitek.
Zeměměřictvi 1954, Vol 4/42, No. 7-8,
pp. 122-126.

[175] Terzić Milorad J, Gen: Les travaux Géodésiques de l'Institut Geographique Militaire 1936-1939. Beograd 1939.

[176] Tinter W. Dr.: Die Schlussfehler der Dreiecke der Triangulierung erster Ordnung in der K.u.k. Öster-Ung. Monarchie. Wien 1904.

[177] Tjabin-Filipović, Cols: Razmatranja o karti 1:25,000. Geodetski list 1955, Vol IX (32), No. 1-2, pp. 36-57.

[178] Trombetti Carlo Dr.: Riduzione del modulo e delle coordinate, Approssimazione Grafica, Scala di una Carta e Modulo di Reduzione Lineare. La proiezione conforme di Gauss-Boaga, I fusi della catografia ufficiale Italiana, Le coordinate N ed E. Il Bollettino risponde 1950, Vol IX No. 3.

[179] Trombetti Carlo Dr.: Triangolazione Solare Santoni, Istituto Geografico Militare 1952

[180] Weixler Adolph: Bearbeitung des trigonometrischen Gradmessungsnetzes für Zwecke der Landesvermessung. Mitteilungen des K.u.k. M.G.I. 1900, Vol XX, pp. 64-95.

[181] Werkmeister P. Dr.: Topographie, Berlin 1930.

[182] Zokić Lazar: Primena fotogrametrije u novom katastarskom premeru. Geodetski list 1956, Vol X (33), No. 9-10, pp. 255-260.

Submitted:

ANDREW M. GLUSIC
Geodesist
Research and Analysis Division

Recommend Approval:

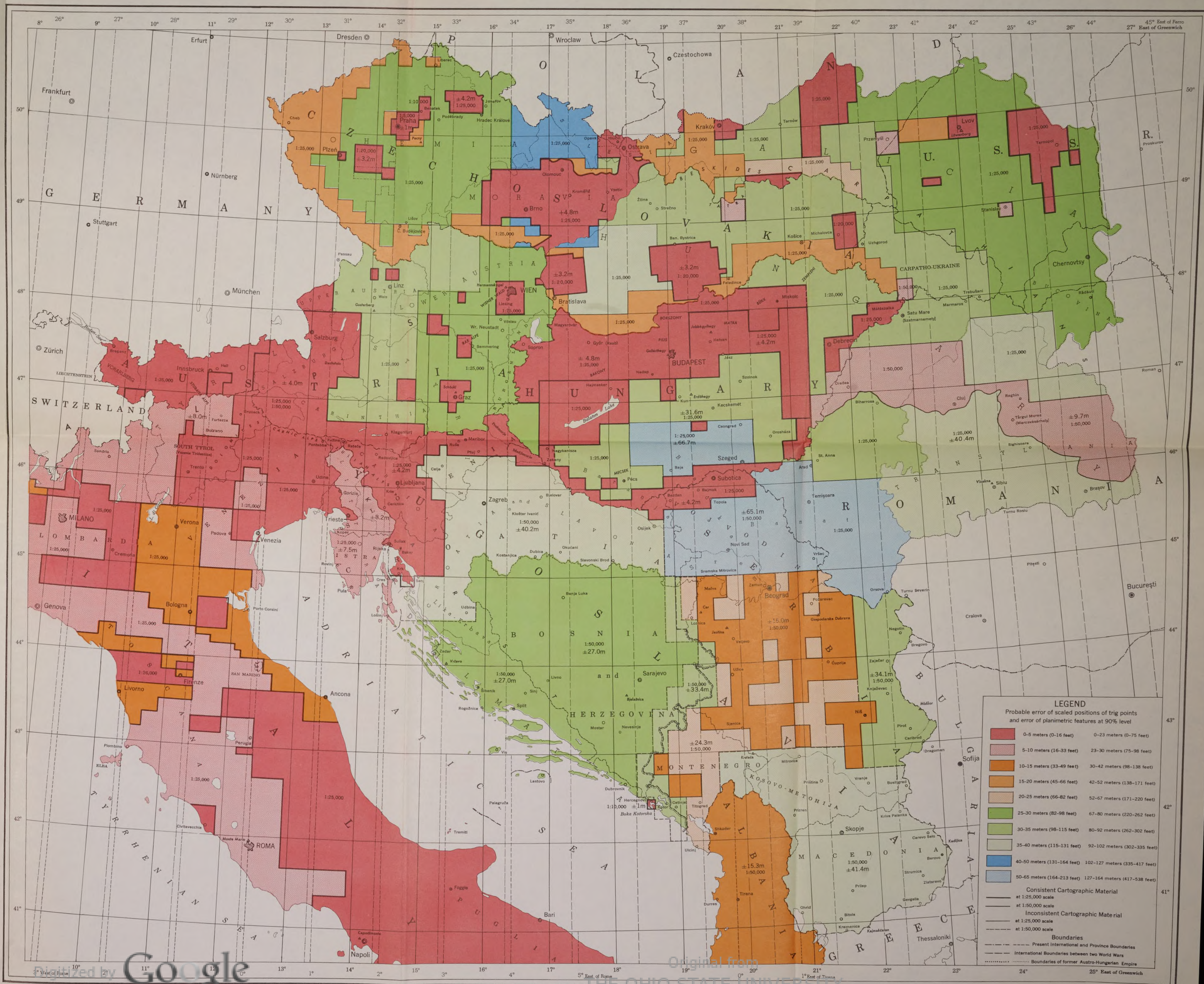
D. L. MILLS
Chief, Department of Geodesy

Approved:

F. O. DIERCKS
Colonel, Corps of Engineers
Commanding

Inclosure 50

SCALING ACCURACY OF CARTOGRAPHIC MATERIAL



SCALE 1:3,000,000