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GERMAN CARTOGRAPHIC AND MAP COLLECTING AGENCIES : THE GEODETIC BASES OF GERMAN CARTOGRAPHY

M-2

CENTRAL INTELLIGENCE AGENCY

March 1948

FOR THE ASSISTANT DIRECTOR
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SUMMARY

Germany is one of the few countries in the world that has complete, accurate, and detailed geodetic and topographic surveys of the major part of its area. The program of unification and coordination of surveying and cartography initiated in 1935, however, created several serious problems for German geodetic and cartographic agencies. Most of the German states except Bavaria and Württemberg had adopted the Bessel ellipsoid. Polyhedric projections with degrees of longitude measured from Ferro (Canary Islands) were used on many of the older, large-scale maps. The large-scale maps of Bavaria and Württemberg and the cadastral maps of many north German states and provinces, however, were compiled on the Soldner and Soldner-Cassini grids; and Bavaria used the Bonne projection. In the recent unification program, the Gauss-Krüger projection was introduced. All large- and medium-scale maps published since the beginning of World War II have a geographic grid based on the Gauss-Krüger projection superimposed on them. The Gauss-Krüger projection has been developed in three-degree bands by the Reichsamt für Landesaufnahme and in six-degree bands by the General Staff of the Army.

Although Germany is covered by a number of dense and accurate triangulation nets, they were poorly integrated because they were surveyed at different times and by different states. By 1938, several nets had been resurveyed, and other areas were scheduled for resurveying. In some areas, where differences between nets were not too great, adjustments had been computed. The outbreak of the war slowed down surveying, but along the Westwall Germany attempted to

NOTE: The Intelligence Organization of the Department of State and the Office of Naval Intelligence have concurred in the report; the Intelligence Division of the Department of the Army and the Air Intelligence Division, Directorate of Intelligence, Department of the Air Force, had no comment.

complete new, accurate triangulation nets; and between 1939 and 1941, first-order triangulations of Mecklenburg, Württemberg, Bavaria, western Austria, and southern East Prussia were completed or continued.

Before the war, Germany had started to connect its triangulation net with those of adjoining countries, but the German net differed considerably from those of France and Poland. After these countries were conquered, their nets were adjusted to the German net even though comparatively large junction differences had to be absorbed. The first-order connection of the German-Belgian nets was completed, as were also the German-Polish nets with the exception of the Warthe net.

The level net was renewed continuously because of deterioration due to slight shifts or loss of bench marks. At the outbreak of war, approximately one-third of Germany had been covered by new first-order and small parts by a second-order level net. An older first-order level net covered all Germany. Although many of the old markers have been lost, a number remain and are accurate within a few millimeters.

Until 1941 hydrographic surveys along the German coast were continued by the Deutsche Seewarte, the leveling being done by the Reichsamt für Landesaufnahme. The results of these surveys, however, may have been lost.

INTRODUCTION

Germany is the classic example of a country that has complete, accurate, and modern horizontal and vertical control surveys of the major part of its area. However, technical advances in road construction, mining operations, land redistribution, and military science require surveys of increasingly higher degrees of accuracy. In the past, the planning and execution of a comprehensive program for the production of large-scale maps were hampered by the existence of numerous small survey districts whose activities were not co-ordinated. To remedy this situation, Germany inaugurated in 1935 an extensive surveying program to provide a uniform basis for large-scale topographic maps. This paper, which outlines the status of this program at the time hostilities ceased, has been revised to include immediate postwar developments.[1]

I. DIMENSIONS OF THE EARTH, AND GEOGRAPHIC GRIDS

One of the basic difficulties in the unification of German cartographic work is the use by various states of different dimensions for the "geoid" or earth ellipsoid. Since the smaller state cartographic agencies were either absorbed by the Reichsamt fur Landesaufnahme or followed its lead, only the three assumptions that are discussed in the following paragraph remain to be considered.

The Württemberg map projection was based on the ellipsoid of the Wurttembergian astronomer Bohnenberger. The Bavarian projections were based on a sphere with a radius of 6,388,172 meters. The dimensions of this sphere were determined from the Laplacian spheroid, which has an equatorial circumference of 40,000,000 meters and a curvature at the latitude of Bavaria that is almost identical with the Bavarian reference

1. Unpublished report by Captain Spencer D. Smith, in charge, Land Survey Office, Bamberg, Germany, September 15, 1947.

sphere. Prussia and all the states following its lead adopted the dimensions determined by Bessel who, in 1841, computed the polar radius 6,356,078.963 meters and the equatorial radius 6,377,397.155 meters.[1] On some airway maps there are notes stating that a "normal" radius of 6,370,000; 6,382,750; or even 6,395,000 meters has been used.

By 1924, all German states, most of which had previously used Ferro, had adopted Greenwich as the prime meridian. On their surveys, Prussia and Bavaria calculated that Greenwich was 17° 39' 57.5" east of Ferro and subtracted 17° 40'. Since German topographic maps are bounded by meridians and parallels, the subtraction of 17° 40' made it possible to retain the old borders without change. For example, 20° 50' E of Ferro became 3° 10' E of Greenwich. Only for Baden did the sheet borders have to be changed. These changes were made during the war. The margin of error introduced was less than 0.5 mm., even on the 1:100,000 map. Baden and Württemberg relied on the Württemberg Observatory at Tübingen in establishing their latitude and longitude. Owing to a mistake in calculating the latitude and longitude of Tübingen and to a slight torsion in the established prime meridian, these two states could not easily adjust the established geographic grids to the accepted Greenwich-equator system. Baden, which had based its prime meridian on the now demolished observatory at Mannheim, discovered an eastward deviation from the true north of 10.7914" along this meridian north of Mannheim. The amount of deviation along the Württemberg meridian based on Tübingen is not known.

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1. The internationally accepted dimensions are those of Hayford - for the polar radius 6,356,911.946 meters and for the equatorial radius 6,378,388.000 meters. In Germany these dimensions are used as reference only for leveling connections with Baltic countries. Figures for the Bessel ellipsoid are given in German legal meters, whereas those for Hayford are in international meters. 1 legal meter = 1.000,013,355 international meters.

When the borders of the Baden and Württemberg surveys were compared, a difference of 4.32" in latitude and 2.58" in longitude became apparent. On the ground, this error amounted to between 135 and 141 meters in latitude and between 35 and 40 meters in longitude, respectively. The Württemberg and Bavarian nets, however, were adjusted satisfactorily, leaving a mean error of two to three meters. The difference between the Prussian and Baden nets was 9.1" in latitude or 280 meters on the ground.

II. PROJECTIONS

In projections differences between states were even more complicated because a single state might use a variety of projections, depending on the scales of the maps produced. Württemberg and Bavaria used the Cassini-Soldner projection and co-ordinates for their large-scale maps at 1:2,500 and 1:5,000. This projection virtually shifts the poles and equator of the sphere in such a way that the prime meridian and equator intersect at the center of an area surveyed. This means that if a 1-degree area is projected as a quadrangle, the distortion is reduced to a minimum. The zero of the co-ordinate system for Württemberg is the observatory in Tübingen, and for Bavaria the co-ordinate zero is the northern tower of the Liebfrauen Kirche in Munich.

Originally the Prussian topographic map at the scale of 1:25,000 (Messtischblatt) was drawn according to the Prussian polyhedric projection. This projection disregards the curvature of the earth, and considers each part of the sphere as a plane bordered by two successive Ferro meridians and two successive parallels. Length, area, and angles are absolutely correct at the corners of each of the isosceles trapezoids so formed and the error at the center is insignificant. The Bavarian map set at 1:25,000, on the other hand, was drawn in two forms; a topographic map (Gradabteilungs-blatt) on the Prussian polyhedric projection with Bessel's reference spheroid, and a location sheet (Positionsblatt) on the Soldner polyhedric projection bordered by parallels and meridians. Recently the latter have

been made on the Gauss-Kruger projection, using the same sheet lines as the Prussian Messtischblatter. The prime meridian adopted by Bavaria in the Soldner system was 29° 16' 08.8" east of Ferro. Bavarian latitudes also have had to be adjusted by adding 02.6" - owing to the use of independent astronomic locations. Bonne's projection with Soldner's reference grid is used for the maps of the Bavarian Topographic Atlas at 1:50,000. The standard parallel is 45°N and meridian is that of the old Munich Observatory, which has now been demolished.

Polyhedric projections were used also on the Baden and Hessian 1:25,000 maps. Because parallels are drawn as straight lines on all polyhedric projections, instead of being slightly curved, there is an insignificant error along the middle line of the maps. The greatest difference between the lengths of the chord on the 1:25,000 map and the arc of the true parallel is 0.13 mm., or 3.2 m. on the ground, and on the 1:100,000 map 0.3 mm., or 29 m. on the ground. These errors lie within the margin of uncontrollable error in map production.

About 1928, the Reichsamt für Landesaufnahme adopted the policy of superimposing on all German topographic maps a plane co-ordinate grid derived from the Gauss projection, a technique suggested by the use of the Lambert grid by the French. Krüger was editor of Gauss' papers after his death, and completed and amplified some of the Gauss computations.

The Gauss-Krüger projection, from which the co-ordinates of the same name are taken, is a modified transverse Mercator projection adjusted to the spheroid. The projection cylinder is tangent to the spheroid along a meridian, which therefore, like the equator in the Mercator projection has no scale error. In order to keep the distortion within small limits, the extension of the projection to the east and west of this central meridian is limited to 1° 30' on German non-military maps. Thus, from east to west new cylinders are used as projection surfaces at progressive intervals of 3 degrees of longitude. This results in a series of narrow

strips or bands. The ordinates of the Gauss-Krüger projection are not meridians but small circles parallel to the central meridian. The abscissas are not parallels of latitude, but great circles perpendicular to the principal meridian. All grid lines appear as straight lines, distances can be measured easily, and angles are conformal. The projection is not equal area, but the distortions are too small to be measurable if the band is sufficiently narrow. The main disadvantage is that true north is coincident with co-ordinate north only along the central meridian.

In February 1942, the Army adopted the Russian system of 6 degree meridian bands for its maps. This difference in width of projection bands distinguishes the army grid (Deutsches Heeresgitter, DHG) from the grid of the Reichsamt für Landesaufnahme (Deutsches Reichsgitter, DRG).

The distortions are, of course, more pronounced on the military grid than on the Reichsamt grid. The following tabulation, computed for 55° N, shows the comparative distortions at the edges of the meridian bands:

	DRG (3° bands)		DHG (6° bands)	
Measured Distance	1 km.	10 km.	1 km.	10 km.
N-S distortion	0.11 m.	1.25 m.	0.45 m.	4.76 m.
E-W distortion	0.2 m.	2.4 m.	0.5 m.	4.8 m.

The Gauss-Krüger co-ordinate grid divides the map into squares whose sides vary in length according to the scale of the map. The relationship between the size of the squares and the scale of the map is given below:

Scale	Size of Square (In cm.)	Size of Square (In km.)
1:25,000 and 1:50,000	4.00	1 2
1:100,000 and 1:200,000	5.00	5 10
1:300,000	3.33	10

The co-ordinates are so numbered that the meridian 6° is marked 2,500,000 m.; that of 9° is 3,500,000; that of 12° is 4,500,000, and so on. Between these principal meridians, measurements are made in meters which, as Germany is east of Greenwich, are designated as Rechtswert or rechts (to the right). Latitude is measured as the true length in meters from the equator and is called Hochwert or hoch (high). The following tabulation gives a comparison of the DRG and DHG numbering systems:

	DRG	DHG
3°	1,500,000 m.	1,500,000 m.
6°	2,500,000 m.	- - -
9°	3,500,000 m.	2,500,000 m.
12°	4,500,000 m.	- - -
15°	5,500,000 m.	3,500,000 m.

The Germans used two types of reference grids. The Army grid (Heeresmeldnetz), used for tactical purposes, was based on the Gauss-Krüger projection with 6 degree bands (DHG). The geographical reference grid, (Gradmeldnetz), used for operational purposes (especially by the Air Force), was based on parallels and meridians.

The 1:1,000,000 map of the world was drawn on a modified polyconic projection with straight meridians. On each sheet, the meridians 1 degree west and 1 degree east of the central meridian are true in length.

The Army surveyors have used the Gauss-Krüger grid with 6° bands exclusively in recent years. The Navy has always used the Mercator projection for its maps; no exception is known. There is no indication that the Navy will follow the lead of the Army. Obviously, in order to take advantage of rhumb lines in air navigation, most of the general maps used by the Air Forces are drawn on the Mercator projection. On these maps, the scale is correct for one of the three parallels 70° N., 51° N., or 23° N., depending on the area covered. Occasionally other projections are used, including the gnomonic with an oblique axis and the center of reference at latitude 50°N

but at different longitudes, the stereographic, and the azimuthal with various centers (Table 1). Maps on a larger scale were planned, but nothing is known about projection selected. In the meantime, the air force has used an adaptation of the old Vogel map at 1:500,000 on the Bonne projection, or the general map at 1:300,000 (see above).

III. TRIANGULATION

A. Triangulation before 1938

Germany was covered by a dense network of triangulation points, but the observations were made at different times and with various degrees of accuracy. Those areas for which the coverage was considered unsatisfactory were either resurveyed or were scheduled for new triangulation. In some states, such as Mecklenburg, the triangulation had to be repeated since the original values could not be adjusted to the general system.

The resurveying of the first-order net was begun in 1936 and was scheduled for completion in 1942. Most of the second-order nets completed since 1900 could be converted to the new datum. Only a small amount of second- and third-order work was required along the Mecklenburg-Prussia, Saxony-Prussia, Bavaria-Prussia, and Bavaria-Austria boundaries. Some of the third-order work in Bavaria and Württemberg would normally have required two to three years, and the triangulation of Germany within its prewar boundaries could have been completed by 1945 if the war had not intervened. Figure 1, though dated in 1938, actually gives data for 1935. By 1938, the new triangulation of Mecklenburg, Württemburg, and Bavaria was nearing completion.

In Germany the accuracy of triangulation usually was established by plotting all values of a given point as determined by the various observations. If these values fell within an ellipse whose major axis did not exceed 0.30 m. in length, the triangulation was regarded as sufficiently accurate. The pertinent figures for triangulation of first order are:

(1) The average length of half of the major axis of the ellipse is A ± 0.04 m., the maximum error should not exceed three times the absolute mean; (2) the mean deviation from the adjusted direction is ± 0.2" computed for a mean distance of 40 km., and the maximum deviation is in accord with the newer first order (± 0.15" to ± 0.20"); (3) the accuracy in measurements of base lines increased progressively, from 1 in 2,000,000 in earlier measurements to 1 in 3,000,000 in 1935 for the base line of the Island of Rugen.

A nation-wide triangulation net of three orders of accuracy was planned to replace the various state systems. The Reich was to be responsible through the Reichsamt für Landesaufnahme for the establishment and maintenance of the first-order triangulation net, although for the time being Bavaria, Württemberg, and Baden were allowed to continue their separate triangulation nets. Württemberg and Baden surveyors were attached to Reich survey parties, however, and Reich and Bavarian surveyors took part in the execution of triangulation in Württemberg and Baden. The reconnaissance and signal tower construction for the new Bavarian first-order net was done by the Reichsamt für Landesaufnahme, and the observation by the Bavarian surveyors under the supervision of the Reichsamt.

In first-order triangulation a distinction was made between principal and intermediate triangulation stations, the latter being observed only after the establishment of the principal net. Their accuracy, however, equalled that of the principal stations, and after August 1940 both were accepted as comprising the Reich Triangulation Net (Reichsdreiecksnetz) and were designated as TP(R). Points of the third order were to make up the State Triangulation Nets (Landesdreiecknetze) and were designated as TP(L). All points of fourth order were included in the Survey Net and designated as TP(A). The relation between points of various orders is shown below.

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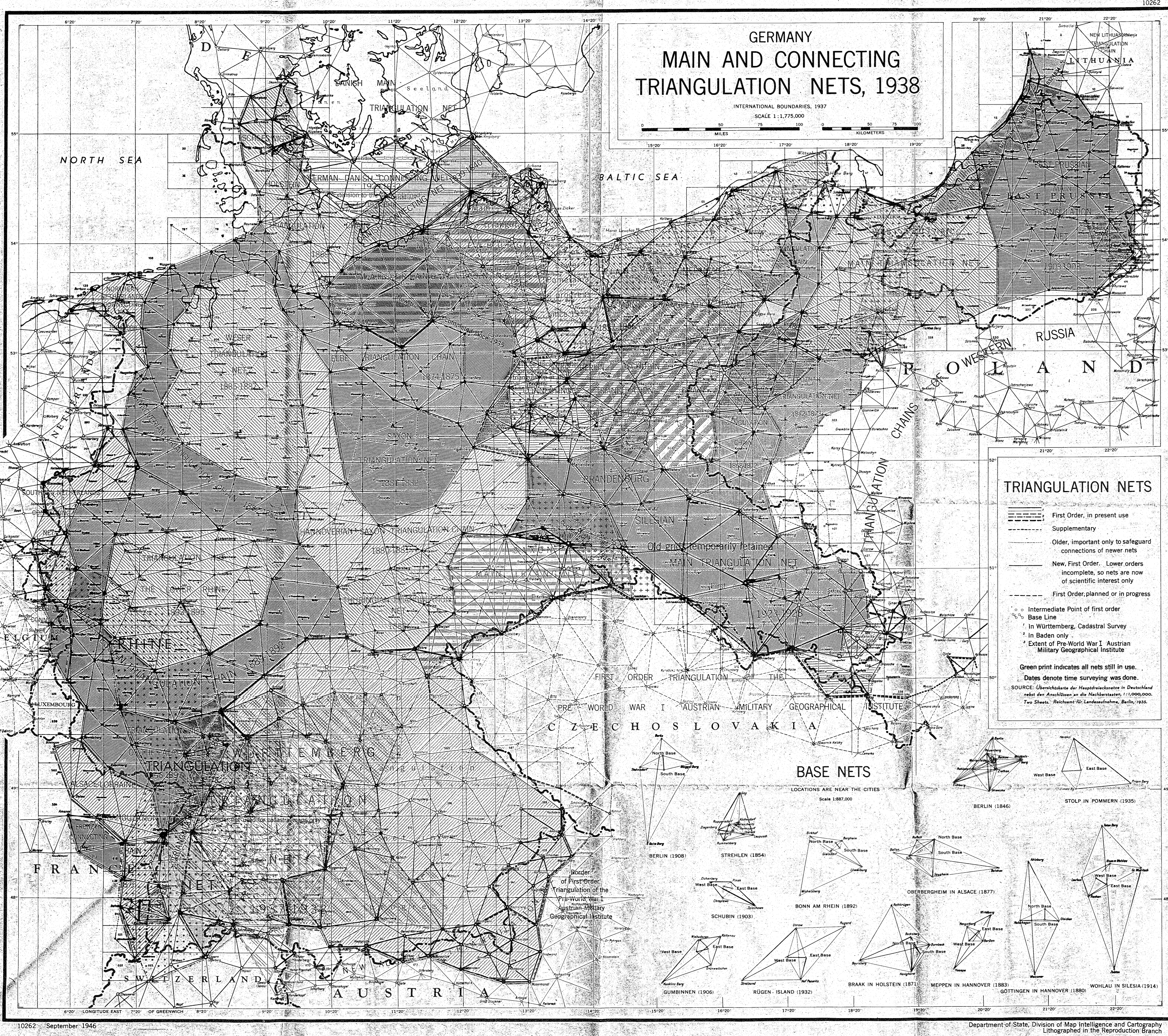
GERMANY
MAIN AND CONNECTING TRIANGULATION NETS, 1938
INTERNATIONAL BOUNDARIES, 1937
SCALE 1:1,775,000
MILES
KILOMETERS
NORTH SEA
BALTIC SEA
DANISH MAIN TRIANGULATION NET
GERMAN-DANISH CONNECTING NET
WESER TRIANGULATION NET
ELBE TRIANGULATION CHAIN
SAXON TRIANGULATION NET
HANNOVERIAN-SAXON TRIANGULATION CHAIN
BRANDENBURG
SILESIAN
Old grid temporarily retained
MAIN TRIANGULATION NET
EAST PRUSSIAN MAIN TRIANGULATION NET
LITHUANIA
RUSSIA
POLAND
CHAINS OF WESTERN TRIANGULATION
FIRST ORDER TRIANGULATION OF THE PRE WORLD WAR I AUSTRIAN MILITARY GEOGRAPHICAL INSTITUTE
CZECHOSLOVAKIA
BELGIUM
LUXEMBOURG
FRANCE
SWITZERLAND
AUSTRIA
RHINE
WÜRTTEMBERG
ALSACE-LORRAINE
Border of First Order Triangulation of the Pre-World War I Austrian Military Geographical Institute
TRIANGULATION NETS
First Order, in present use
Supplementary
Older, important only to safeguard connections of newer nets
New, First Order. Lower orders incomplete, so nets are now of scientific interest only
First Order, planned or in progress
Intermediate Point of first order
Base Line
1 In Württemberg, Cadastral Survey
2 In Baden only
3 Extent of Pre-World War I Austrian Military Geographical Institute
Green print indicates all nets still in use.
Dates denote time surveying was done.
SOURCE: Übersichtskarte der Hauptdreiecksnetze in Deutschland nebst den Anschlüssen an die Nachbarstaaten, 1:1,000,000. Two Sheets. Reichsamt für Landesaufnahme, Berlin, 1935.
BASE NETS
LOCATIONS ARE NEAR THE CITIES
BERLIN (1846)
STOLP IN POMMERN (1935)
BERLIN (1908)
STREHLEN (1854)
OBERBERGHEIM IN ALSACE (1877)
BONN AM RHEIN (1892)
SCHUBIN (1903)
GUMBINNEN (1906)
RÜGEN - ISLAND (1932)
BRAAK IN HOLSTEIN (1871)
MEPPEN IN HANNOVER (1883)
GÖTTINGEN IN HANNOVER (1880)
WOHLAU IN SILESIA (1914)
LONGITUDE EAST OF GREENWICH

10262 September 1946

Department of State, Division of Map Intelligence and Cartography
Lithographed in the Reproduction Branch

Table 1. SET OF "GREAT CIRCLE MAPS FOR AIR NAVIGATION" (GROSSKREISKARTEN)[1]

Area	Projection	Center of Projection	Radius of the Sphere (in mm.)	Radius of the Earth (in km.)	Scale at Center of Projection
North Polar Region	Polar Azimuthal	North Pole	479.0	6,370.7	1:13,300,000
Northern Atlantic Ocean	Oblique Azimuthal	Lat. 40° N Long. 30° W	392.0	6,370.0	1:16,250,000
Middle Atlantic Ocean	Equatorial Azimuthal	Lat. 0° Long. 30° W	217.5	6,372.75	1:29,300,000
Europe-Asia	Oblique Azimuthal	Lat. 30° N Long. 75° E	205.5	6,370.5	1:31,000,000

1. Ordered by the Minister of Air Navigation and Supreme Commander of the Air Force, compiled by the Deutsche Seewarte, Hamburg, printed by Gebruder Sülter, Hamburg 36.

	Order	Sätze	Length of Sides	Density (1 point per)
TP(R)	(1st	12	(30 km. (average)	
	(2nd	6	6-15 km.	50 sq. km.
TP(L)	3rd	3	3.5 (average)	5 sq. km.
TP(A)	4th			

In the above tabulation, "Sätze" is used in place of "Number of Pointings," since the latter might be misleading. In the Schreiber method of observations used by the Reichsamt für Landesaufnahme, each angle and all combinations of angles about a station are measured a number of times, according to the total number of angles. For example, in first-order observations from a five line station, each angle and combination of angles is measured five times with the telescope in the direct position and five times with the telescope in the reverse position.

Triangulation stations were characteristically marked by stone plates surmounted by stone pillars. The pillars had crosses chiselled on the top, and the letters TP and a triangle were engraved on the sides. Aufnahme or fourth-order stations were marked AP on one side and a metal pipe or bolt was used for the subsurface marker. Metal bolts or plates were used only as bench marks. Church spires and lookout towers used as triangulation stations had leveling bolts at their base. The bolt, stamped TP (or HP if it is also a levelling point), had a hole drilled in the top. The center axis of the hole was used as an eccentric station mark.

Second- and third-order triangulation stations are distinguished from first order only by a lower degree of accuracy, which means that observations were not repeated as often as for those of first order. In many second- and third-order nets, however, the accuracy is as good or better than the average for the Reich triangulation nets. Only in a few cases is the maximum permissible error for first-order triangulation exceeded, and then usually because of forced adjustments to older adjoining nets. Similarly, in many cases the probable error of the adjusted direction

is well within the Reich average. In the old third-order nets, however, the error is much larger, amounting to a maximum error of 15.3" in the southern part of Pomerania. The error in the new first- and third-order nets are well within the Reich average. The triangulation program called eventually for a density of stations averaging about one station to each square kilometer. There are about 54,000 triangulation stations in Prussia. The number was to be increased to between 250,000 and 300,000. This density was considered necessary (a) for military reasons, (b) to create a sufficient number of control points for the use of aerial photographs, and (c) to enable the local authorities to fit their local surveys into the national net. There were 6,000 additional stations in the smaller north German States, and 60,000 in southern Germany. Of these triangulation stations, 12,000 were of first-order accuracy in 1938. Since then, the army established an unspecified additional number of points, especially in the territory of the West Wall, where they are called artillery points (AP).

For purposes of surveying, the French and Belgian division of the right angle into 100 degrees, 10,000 minutes, and 1,000,000 seconds was adopted, even the French abbreviations being retained. It was decided, however, to express measurements in decimals rather than use the abbreviations for minutes and seconds. The term "Neugrad" (new degree) was coined for this new unit.[1] Instead of manufacturing new theodolites, it was planned to equip those already in use with the new scale by April 1, 1945. Computations have been made in this new system since 1938.

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1. Circular Order...of October 18, 1937, concerning the division of angles, ibid., Vol. 14, No. 2, 1938. The centesimal system was not used for first-order triangulation. This exception was officially sanctioned by Section II, paragraph 2, of the Circular Order of October 18, 1937.

The decimal graduation was printed also on airway maps, together with the much older division of the circle into 64 points (Striche), each one subdivided into 100 points (also called Striche).

The German Reich is thus covered by a system of triangulation nets of various ages and degrees of accuracy. Originally triangulation arcs were surveyed, which were later used to combine isolated nets. For these arcs and nets, base lines from 3 to 10 km. (2 to 6 miles) in length were measured, which were expanded by triangulation to a junction with the larger sides of the nets. To insure accuracy, most of the base lines were remeasured and compared with the bases of 960 m. at Potsdam and of 1248 m. near Munich. These remeasurements were necessary also because all base lines were originally measured with the Bessel apparatus rather than the recently introduced invar wires. The Munich base line was the first to be measured with invar wires. The use of two primary base lines for purposes of control was adopted because of the possibility of changes in the true length of one of them. No triangulation point was to be more than 200 km. (about 120 miles) from the nearest base line.

B. Maintenance of Triangulation Stations and Restoration of Station Marks

Even a perfect triangulation net needs continuous supervision. Buildings are removed and highway and building construction destroys station marks; mining operations may change the surface of the earth, and station marks may be damaged by the negligence of landowners. The restoration and maintenance of station marks is, therefore, a continuous process. Before the war, reports on station marks were made semi-annually by local policemen. Geodetic engineers usually recovered about 90 percent of those reported as lost.

Since the outbreak of World War I, maintenance has not kept pace with needs. In 1935, about 3,900 of the 55,000 triangulation stations in the Reichsamt net were reported to be damaged or lost, and by now the figure is probably much higher. Furthermore, systematic restoration

in some areas showed that 30 to 60 percent more station marks than estimated had to be either restored or replaced. Such restoration can be done only by experienced surveyors and, until 1936, sufficient trained personnel was not available. During 1936, 1,546 station marks were restored, but in the following year, when surveyors were needed for other work, less than half that number was restored. Triangulation stations known to be damaged or lost as of April 1, 1938 numbered 2,944. Restoration has progressed furthest in Silesia and Pomerania, the state of Lippe, and the northern part of the Rhineland.

The restoration of lost station marks, especially if the surface plate has been lost, is both time-consuming and expensive. The Reichsamt für Landesaufnahme, therefore, charged one of its surveyors with the problem of experimenting with the parallactic polygon chain method, which Professor W. W. Danilow of Moscow had formulated. The theory is based on the fact that the lengths of the longer diagonal of a very long and narrow deltoid (kite-shaped quadrangle) can be determined from the length of the smaller diagonal and the very small parallactic angles at the ends of the longer diagonal. In practice this involves the difficulty of measuring very small angles and distances with sufficient accuracy. If the following conditions can be fulfilled, however, the method is accurate enough for use in replacing triangulation stations of second and third order. The smaller diagonal line must be measured with absolute accuracy by an invar wire, and its two parts, formed by its intersection with the longer diagonal line, must not differ more than 0.2 m. The angle at the intersection must not deviate more than 2' from a right angle, and the line of sight from the theodolite to the marker should be high enough above ground to exclude refraction. The theodolite itself must be accurate. Under these conditions, the deviation from the true length is less than 1 in 35,000.

It is understood that this method has proved satisfactory in at least two trial measurements; once in 1935, when two lost points in Holstein were restored, and again in 1936, not far from Berlin along the planned route of a super-highway that cut through the woods and offered, therefore, conditions unfavorable for the usual method of triangulation. The parallactic polygon chain method was not intended for use in mountainous areas.

After the outbreak of war, the Germans stopped showing the exact locations of subsurface station marks on their maps, in spite of the resulting inconvenience, because such information was considered too valuable to the enemy.

C. The Situation, 1938-44

It is possible to give a fairly accurate picture of the condition of German triangulation in 1935 as well as the plans for the future from a report of President Vollmar of the Reichsamt für Landesaufnahme of December 1, 1935 (see Figure 1). The scattered information on plans for triangulation during the next few years has recently been supplemented by an unpublished report prepared by Captain Spencer D. Smith, in charge of the Land Survey Office, Bamberg, Germany. Of the first-order nets, the Mecklenburg net was completed in 1938, the Danish connecting net in 1939, the two Pomeranian nets in 1936 and 1937, the Saxon connecting chain in 1941, the North and South Bavarian nets in 1940, the Baden-Württemberg net in 1937, and the Austrian net in 1940. In Germany all modern nets of first order are completely adjusted to adjacent nets. Older triangulation data are still in use, especially in land registry, because the 1:2,500 and 1:5,000 maps were often bordered by co-ordinate lines on the old grid system, and because thousands of fourth-order (Aufnahme) stations were given in the old state survey systems. A summary of the situation is given in Appendix A.

The Temporary Reich Survey Net was completed in 1928 and the final Reich Survey Net was ready for publication in 1944. The Reichsamt für Landesaufnahme had assembled a complete card file for Greater Germany showing for each triangulation station, (1) geographic positions and elevations; (2) Gauss-Krüger co-ordinates (DRG) in the temporary system, i.e., the system wherein adjustments are made without taking into consideration the base lines and Laplace stations outside northwestern Germany; (3) co-ordinates in the final system in which all possible adjustments are made, and (4) the Military Gauss-Krüger co-ordinates (DHG). These files were used in all HVA's (Hauptsurmessungsabteilungen) and the Army Cartographic office received several copies of all cards. At the end of the war, the file for the final Reich Survey Net was loaded into two trucks. One half was sent to Wittenberg and may be in Russian possession and the other half was sent to Imrsbruch and is believed to be in the possession of the French Army in Paris. No examples are in U.S. or German possession.

Such files are necessary, since maps can show the positions of triangulation stations only within graphic limits. On 1:50,000 maps, triangulation stations are given with an accuracy of ±10 m., other points ±30 m. On maps at 1:25,000, the accuracy increases to ±5 m., and ±20 m., respectively. To obtain the position of a point with an error of not more than one meter, it is necessary to use the Grundkarten at 1:5,000, or cadastral maps for states such as Baden, Bavaria, Hamburg, Hessen, Saxony, and Württemberg, and for parts of Thuringia.

1. Areas with Adequate Triangulation Nets

The regions discussed in the following paragraphs are provided with adequate triangulation nets, though not necessarily of all three orders. In Germany, moreover, a distinction must be made between an arc of triangulation and a triangulation net. The former covers a strip of land 50 to 70 km. wide, while the latter may be any irregularly shaped area.

a. Prussia West of the Elbe and Connecting Nets. Adequate triangulation was established in this region between 1878 and 1900.[1] The different triangulation arcs and nets have been adjusted satisfactorily. The Prussian net was the largest of the German nets and contained the datum point of Rauenberg (related to the observatory in Berlin), and the base lines of Berlin 1846, Königsberg 1834, Strehlen (Silesia) 1845, Braak (Holstein) 1871, Oberbergheim (Alsace) 1877, Göthingen 1880, Meppen 1883, and Bonn 1892. Consequently all other nets were converted to the Prussian system. The newly measured nets of East and West Prussia, with the base lines of Schubin and Gumbinnen, were adjusted to each other and connected with the Prussian net by holding the border stations fixed by the old net.

In 1924, the Prussian system was transferred to the Gauss-Krüger grid and was called the Preliminary Reich Survey Net. Mecklenburg, Württemburg, Saxony, Bavaria, and Baden thereafter were converted to the system by computation only and without additional measurements. Many discrepancies remained along the borders. All stations in all orders were completely converted to this adjustment and the results were published in trigonometric lists and on index cards.

In 1936 it was decided to hold the northwestern part of Germany invariable (nets underlined in Figure 4, Appendix B) in order to avoid changes in position. The eastern nets were adjusted internally without base or Laplace conditions, were connected to adjacent nets by the Helmert method, and then connected with the northwestern nets. The southern nets were connected to the combined northern net. The adjustment was further enlarged by addition of the Polish, Czechoslovakian, and Austrian nets in 1944. The result was called the Final Reich Survey Net.

In July 1945, the U.S. and the British Armies decided to readjust the Final Reich Survey Net by the Bowie method, using all base lines and

1. "Official Triangulation Grid," ibid, Vol. 16, No. 5, 1940.

Laplace stations. The junction figures and sections of this adjustment were completed in July 1947 and called the Central European Net. The polygons should be completed by July 1948.

b. East Prussia. Triangulation of all three orders has been completed.

c. West Prussia. Triangulation of all three orders has been completed in the former Province of West Prussia. The greater part of this net, however, lies beyond the 1937 boundaries of the Reich, in the Polish Corridor and Danzig. A small part of the triangulation is in the section of West Prussia that was joined to East Prussia in 1919, but it is still referred to in German publications as part of the West Prussian net.

d. Berlin-Schubin. A first-order triangulation arc connects Berlin and Schubin, the latter in the part of Poland that belonged to West Prussia before 1919. At Schubin, the arc connects with the East and West Prussian nets mentioned. The adjustment of the Berlin-Schubin arc revealed large junction errors. By moving the Prussian nets 2.3 m. (or 0.1184") to the west, these errors were reduced, but a slight distortion developed in the north (see Table 2).

e. Märkisch-Silesian net. Principal first-order triangulation (without intermediate points) has been completed for this area. The second-order has been remeasured and the third-order partly remeasured in the eastern part of the area. The base line near Wohlau, which had not been used before, was remeasured in 1941 and was used in adjusting the net.

f. Schleswig-Holstein, Hamburg and Lübeck. Triangulation of all three orders has been completed.

g. Eastern Pomerania. The principal first-order triangulation has been completed for Eastern Pomerania, and the intermediate net was

scheduled to be completed in 1936. The net reaches from Jordansee (on Wollin Island), Vogelsang (near Stettin), and Gornow in the west to the Berlin-Schubin triangulation arc in the south. Northeast of Stolp, a new base line 9.6 km. long was measured with invar wires in 1935. As the triangulation data were urgently needed for the area east of the meridian 15° 20' E. because of the many new German settlements in the area, the second and third-order triangulation, though observed independently, was done at the same time as the first-order triangulation. The necessary adjustment to the first order stations, a relatively simple office procedure, was scheduled for the winter of 1938-39.

h. Vorpommern (Northwestern Pomerania). A first-order triangulation net was completed in this area. A base line of 4.8 km. was measured on Rügen and another of 10 km. was planned for the Werbelliner heath. In 1938, there was no plan for second- and third-order triangulation and, because of the war, it is unlikely that any has been done.

2. Surveys Planned or in Progress

a. German-Danish Net. In the east, the German-Danish net joins the Vorpommern net, which in turn joins that of East Pomerania at Jordansee, Vogelsang, and Gornow, and in the south the Berlin-Schubin arc. This German-Danish net was to be enlarged to include the northern part of Mecklenburg and to join the Holstein net in the west. This would provide a trustworthy framework for the future triangulation of Southern Mecklenburg. The first-order triangulation was completed in 1939; second- and third-order triangulation was planned only for the Mecklenburg-Prussia border.

b. Märkisch-Silesian Net. In the area covered by the Märkisch-Silesian net, observations for intermediate first-order triangulation stations were scheduled to begin in the summer of 1938. Second- and third-order triangulation was completed in parts of Upper Silesia

because of settlement projects, but no plans had been made for the rest of the second- and third-order nets, since it was considered unnecessary.

c. East Pomeranian Net. In the area west of meridian 15° 20' in East Pomerania, second- and third-order triangulation, started on completion of the first-order net, has been completed.

d. Vorpommern Net (Northwestern Pomerania). Same as above.

e. Berlin-Schubin Arc. When the Berlin-Schubin triangulation arc was completed, plans were made for future second- and third-order triangulation. Computations were started to adjust the Märkisch-Silesian net to the Berlin-Schubin arc, but the adjustments could not be completed because of other connections with adjoining nets. The adjustment of the Märkisch-Silesian net, however, would move the points in southeast Silesia about 6 m., which was not acceptable to land registry authorities. Other types of adjustments were, therefore, under investigation. The Märkisch-Silesian triangulation net had its own base line near Wohlua, measured as early as 1914. No adjustment to this base line was made at the time, because of the outbreak of World War I. It was necessary, therefore, to remeasure the base line, which was finally done in 1941 (see above).

f. Sächsischer Anschluss. A reconnaissance was made in 1935 for the Sächsischer Anschluss (Saxon connection), covering a small area located between the principal Märkisch-Silesian triangulation net, the Saxon-Hannoverian triangulation arc of 1880-1881, and the principal Saxon triangulation net. First-order triangulation has been completed, as well as a small amount of lower-order triangulation along the Saxon border.

g. Mecklenburg-Märkisches Net. The Mecklenburg-Märkisches first-order triangulation was observed between 1936 and 1939, and in 1941 a base line was measured on the Schorffheide. This net is bordered by the Elbe arc of 1874-5; the Holstein arc of 1869; the German-Danish

TABLE 2. RELATION BETWEEN CONNECTING NETS IN THE PRELIMINARY REICH SURVEY NET[a]

Nets	Common Points: Number	Location	Average Distance Apart (in meters) Gauss-Krüger: Shortest Distance	N-S (Hochwert)	E-W (Rechtswert)	Notes
A. After adjustment Rfl[b]-East Prussia West Prussia	6	3 north and 3 south on Pomeranian border	0.90 (N) 1.46 (S)	--	--	East and West Prussia nets moved 2.3 m. westward as a unit
RfL - Mecklenburg	--	All first-order triangulation stations in Mecklenburg	9.59	--	--	Maximum: 1:50 m.
RfL - Saxony	50	All first-order stations in Saxony	0.21	--	--	Minimum: coincidence - 2 cases Maximum: 0.60 - 1 case
Bavaria-Württemburg	10	Along the border near Ulm	1.73 2.83	-0.74 to +0.54	+1.64 to +2.31	
Württemberg-Baden	16	SE corner of Württemberg	6.39-7.87	+3.55 to +5.41	-5.97 to -4.56	
Baden-Alsace	30	Along the common border	0.76-2.04	+0.59 to 1.60	-1.62 to +1.87	
B. Before adjustment Württemberg	--	--	--	135-141 (or 4.32")	35-40 (or 2.58")	
Baden - RfL	--	--	--	about 280 (or 9.1")	--	

a. Although the Baden net is connected with the net of the Reichsamt für Landesaufnahme via Württemberg, the two nets touch at one point. The error introduced by indirect connection results in a difference of 9.1" or about 281 m. in the N-S direction, using the Gauss-Krüger system. These discrepancies are for identical stations along the boundaries of adjacent states, but will not appear in the final net, which should be completed in July 1948.

b. RfL - Reichsamt für Landesaufnahme.

connecting net, which covers northern Mecklenburg; and the principal triangulation net of Western Pomerania, which comprises parts of eastern Mecklenburg, the Berlin-Schubin connecting triangulation arc, and the principal Saxon triangulation net. The older Mecklenburg first-order triangulation, originally observed in 1853-60, had to be discarded because of excessive errors in azimuth, which prevented satisfactory adjustment to the Prussian triangulation. Most of the old Mecklenburg stations, however, were scheduled to be absorbed into the new net as second-order triangulation stations. First-order adjustments were completed in 1939. For Mecklenburg, second- and third-order nets were remeasured between 1910 and 1912. The computation to connect the second- and third-order with the first-order was started in 1944 and is now (1947) being completed by HVA VI.

h. Bavarian Triangulation. In Bavaria new first-order triangulation was started in 1920. It was connected with the Hessian, Thuringian, and Saxon triangulation nets, following the methods and rules established by the Reichsamt für Landesaufnahme. A base line was measured near Schleissheim, but the base line near Nürnberg was not agreed to by the Ministry of the Interior and was not measured during the survey work of 1941. Reconnaissance and remeasuring of the entire first-order net was completed by the Reichsamt für Landesaufnahme and Bavaria. No intermediate triangulation was undertaken, and second- and third-order were planned only for some area. At Schleissheim, Bavaria measured a base line with invar wires in order to compare it with another older base line near Munich, which had been measured with the Bessel apparatus. There are, however, two bases in Germany that may be used as standards of comparison at Potsdam and at Munich. Thus, it is possible to detect tectonic changes in either one.

i. Bavarian Palatinate Triangulation. In 1937, second-order triangulation was completed for the Bavarian Palatinate. No plans were made for immediate continuation of third-order triangulation, presumably because the surveyors were needed on the main Bavarian triangulation. Since the army did a tremendous amount of triangulation in all areas crossed by the West Wall, presumably the Bavarian Palatinate was included. To what extent the army survey fulfilled the requirements for the third-order triangulation is unknown.

j. Baden and Württemberg Net. Although the old triangulation net of Baden and Württemberg was connected with the old Rhine Survey net, which afforded a connection with Prussia, it was not satisfactory and new triangulation was considered necessary. Observations for the principal first-order stations were completed in 1937. Because of nearness to the Schleissheim and Oberbergheim (Alsace) base lines, no others were planned for Baden and Württemberg, but several Laplace astronomical stations were planned. Intermediate triangulation was not completed in the southern part of the area but is now being done by HVA XII and should be finished by the end of 1947.

k. Hessen Net. Inasmuch as Hessen adopted the principal triangulation net of the Reichsamt für Landesaufnahme, there was no obstacle to the integration of its lower-order net into that of the Reich. In 1937, the positions of a number of intermediate first-order stations were published.

IV. CONNECTIONS OF THE GERMAN TRIANGULATION WITH THOSE OF OTHER COUNTRIES

In general the German triangulation net is connected with those of adjoining countries. Where there are junction difficulties, they are due less to insufficient common points than to the peculiarities and, in some cases, deficiencies of adjoining nets. During the war, the Germans conceived a far-reaching program for the unification of surveying and mapping in all Europe. Preliminary steps were taken, especially in Western Europe. The first German triangulation in France included the parallel from Paris to Brest, the parallel of Rochefort, and the section of the meridian of Bayeux that connects the two parallels. Extensive second-order triangulations were carried out along the Atlantic and Channel coasts.

The two most important states adjoining Germany - Russia and France - had no elaborate triangulation like that of Germany. Instead, between the triangulation arcs that criss-crossed the countries were wide intervening areas that were filled in more or less adequately with lower-order triangulation.

On October 14-16, 1943, a conference of military survey officers was held in Vienna to create a European Geodetic Union under the leadership of the German Army. The army proposed to take over most of the work of the Reichsamt für Landesaufnahme. The adjustment of a European net was planned and later executed for large areas of Europe by the army. The results, which were inadequate, were in the possession of the army only. Since differences became progressively larger as the distance from the northwest German block increased and since the block was regarded as fixed, the difference could not be adjusted adequately. Discrepancies along the eastern borders of Moravia and Austria, however, were only about one meter. It was stipulated that maps of all European

states should be made according to the same specifications, on the Gauss-Krüger projection using the Gauss-Krüger military grid.

In July 1945, the U.S. and British Armies decided to undertake the readjustment of the Final Reich Survey Net, using the Bowie method. This was to be called the Central European Net, the title indicating its ultimate scope. (See above p. par. 4.)

A. Lithuania

Among the successor states of Czarist Russia, only Lithuania and Poland had common borders with Germany. The northwestern part of Lithuania is crossed by a triangulation arc that has four points in common with the East Prussian net. This arc forms the backbone of the Lithuanian triangulation. Lithuania adopted the Gauss-Krüger grid and its recent map, scale 1:25,000, has the same sheet size and scale as the German Topographic Map. Consequently, the new Lithuanian maps and the adjoining German maps fit together accurately. The Lithuanian triangulation was scheduled to be completed in 1943, but was retarded by the war. The work completed, however, was done by Lithuanian surveyors under German supervision.

B. Poland

Poland tried until 1927 to combine the parts of the German, Austrian, and Prussian triangulation nets within its borders, but failed because of the lack of a sufficient number of common points. The locations of first-order triangulation stations differed by as much as 5 meters, the differences where the triangulation nets joined in the border areas were up to 120 meters; and some station marks could not be recovered. Thus there were junction errors not along the German border of 1919, but along the pre-First World War border, which coincides with the 1919 border only in East Prussia and approaches the 1920 (Versailles) boundary only in Upper Silesia. Difficulties were

encountered also at one place along the Pomeranian border of the Polish corridor, when the new East Pomeranian net was surveyed. The old nets of this area were discarded, but Poland and Germany could not come to an agreement that would make possible the connection of their respective nets.

One of the original Russian arcs followed the border of Suwaki Province from its northern border to north of Lomza. Southeast of Lyck, it was connected with an old Prussian arc of 1859. This arc is retained only as the connecting link between the newer East Prussian net and the old Russian arc, although it has only two stations - near its northwestern end - in common with the East Prussian net of 1903-08. Its other stations are no longer used for German internal measurements.

A Russian arc leading north from Warsaw had two stations along the German border, but no connection with the Prussian net was established. Another arc from Warsaw followed the Vistula River and originally joined the discarded Prussian Weichselkette of 1853 near Torun (Thorn). At this point another old Russian arc branched off to the south, paralleled the old border, and joined the "Anschluss Tarnowitz" of 1852, which was still legal and in use in 1944. The survey of a new first-order net, however, is in progress in the area.

In the broad area between the Lomza-Lyck and Tarnowitz regions, junctions errors could develop because the nets were surveyed independently; but, in the areas most distant from the junctions of the nets, the adjustment is purely an internal Polish problem. To overcome difficulties along the historical boundaries within Poland, differences have been temporarily adjusted graphically on the maps. As a result, maps covering areas on both sides of the old border cannot be considered adequate.

A new Polish triangulation net was begun in 1927. Arcs of triangulation were planned to cross and join one another, thus forming

10 more or less regular polygons. The triangulation around eight of these polygons was completed by 1939. The remaining triangulation arcs, which were to close the two remaining polygons, were postponed because they were in territory formerly belonging to Prussia, where the old triangulation seemed most nearly adequate and where a new survey was therefore least urgent. In general, these arcs were of first-order accuracy, except in a few areas along the eastern border (now in Russia) and around Warsaw. Bessel's reference spheroid is used. The use of a new projection was planned for future maps, a stereographic projection according to Roussilhe. As far as it is known, no maps on this projection have been published.

After the conquest of Poland, the Germans tried to adjust this new Polish net to the German net, despite the difficulties arising from the use of a different reference spheroid and the long distance from the Northwest German net. An intensified program of observating was planned to complete the gaps in the new triangulation, but only the work in the Suwaki region was completed. Contrary to professed principles, most of the work in 1940 and 1941 was done along the Soviet border; later the tempo of the whole program seems to have slackened.

C. Czechoslovakia

Czechoslovakia and the Republic of Austria, both heirs to territory of the old Austro-Hungarian Monarchy, may be discussed together. The old Austrian Empire was the first large country to cover its entire area with a triangulation net of uniform accuracy and specifications. This net is usually called the grid of the Military Geographical Institute, after the agency responsible for it. A feature of this triangulation to be noted is that it stopped some distance from the international boundaries. No first-order stations were established with a view to connecting the net with the triangulation of other countries. In 1878, an Österreichischer Anschluss (Austrian connection) was established by means of the Prussian

triangulation in the southeasternmost part of Upper Silesia, which connected with the Austrian triangulation in Austrian Silesia (after 1918 Czechoslovakian Silesia and the Polish part of Teschen). Along the other parts of the border also, German triangulation was extended across into Austria to the triangulation stations of the Military Geographical net, which later became the Austrian and Czechoslovakian state nets.

The Austrian Republic and Bavaria had new triangulation underway at the same time and worked in close collaboration with each other. After the conquests of Austria and Czechoslovakia, the triangulation nets of both countries were adjusted to the Reich net. In Bohemia, a new net - probably containing only first-order stations - was surveyed in 1943.

Maps of both countries differ slightly from those of Germany. Austria as well as Czechoslovakia retained the polyhedric projection, the unit being a quadrilateral framed by two meridians 30' apart and two parallels 15' apart. Longitude was measured from the meridian of Ferro. Germany, however, had given up use of the meridian of Ferro and, even on older sheets where it had been used, the projection unit was a 1-degree quadrangle. Practically all German maps, with the exception of the Bavarian Positionblätter, use longitude referred to Greenwich. The Positionsblätter, which have been replaced by newer maps to only a small degree, are similar to the Austrian and Czechoslovak sheets but differ slightly from them. On the German sheets, including the Positionsblätter, the bounding parallels are straight lines, the secants of arcs; whereas on the Austrian and Czech sheets arcs are used and the resulting parallels are slightly curved. Both Austria and Czechoslovakia consistently made allowance for this slight curvature.

Bessel's reference spheroid is used in Austria and Czechoslovakia. It is also used in Prussia and Saxony and is sufficiently similar to the one used in Bavaria to avoid bad junction errors.

Though such theoretical differences may be of minor concern, the difference in basic scales employed creates a practical difficulty. The Austrian and Czechoslovakian scale of 1:75,000 is not used on any official German map. The few existing Austrian maps at 1:25,000 are of large cities and their environs. Czechoslovakia, however, has a considerable number of 1:25,000 sheets along the German border. The new Austrian sheets at 1:50,000, like the German sheets at the same scale, are few in number.

The Austrian and Czechoslovakian general maps at 1:200,000 are on the polyhedric projection with a 1-degree grid - a combination that was never employed by the Germans. Since the corresponding German maps have greater distortion at the corners of the sheets (up to 5mm., the equivalent of 250 m. in the field), it is difficult to match them to Austrian and Czechoslovakian sheets. Along the edges where the maps are joined, discontinuities appear in the form of gaps, overlaps, or displacements, amounting at places to as much as several hundred meters.

D. Switzerland

Switzerland, like Bavaria, used the Bonne projection for its topographic maps. Bavaria, however, is the south German state with the shortest common boundary with Switzerland. The triangulation of all south German states has been closely connected with that of the Swiss for many years.

E. France

The condition in France is badly confused, partly because of inadequate adjustment between the French triangulation nets, (and consequently between the maps themselves) and partly because of the change

in allegiance of Alsace-Lorraine. Alsace-Lorraine was connected with the other German nets through the 1876 triangulation arc. In 1899, a temporary connection was made with the triangulation arc of the parallel of Paris in the Department de Vosges. A short time before the outbreak of World War II, the French surveyed a new triangulation arc extending along the parallel of Paris to the Rhine, incorporating triangulation stations of the earlier German triangulation. Through this rearrangement, the arc of the parallel of Paris now joins the German triangulation through two common stations that form one side of Belchen-Kaiserstuhl of the Rhine-Baden triangulation, as well as of the French triangulation. This new triangulation was not completed for all orders, but serves as control for the 1:10,000 and 1:20,000 maps (Plans directeurs), and the 1:50,000 map (Nouvelle carte de France). Other French maps are based on older triangulation. Conversion tables have been prepared for transferring the old positions to the new system. At some distance from the main triangulation arc, junction differences of 100-150 meters develop. This is especially noticeable on the 1:80,000 map and consequently on its enlargement to 1:50,000.

The 1:80,000 map is the only map of large scale that covers all of France. It is drawn on the Bonne equal-area projection, using the reference spheroid of Plessis. The latter is an adaptation of the spheroid according to Delambre, insofar as it assumes a periphery of 40,000 km for the spheroid, which creates an error of 1 m. for every 13.8 km. This does not exceed the normal error of drafting or of expansion or contraction of paper. It is also consistent with the French adaptation of the decimal system to longitude and latitude.[1] Thus, a second is exactly 10 meters long and a minute 1 km. However

1. According to this system the right angle is divided into 100 degrees (100^{g}) of 100 minutes (100^{c}) each, which are made up of 100 seconds (100^{cc}) each.

the more recent geodetic work in France is based on Clarke's spheroid of 1880.

The Bonne projection for France used the Paris meridian as its central meridian and latitude 50^{g} (45°) North as its central parallel. The error in azimuth may be as great as 30^{c} (17'), or 0.5 meter in a 1 kilometer. The scale error may amount to 1 in 400, or 2.5 meters per kilometer. Since the First World War, a grid based on this projection has been used on French maps.

In 1920, the Lambert projection was adopted. This is a conformal projection, with parallels shown as concentric circles and meridians as straight lines. The distortions are less than on the Bonne projection. Scale error increases with distance from one of the standard parallels. For this reason, three slightly overlapping zones were established, each with a width of 4^{g} latitude. The scale error generally is less than 1 in 6,250, but in outlying areas such as Alsace and Brittany it may amount to 1 in 2,000.

On its own Lambert projection, there is also a separate zone, Nord de Guerre, whose central meridian is 6^{g} east of Paris, central parallel 55^{g}, and with standard parallels 53^{g} and 57^{g}N. This zone is to be eliminated gradually, but at present many maps use this grid. The older maps are shaped according to the rectangular Bonne grid, which has its origin at the intersection of the central parallel with the meridian of Paris. They do not fit together exactly however, because the main triangulation arcs were not adjusted to one another. There also are similar differences between individual sheets, depending on which triangulation arcs they are based on. For example, the 1:80,000 Strassbourg sheet differs as much as 20 to 30 meters from adjacent sheets at its corners, and as much as 50 to 100 meters at the middle of the upper edge. Because about 70 percent of the old triangulation station marks have disappeared, the geodetic data in

these areas are insufficient for the control of aerial photogrammetry and for artillery range-finding. This is less significant for maps at 1:80,000 or smaller scales, than for the old maps at 1:10,000 and 1:20,000. The new French sheets on the Lambert projections are bounded by meridians and parallels.

The newest French survey and mapping program progressed furthest in eastern France. Since the new triangulation was not connected with the German until 1943, it cannot have had much practical influence on the co-ordination of German and French maps. There was, however, another older indirect connection via the Belgian net.

Few general statements about the relationship between French and German maps may be made, since junction errors and distortions can be found even between adjacent French sheets. Because Germany continues to use 360° for its topographic maps, and France has adopted the 400^{G} division, sheet sizes differ in the two countries, and it is impossible to correlate them. The new 1:50,000 French map, however, is a well designed accurate set covering the entire border region. It may, therefore, be assumed that disturbing features will develop only at a distance from the border if the new French set is used, but may be expected to develop anywhere if the older sheets are used. The distortions of the Lambert projection on the French side are too slight to affect the fitting together of adjoining French and German sheets.

F. Luxembourg

The Luxembourg triangulation net was surveyed by the Belgians about 1930 and was closely linked up with the survey of Belgium. Good connections were also established with two French triangulation arcs. During World War II, the Reichsamt für Landesaufnahme surveyed a new net, which was closely integrated with the triangulation in the Rhineland and with the Old Alsace-Lorraine triangulation arc.

G. Belgium

Belgium was linked with Germany through connecting triangulation in 1894. During the World War II, the Germans wanted to integrate the Belgian triangulation net into that of the Reich, but had not quite completed the computations when the Allies liberated Belgium.

The older Belgian maps are on the Bonne projection; recently the Lambert conic conformal projection was introduced. The distortions of the Bonne projection are insignificant for as small an area as Belgium. The same is true for the Lambert projection. The scale error does not exceed 1 in 10,000 or 10 centimeters in 1 kilometer. The Hayford spheroid of reference was adopted at the same time as the Lambert projection.

H. Netherlands

The Dutch triangulation is well connected with the German through two nets. One net has several stations in common with the German triangulation between Limburg in the south and Bentheim in the north, and was surveyed in 1889-92. The second, a smaller net with three common points in Friesland, was established 1884-88. The German and the Dutch computations of the geographic positions of these stations, however, differ from 1 to 2 meters.

The Dutch reference spheroid differs little from the Bessel spheroid used in Germany. The Bonne projection is used for older Dutch maps, but in 1940 it was about to be replaced by a stereographic projection. Owing to the smallness of the area, distortions on both projections are so insignificant that German and Dutch sheets at the same scale can be joined without difficulty.

The prime meridian of the older Dutch sheets is Amsterdam, 4° 53'0.0"E., and of the newer maps the meridian of Ammersfoort, 5° 34'15.5"E.

In adjusting the triangulation nets of Belgium, the Netherlands, and Luxembourg to the German Reich net, only minor difficulties were encountered. The junction errors remaining along the Dutch border average 0.40 m. and do not exceed 0.60 m. The computations of the Belgian-Luxembourg adjustment were almost completed by the middle of 1944.

I. Denmark -

Danish and German triangulation nets were connected across the narrow seas at an early date, more than 100 years ago. In 1869, a triangulation arc was surveyed through Schleswig and Holstein, which has a direct continuation in Danish Jutland. The German-Danish connecting net across the Baltic was resurveyed in 1929-32.

Danish maps are on a Lambert conical projection. Direct evidence is not available, but it may be assumed that owing to the smallness of the country no significant distortions have developed, and that because of the integration of the triangulation nets at an early date, adjacent Danish and German sheets fit together well. The prime meridian for Danish maps is Copenhagen, 12°34'40" E.

V. THE REICH LEVEL NET

Because of natural soil movements, cultural changes, and other factors, level nets deteriorate rapidly and should be renewed once in each generation. The old German net is based on leveling performed during the years 1869-1900 and was being releveled when the Second World War broke out. Details of the new leveling were published in Die Nivellements von hoher Genauigkeit. The first volume (1923) covered a part of Mark Bradenburg, the second (1927) northwestern Germany, and the third (1935) the administrative districts (Regierungsbezirke) of Düsseldorf, Aachen, Cologne, and Arnsberg. (See Figures 2 and 3.) A series of booklets entitled Ergebnisse der

Feineinwägungen, started publication in 1930 and continued until 1939. One booklet was issued for each Regierungsbezirk and the series covers all Germany with the exception of Bavaria. The series contains the most recent published results of levelling and supersedes all other publications on elevations.

Since more urgent problems needed attention, only a few lines around Lübeck and Stettin were leveled. First- and second-order leveling in Holstein led to the discovery that the entire region between the Baltic Sea and the North Sea is slowly rising most perceptibly in the northwest. Germany is connected by lines of level with the Danish islands via Fehmarn, and with the Netherlands, Poland, and Lithuania, in most cases at the request of these countries.

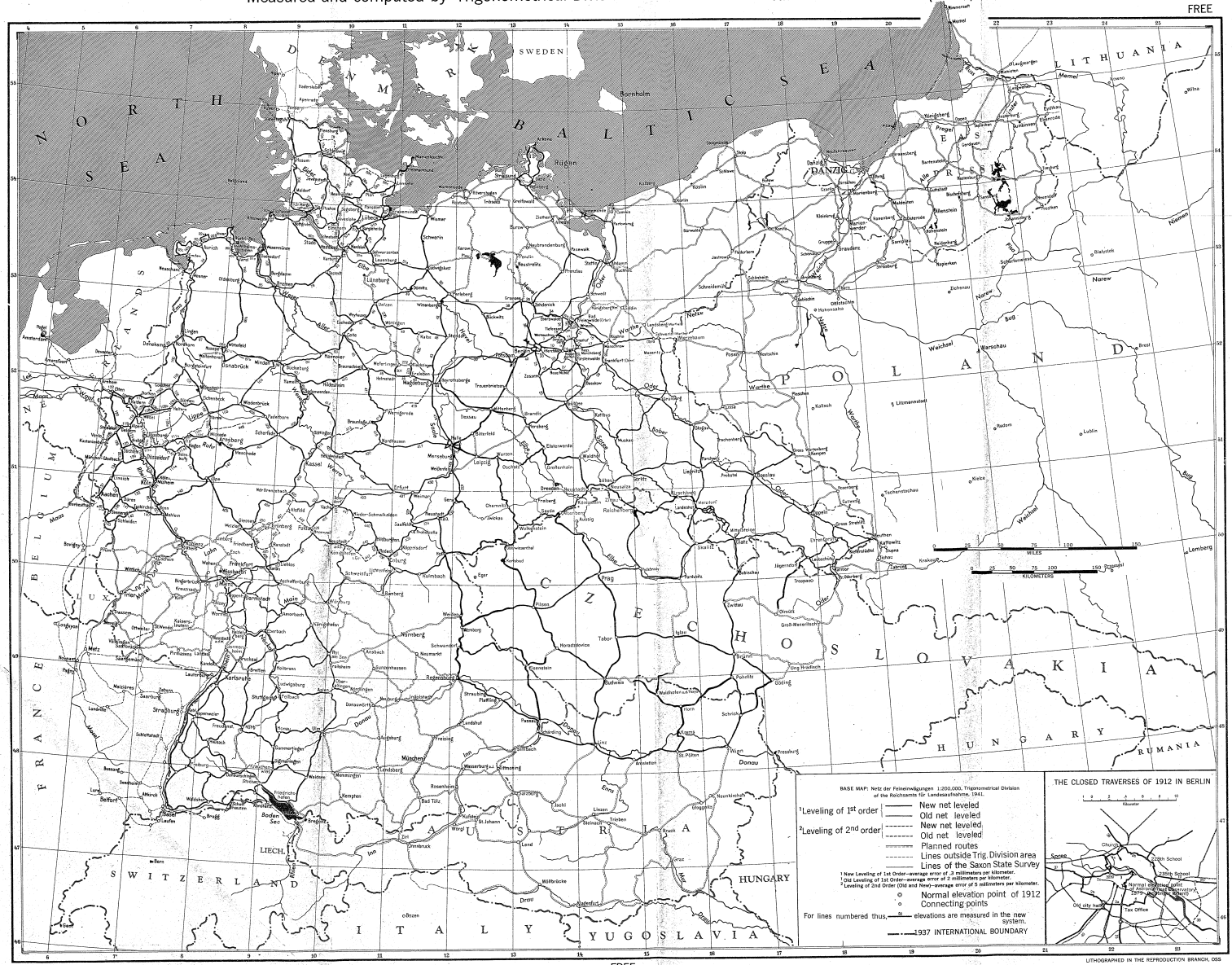
The most important levels of 1936, 1937, and 1938 were in Thuringia, Anhalt, and the Regierungsbezirke of Hildesheim and Kassel, which were for the purpose of connecting these regions with the Bavarian net. The results of leveling were published in pamphlets, one for each Regierungsbezirke. In them the results of the 1868-90 levelings are called "heights in the old system." The results of the old and new levelings differ very little. When the connection is comparatively completed, Bavaria, whose own surveys are progressing comparatively rapidly,[1] will be able to adjust its levels to the new system of the Reichsamt. The leveling of Thuringia was also initiated to connect it with the level net of Saxony, which had been completed several years earlier. Both the Bavarian and Saxon level nets were consistent within themselves, but lacked any connection with leveling lines leading to N.N., the standard datum point.[2] The leveling of Silesia was completed

1. The comparatively rapid progress of the Bavarian leveling is due to the fact that first-order lines usually follow railroads, whereas in Prussia and Württemberg the lines follow highways in order to secure greater stability of bench marks.

2. N.N. is the usual German abbreviation for Normal Null or normal zero, the standard datum point.

NET OF PRECISION LEVELING

Measured and computed by Trigonometrical Division of the Reichsamts für Landesaufnahme (1941).



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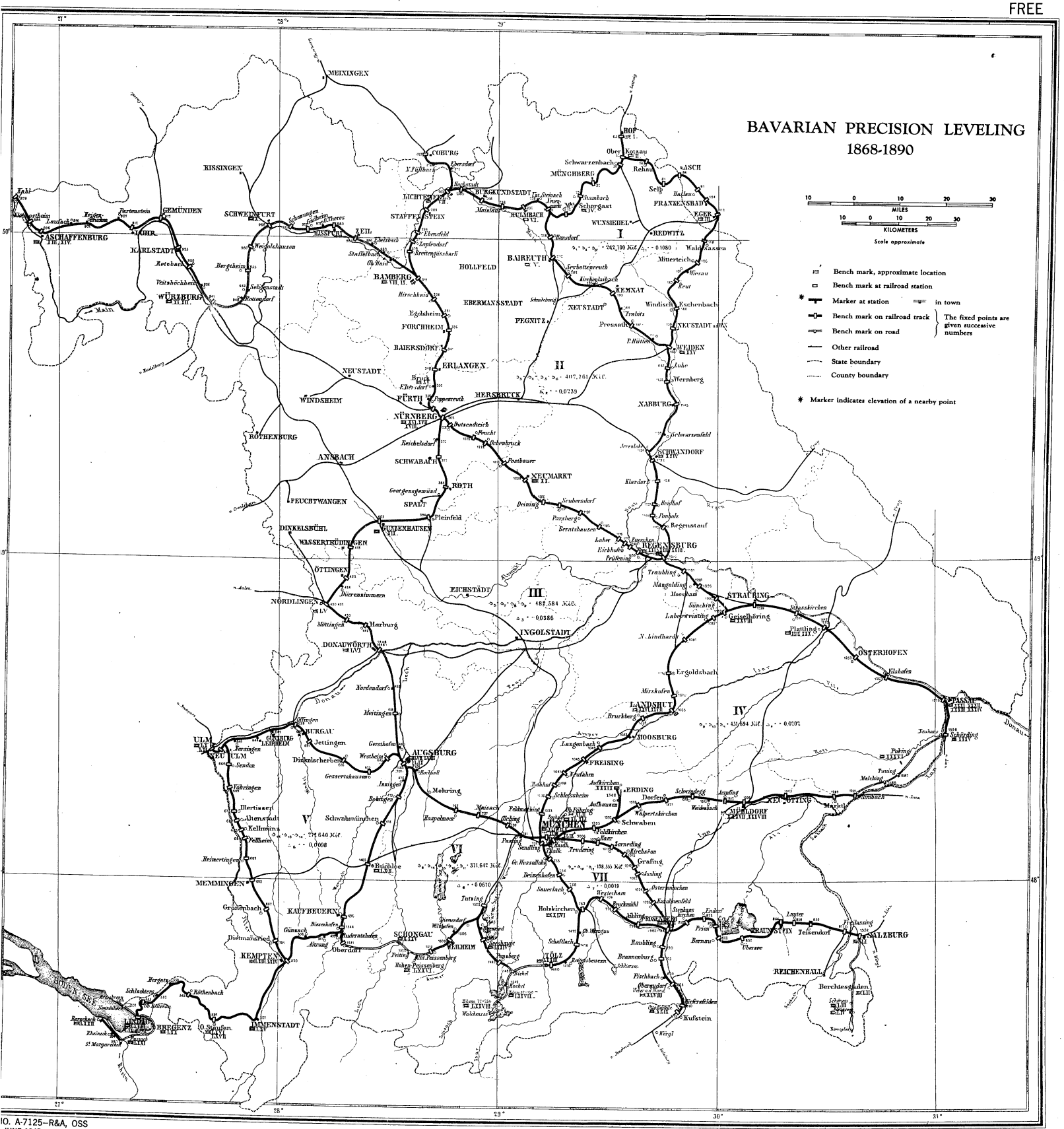

before the war, but results have been published only for the Regierungsbezirke Liegnitz and Oppeln in Upper Silesia. First-order leveling has been completed in the northern half of Wurttemberg.

Plans for 1938 and 1939 provided for the determination of elevations by the Reichsamt in the Regierungsbezirke of Koblenz, Wiesbaden, and Trier, the State of Hessen, the Bavarian Palatinate, and the Saar Territory, and for the continuation of the work in Baden, southern Wurttemberg, and Bavaria. In Bavaria, the level net, even the first-order net, was far from completion at the outbreak of war. In Baden, the levels still require some checking, especially in the region of occasional earthquakes. Only Hessen, Regierungsbezirk Wiesbaden, and possibly the Saar were completed when plans had to be dropped because of war.

The Reichsamt für Landesaufnahme also started leveling along the Baltic coast. This leveling was scheduled in accord with the decision of the Baltic Geodetic Commission and adjustments were to be made according to a common plan. Leveling of the entire coastal area by all of the Baltic states was decided upon; and by 1939, Denmark, Latvia, and Lithuania had completed their parts and German leveling extended as far east as Koslin in Pomerania. The old leveling between Koslin and Königsberg has an accuracy of only ±6-8 mm. The rise of 0.12 m. in the level of the Baltic Sea from Travemünde near Lübeck to Pillau near Königsberg noted by the Germans was therefore probably based on readings of several open-sea water gages.

The Reichsamt für Landesaufnahme planned to follow first-order leveling by second-order leveling. Although no definite programs had been prepared for most regions by 1938, the work was regarded particularly important since the principal first-order level lines were in some cases more than 100 km. apart. As a rule, second-order levels will be run in

only one direction. Second-order levels are not as accurate as first-order levels but should be sufficiently accurate for technical and economic purposes. Some of the larger cities, including those in the Ruhr area, started second-order leveling without waiting for the Reichsamt. The leveling in the Ruhr region was especially urgent because of ground settlements caused by mining. For this reason, the Reichsamt program provided for a loop of first-order circuits around the Ruhr on stable ground and a connecting second-order line passing through it. Levels in urban areas were to start from these lines. In addition, many second-order levels along their rights of way have been measured by railroads and along rivers by the Landesanstadt für Gewasserkunde. All are connected with the first-order leveling of the Reichsamt fur Landesaufnahme.

In 1935, the level net of the Reichsamt für Landesvermessung included 15,000 accurate elevations, which were connected by 16,000 leveling lines. The number in southern Germany is proportionately large. In addition to the leveling connections with Lithuania, Poland, and Denmark, which have been made during recent years, there are older connections with all adjoining countries, including not less than 5 from Prussian Silesia into Czechoslovakia, several into Belgium and France, and one from Baden into Switzerland. Bavarian levels were connected at two points with the Prussian levels in the old net and at all crossing points of the new net. Nothing is known about leveling across the Bavarian border, to the south except that Bavaria formerly based its elevations on the old Austrian sea level datum at Trieste. Consequently, there must be at least one line from Bavaria into Austria.

The Reich elevations are referred to N.N. which is supposed to be the same elevation as the Amsterdam sea level datum (A.P.). It is actually 16 mm. above this point and 66 mm. above the mean level of

the Baltic Sea at Swinemünde. A bench mark (N.H. or Normal-Hochpunkt 1879) was established at the former Astronomical Observatory in Berlin in 1879 to insure the constancy of N.N. In 1912, it was replaced by a new bench mark near kilometer 40.7 on the highway from Berlin to Manschnow (N.H. 1912), which was connected with N.H. 1879 by lines of precise leveling. The establishment of N.H. 1912 did not change N.N., and all elevations in Germany are still measured as above N.N.

Since about 1930, all of the south German states have completely revised their separate systems and now refer their elevations to N.N. Originally the elevations in southern Germany were based on the mean level of the Adriatic Sea, as evidenced by older maps still in circulation. Some old Bavarian maps state that elevations on them are about 1 m. higher than they would be if measured from N.N. Recent leveling however, seems to indicate differences of as much as 2 m. in Bavaria and 1.74 m. in the Bavarian Palatinate. Until 1910, Baden referred its elevations to the floor level of Strassbourg Cathedral, which is actually 143,730 m. above the mean level of the Adriatic Sea although it had been erroneously assumed to be 145,752 m. Wurttemberg referred its net to an elevation of 272.5 m. above N.N. which seems to have been derived from the Baden level and, therefore, shares its error. Both the Baden and Württemberg reference levels were especially unsatisfactory because large parts of both states lie at levels lower than their reference points. Only the Hessian maps refer to the mean level of the Baltic Sea, which is not the same as N.N. The accuracy of elevations in Hessen, varies from 0.10 to 0.15 m.

The unification of the elevations within Germany also correlates them with points in most of the neighboring countries. Only Belgium has widely different elevations, because they are measured above mean low tide at Ostende, which is 2.34 m. below the German N.N. Other

international differences are given below.[1]

Belgium		-2.34 m.	Elevations above mean low tide at Ostende.
Netherlands		±0.01 m.	Due to slight inaccuracy by deriving the German N.N. from the Amsterdam sea level datum (A.P.)
France		+0.26 m.	Mean level of the Mediterranean Sea at Marseilles.
Switzerland		+0.307 m.	The newer maps show elevations 3.26 m. lower than the older maps.
Austria		+0.36 m.	Mean sea level on the Adriatic Sea at Trieste.
Czechoslovakia		+0.36 m.	Same as Austria.
Poland	0.0	-0.06 m.	Derived from the Amsterdam sea level datum via the German N.N. Elevations theoretically equal.
Lithuania		-0.24 m.	Referred to sea level datum at Kronstadt near Leningrad.
Denmark		+0.245 m.	

On nautical charts, elevations near the coast are referred to mean high water, and therefore have no common reference level.

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1. Plus sign (+) indicates that datum point is higher than N.N.; and minus sign (-) lower.

VI. HYDROGRAPHIC REFERENCE DATUM

The German navy (Oberkommando der Kriegsmarine) had its own nautical division, charged with all matters pertaining to surveying and mapping. Though the coastal features were taken from topographic maps, the navy was equipped to do its own surveying in order to keep correct the continuously shifting features of the coast line. Likewise, hydrographic surveying was continuous in order to keep the depths on the nautical charts correct. In general, the navy was able to keep the data reasonably up-to-date. Unlike the triangulation and leveling nets the depth measurements along the German coasts never became so out-of-date that new systematic soundings throughout whole areas became necessary. The hydrography in the German parts of the North Sea and the Baltic Sea seems to be satisfactory throughout. A service was maintained through private firms that enabled ships to obtain revised charts at every port of call.

The plane of reference in the North Sea is mean low water; in the Baltic Sea it is mean sea level.

The Mercator projection is used for nautical charts.

VII. MAGNETIC NORTH

Since 1930, most German maps have carried some information on magnetic declination. The newer maps, however, instead of showing the declination (Missweisung) from true north, show the deviation from the straight lines of the Gauss-Krüger grid (Nadelabweichung). On Reichsamt maps the deviation is shown in the margin, and on the maps of the south German states additional numerical information is given. The magnetic declination is westerly throughout most of Germany, and it is decreasing by 0.2° yearly. Only in parts of East Prussia is the declination easterly. Formerly, German maps gave the declination

for April 1925 in order that computations could be made on a uniform basis. The accumulated deviations, however, had become so large that a new basis was adopted as of the middle of 1936. On more recent air force maps the basis for calculation of the declination may be either 1938, 1940, or 1942.

APPENDIX A

a

Summary of the basic geodetic facts of the German states.

Name	Origin of the azimuth (counted clockwise)	Triangulation Origin of the Coordinates	Location of Coordinate Files	Gauss-Krüger Coordinates Status	Gauss-Krüger Coordinates Location of records
Baden	S	Former astronomic observatory in Mannheim	1. HVA XII in Stuttgart 2. Baden Ministry of Finance and Economics, Cadastral and Survey Div. in Karlsruhe 3. Survey offices	All geographic positions are computed provisionally.	1. General Command of the 5th Army Corps, Div. Ia Messin Stuttgart 2. HVA XII in Stuttgart
Bavaria (on the right bank of the Rhine)	W 14½ N.	Northern tower of the church of Our Lady in Munich	1. HVA XIII in Munich 2. Oberfinanzpräsident in Munich and branch offices in Augsburg and Landshut; Oberfinanzpräsident in Nürnberg and branch offices in Ansbach and Würzburg 3. Survey offices	Coordinates computed provisionally for large areas in NE, NW, and S and for the vicinity of garrisons.	1. HVAXIII in München

a. Source: Planheft Grossdeutsches Reich, 1944.

b. HVA - Hauptvermessungsabteilung

Name	Origin of the azimuth (counted clockwise)	Triangulation Origin of the Coordinates	Location of Coordinate Files	Gauss-Krüger Coordinates Status	Location of records
Bavarian Palatinate	W	Former astronomic observatory in Mannheim	HVA XI in Wiesbaden	Temporary coordinates	HVA XI in Wiesbaden
Brunswick	N	Same as Prussian	1. Landeskultur and Vermessungsamt (Agricultural and Surveying Office) 2. Landesforstverwaltung (State Forest Administration) 3. Mayor's Office Survey Division of the Buildings Administration 4. Prussian Neumessungsamt (New Survey Office) Herman Göring Werke in Wolfenbüttel	Temporary coordinates	1. Heeresvermessungsstelle (Army Surveying Service) 2. Reichsamt für Landesaufnahme. 3. HVA VII in Gifhorn, Hann. 4. Landeskultur-II und Vermessungsamt in Brunswick

Name	Origin of the azimuth (counted clockwise)	Triangulation Origin of the Coordinates	Location of Coordinate Files	Gauss-Krüger Coordinates Status	Location of records
Bremen	N	Ansgariikirchturm	Vermessungsamt Bremen	Temporary coordinates	1. Heeresvermessungs-stelle (Army Survey) 2. Reichsamt für Landes-aufnahme 3. HVA VII in Gifhorn, Hann. 4. Vermessungsamt in Bremen
Gotha (part of Thuringia)	S	Astronomic observa-tory at Seeburg	Thuringian cadastral office of Gotha	---	---
Hamburg	S	Spire of Gross Michaelis Kirche	HVA VI in Hamburg	Definite coordinates available for most triangu-lation stations	1. HVA VI in Hamburg 2. Vermessungsamt of the city administra-tion of the Hansa City Hamburg.
Hannover	S since 1868 N	Topographical Survey Observatory of Göttingen and 31 survey districts triangulation station of the Gauss triangulation as points of departure for Cadastral Survey	HVA VII in Gifhorn	---	---

Name	Origin of the azimuth (counted clockwise)	Triangulation Origin of the Coordinates	Location of Coordinate Files	Gauss-Krüger Coordinates Status	Location of records
Hessen-Darmstadt (state Hesse)	N	Town church of Darmstadt	1. HVA XI in Wiesbaden 2. Hessisches Landesvermessungsamt in Darmstadt	All old triangulation stations of 1st and 2nd order, 96 percent of 3rd order, and 51 percent of 4th order are Gauss-Krüger	HVA XI in Wiesbaden
Hessen-Nassau (not quite coincident with the present Province of Nassau	N	Triangulation station at Schaumburg	HVA XI in Wiesbaden	85 percent of the triangulation stations were computed provisionally	HVA XI in Wiesbaden
Kurhessen (comprises a somewhat larger area than the present Prussian Province)	N	Kassel, southern tower of Martinskirche	HVA XI in Wiesbaden	The majority of triangulation stations are computed provisionally	HVA XI in Wiesbaden

Name	Origin of the azimuth (counted clockwise)	Triangulation Origin of the Coordinates	Location of Coordinate Files	Gauss-Krüger Coordinates Status	Location of records
Mecklenburg	S	Tower of the castle in Schwerin	HVA VI in Hamburg	The 1st-order triangulation stations are definitely computed, the others provisionally	1. HVA VI in Hamburg 2. Mecklenburgisches Landesvermessungsamt in Schwerin
Meiningen (part of Thuringia)	W $14\frac{1}{2}^{g}$ towards N	Northern spire of Liebfrauenkirche in Munich	Thuringian Cadastral Office in Meiningen	Only the corners of a few sheets are computed	Thuringian Cadastral Office in Meiningen
Oldenburg	Old Oldenburg triangulation S Newer Prussian triangulation N	Tower of the castle in Oldenburg	1. Oldenburgische Vermessungsdirektion 2. Cadastral offices 3. HVA VII in Gifhorn	---	---

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Name	Origin of the azimuth (counted clockwise)	Triangulation Origin of the Coordinates	Location of Coordinate Files	Gauss-Krüger Coordinates Status	Location of records
Prussia and Anhalt (excepting areas enumerated separately)	N	For Topographical Survey-Rauenberg south of Berlin, and since 1923 Helmert tower of the Geodetic Institute in Potsdam. For the Cadastral Survey--40 different points of origin; since 1927 Gauss-Krüger coordinates used in new surveys.	1. Reichsamt für Landesaufnahme 2. HVA I,II,IV-X. 3. Cadastral offices 4. Regierungspräsidenten	All trigonometrical points completed provisionally	1. Reichsamt für Landesaufnahme 2. HVA I,II,IV-X 3. Generalkommandos (Army district commands) 4. Luftgaukommandos (Air force district commands)
Saxony	N	Topographic survey of 1st order in Grossenhain; Cadastral Survey; three local conformal systems	1. Reichsstatthalter (Reich governor) in Saxony, State government 2. HVA III in Dresden	Completed	1. Reichsstatthalter in Saxony, state government 2. HVA III in Dresden

Name	Origin of the azimuth (counted clockwise)	Triangulation Origin of the Coordinates	Location of Coordinate Files	Gauss-Krüger Coordinates Status	Location of records
Sachsen-Weimar (part of Thuringia)	N	Point of origin of the Schreiber projection	HVA VIII in Magdeburg	Provisionally computed	HVA VIII in Magdeburg
Schaumburg-Lippe	N	Ida Tower	HVA VIII in Gifhorn	"	HVA VIII in Gifhorn
Schwarzburg-Sondershausen	N	Triangulation station mark Possen Tower; since 1892 Possen-Stein	1. HVA VIII in Magdeburg 2. Thuringian Rentamt (treasury) in Sondershausen	Provisionally computed most triangulation stations	HVA VIII in Magdeburg
Württemberg and Hohenzollern	N	Astronomic Observatory in Tübingen; no longer extant	1. HVA XII in Stuttgart 2. Württemberg Ministry of the Interior, Cadastral and Survey Division 3. Messungsämter	Provisionally computed	1. General Command of 8th Army Corps. Div. IA Mess in Stuttgart 2. HVA XII in Stuttgart

SOURCE: Planhoft Grossdeutsches Reich, 1944

APPENDIX B

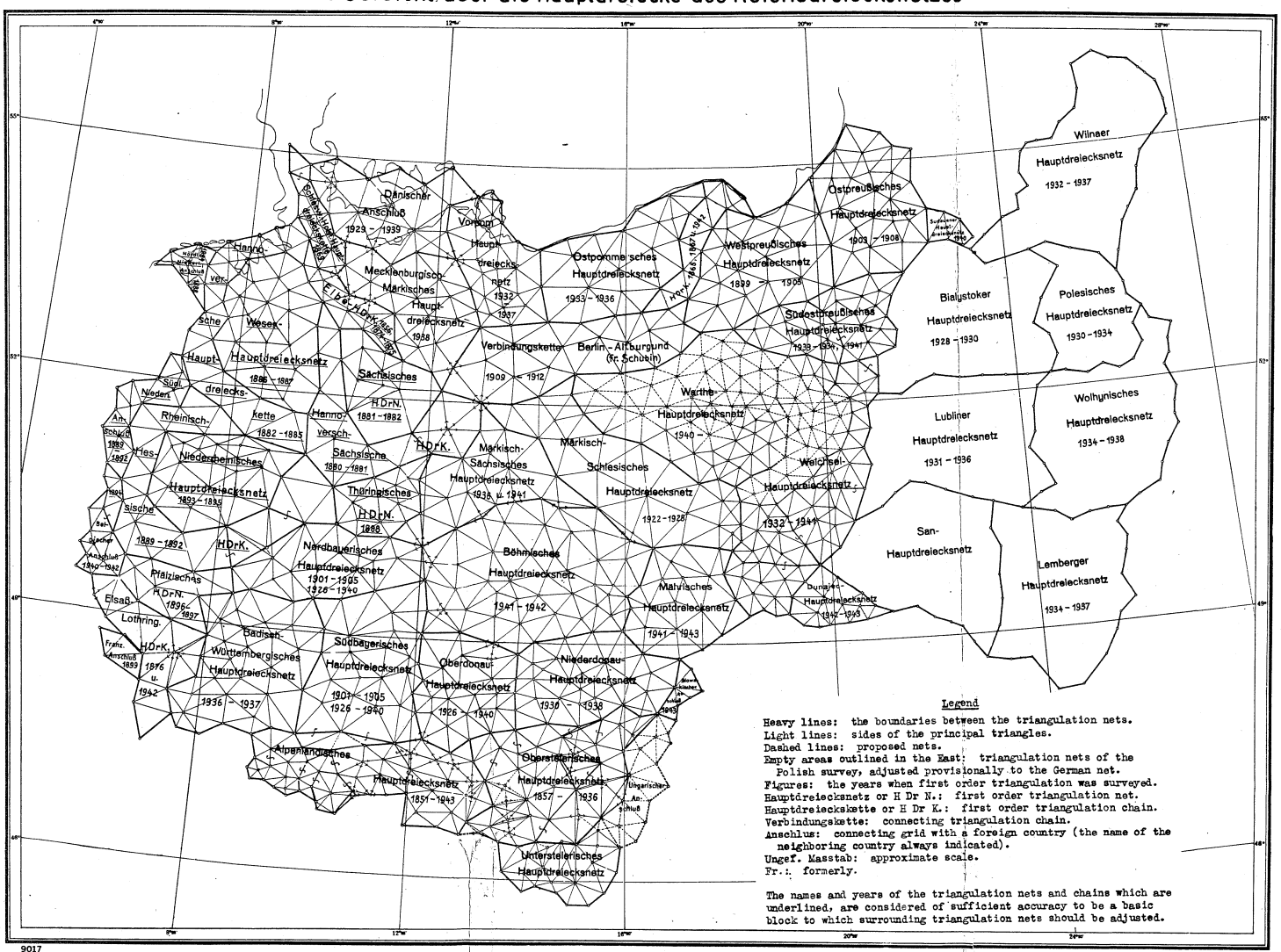
TRIANGULATION NETS OF GREATER GERMANY

The appended German map, dated 1944, showing triangulation completed during the early years of the war has become available since the completion of the foregoing report. Since practically all of the new triangulation was for occupied areas, the map adds little new data for Germany proper. It does, however, confirm the deduction drawn from other sources that German trigonometrical activity came to a standstill after 1941, due apparently to the drain of trained personnel into the army.

THE PRINCIPAL TRIANGULATION NETS OF GREATER GERMANY -- 1944

Anlage 12 (zu Nr. 11)

Übersicht über die Hauptdreiecke des Reichsdreiecksnetzes



Legend

Heavy lines: the boundaries between the triangulation nets.
Light lines: sides of the principal triangles.
Dashed lines: proposed nets.
Empty areas outlined in the East: triangulation nets of the Polish survey, adjusted provisionally to the German net.
Figures: the years when first order triangulation was surveyed.
Hauptdreiecksnetz or H Dr N.: first order triangulation net.
Hauptdreieckskette or H Dr K.: first order triangulation chain.
Verbindungskette: connecting triangulation chain.
Anschluß: connecting grid with a foreign country (the name of the neighboring country always indicated).
Ungef. Masstab: approximate scale.
Fr.: formerly.

The names and years of the triangulation nets and chains which are underlined, are considered of sufficient accuracy to be a basic block to which surrounding triangulation nets should be adjusted.

9017

Ungef. Maßstab 1:4000000

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