SURVEY OF GEODESIC WORK IN THE AUSTRO-HUNGARIAN MONARCHY

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At first geodesic work was limited to military geodesic surveys, but there is no connected and exhaustive literature on this subject. The history of its development can be gathered only from periodic communications, documents and records of the supreme war council, logistic and general staffs, and court authorities.

The aim of this paper is to describe briefly the development of geodesy over the last two hundred years in connection with the teaching of cartography and projection theory, and to complete the literature. On the basis of a comparison of the data collected and the reports based on practical experience, it can be established that from 1760 on geodesy met the requirements and its perfection went hand in hand with the development of the technical sciences and technique. Its development was recognized by the experts both at home and abroad.

From the beginning geodesic work was done by military experts under the direction of the general staff and later the staff of military engineers. Their work constituted the firm basis on which not only the geodesic work of the past and present is built, but on the results of which even the topography and cartography of the future can be based.

The technical conditions of the time when the first surveys were made are hard to image today. The geodesic workers often had to cope with the suspicion, indifference, sometimes resistence of the people. At the same time they had to tour all parts of the high mountains in order to make their surveys complete. We must also know that the territory of the Monarchy was not economically well developed; the western regions were ravaged by the French armies, the Great Hungarian Plain was a partly uninhabited waste with few roads and extensive swamps. The results of the geodesic work of that time seem insignificant by the side of the tremendous progress in the first half of the 19th century when such inventions were born as the steamship, photography, the steam engine locomotive, the telegraph, and metal barometer. In the second half of the century were invented the dinamo, the electric lamp, the motor-car, and the airplane. Under such circumstances the large masses could hardly recognize the importance of geodesy as they could not see its results since they are not visibly expressed on the maps.

Now we are going to deal with the task of geodesy. The task is twofold: first the basis must be established on which the topographic survey of the country can be built, then any measurements must be taken that are needed for the determination of the shape of the Earth in our territory.

In the two centuries mentioned, five periods of the development and application of geodesy can be distinguished:

1. 1762—1798: the first measurements of base lines and the initial triangulations were made,
2. 1799—1829: the first triangulation survey of the Monarchy was completed,
3. 1830—1860: the Military Geographical Institute of Vienna was established and the second triangulation survey of the Monarchy carried, out,
4. 1861—1913: international protraction and the third triangulation survey were made,
5. 1914—1918: the geodesic work of the First World War was completed.

At the beginning of the 17th century, geodesic work was done by private persons and they themselves engaged auxiliary personnel. The state financed the work, and later drew the surveys into its own sphere of competence. It should be noted, however, that geodesic work was also done as early as after the 1650's, and there were even military engineers in the army, but actual geodesic work began only a century later. After this introduction let us examine the different periods one by one.

Measurement of Basic Lines and Initial Ttiangulations

The first period may be reckoned form 1762 because the Jesuit monk, Joseph Liesganig began the geodesic work at the Emperor's order. The essence of the work was triangulation. For a start he determined several basic lines with the help of wooden rods; at the same time he also made astronomical observations. In order to give an idea of the territorial dimensions of the work, we mention a few of the basic lines. There were, for instance, such lines near Wiener Neustadt in Austria, in Marchfeld (the Moravian Plain), and in Galicia. Several basic lines were measured in Hungary, for instance the 4091.45-fathom-long line near the Roman defensive earthwork and the 2778.73-fathom-long line near the settlement of Kistelek. The end points of the base lines measured — with the exception of the neat Wiener Neustadt — were nearly all lost. Thous the result of two years' work was also lost in spite of the fact that though anyway the employement of such primitive measuring devices posterity could not have used these base lines with full accuracy.

The imperial order of May 1764 declared that geodesic measurements in the future belonged in the competence of the general staff at any time. This was Maria Theresa's decision. Thus began the survey of the territory of Hungary. The Hungarian Estates did not like this decision and often ibstructed it, but the successor to the throne, Joseph II caused the work to be finished. The decision of 64 was fully carried out in 1798 and continued in vigor till the fall of the Monarchy. The surveys were usually received with displeasure in Hungary at that time because the idea behind the order was not understood. Such and similar measures only weakened the ties of the Monarchy.

The First Triangulation in the Monarchy

At the beginning of the second period — the beginning of the 19th century — not only in the Monarchy but also in other neighboring countries the need for maps based on geodesy was felt, but the states struggling with economic problems could not entirely finance such work. The primitive surveys were continued because the previous surveys were not in agreement and so the existing maps could not be fitted together accurately. After the Napoleonic wars the imperial army command made a decision on the basis of the proposal of the competent persons that a triangulation department was to be set up within the logistic staff to carry out the first triangulation of the Monarchy with significant subvention.

The triangulation department was established in 1806 under the command of Colonel Richter. Work was started on the base line of Wiener Neustadt. The department bought new instruments, and the work went on feverishly, many clerical and civilian persons volunteering to help carry out the task.

The task was to form a triangulation chain with great accuracy in a W-E direction from Salzburg to Suchava, and in a N-S direction along meridians through Vienna and Tokaj, from which sidelines could be developed. Connected with this project was also the astronomical determination of the eminent points of the chief and secondary chains. On this basis the geodesic work can be checked at any time.

The aim of the work can be summarized as follows:

1. to create a solid geodesic basis within the shortest time,
2. to have a survey basis for any part of the country,
3. to ensure that if the survey cannot for some reason be carried on continuously in an area, the survey should go on in other areas,
4. the geodesic bases had to be ensured for posterity,
5. to establish as soon as possible the triangulation points of the connected area of the Monarchy so that on this basis cartographic work could start.

Starting from the base line of Wiener Neustadt, triangulation was led through Budapest and Eger in 1807; at the same time geodesic measurements were carried out also in Sopron, Moson, Gyor, Komarom, Feher, Pest, Heves, Szolnok and Borsod Counties. This work was interrupt by the repeated inroads of Napoleon's armies The data of the measurements and the drawings were transferred to Petervarad, thus the results of the work done were not lost. After the war the surveys were resumed in 1809.

At the resumption of the measurements the need was felt at once for official instructions to determine the requirements ensuring uniformity in the surveys. The instructions were then made and they concerned the choice and measurement of the base lines, the calculation of the angles, the description of the theodolites and other instruments, and the making of records of the observations. Besides this the instructions included the cases when the reparation of clearings of forests obstructing the line of vision had to be recorded in a register.

In 1810 the second base line was made near Győr, the length of which was 9429.43 Vienna fathoms. Four iron rods of 2 fathoms' length each were used in this measurement. The end points of the base line were marked and astronomically orientated. It should be notied, that this base line was originally designed for the region of Pest, but the measurements could not be carried out in the then swampy area. By the end of the second period, the triangulations, starting from the western part of the Monarchy, reached the meridian of Buda and along the Carpathian Mountains the boundary of Transylvania. The geodesists had to overcome very many difficulties because in many places the inhabitants suspected war preparations in the surveys. The work was made even more difficult by the superstitious fanaticism of the people. These things led to the destruction of the measurement marks in many places. In the decade following 1829 only astronomical observations and minor triangulations were made. The cadastral survey of Hungary is based on these triangulations.

The Second Triangulation in the Monarchy

At Napoleon's instruction a military topographic institute after the French model was established in Milan in July 1800. The task of this institute was to make a detailed survey of the Republic and to prepare maps based on the survey. Milan was liberated from French suzerainty in 1814, and the institute continued to exist under the name of I. R. Institutio Geografico Militare. The institute was reorganized at the order of Francis I. The surveys in the kingdom of Lombardy and Venice, as well as in the provinces of Parma, Modena, Lucca, and the Adriatic littoral were finished by the end of 1838. In January of the next year Ferdinand V ordered the institute of Milan to be transferred to Vienna and to be merged with a similar institute already working there.under the name of Military Geographical Institute. Thus the two great antagonists', Napoleon's and the Vienna Court's foundations were united. The new institute worked successfully for 80 years — till the fall of the Monarchy.

The decisions of the new institute said that it should itself see to it that it could develop adeuqately in science and art and that it should meet the requirements of the age in the domains of astronomy, geodesy, topography in technical, military, and administrational respects. The institute provided facilities for the making of maps as well as for the registration of cartographic and other military sketches and maps. One of the seven departments of the institute was the Triangulation Department, the first head of which was Captain Jacob Marieni. The building of this institute is still to be found in the heart of Vienna; at the beginning of the 1860's an observatory was also housed in it. Since 1880 the exact time is indicated by the ringing of bells in its tower and the dropping of a red ball. Later the building proved too small and another building, called building B was was constructed, which was finished in 1905; all of the technical departments were placed in this building. There was no institution of similar importance in other states at that time.

The workers of the new institute continued the triangulation in Hungary and Transylvania in order to complete the network of first order, and according to the requirements of the tasks points of second and third order were marked out. The determination and astronomical orientation of the basik line of Arad and three other base lines derive from this period.

In spite of the accuracy of the measurements, many mistakes crept into the triangulations, the cause of which was that the most of the base lines were measured by wooden rods; besides this the corrections were not made uniformly, and thus the side lengths were incorrect. The workers of the institute began the second, more accurate triangulation of the Monarchy in 1848, but this work was stopped when protraction was initiated in 1862. The triangulation points thus obtained formed the basis of the old Hungarian cadastral main network.

International Protraction and the Third Triangulation

At the beginning of the 60's geodesy started to develop rapidly. On the initiative of the Prussian general. Dr. Baeyer the competent organs of the Central European states agreed to carry out astronomical and geodesic work necessary for protraction according to common principles. The Austro-Hungarian Monarhy joined the work called International Survey in 1862. As a result of this, the Geographical Institute undertook to carry out new triangulations of first order, which, combined with astronomical place determinations, would be suitable for the determination of the general shape and surface bulge of the Earth.

Therefore the tasks were:
1. triangulation of first order,
2. accurate level determinations,
3. astronomical measurements,
4. measurements with pendulums.

1. Triangulation of First Order

The third triangulation began in 1862 and ended in 1893, with completions in 1913. The aim of this triangulation was to vreate a basis with the greatest accuracy that protraction and topographic measurement require. As the basis of the network, a basic line and two angles were measured; from this the other triangles could be developed by protraction. On a flat terrain the basic lines were determined for a lengt of 3,000—5,000 m. They were checked so accurately by a base line-measuring instrument, that these measurements can be regarded as absolutely correct. In the case of extensive measurements several base lines were measured because the length of the base lines could always be checked by calculation. At the same time the basic lines could be used for completing the network. The mistakes occurring in the protraction were compensated for by calculations based on Gauss's theory of the smallest squares. In the network of triangles they distinguished triangulations of first, second, third, and fourth order:

a) (main) triangles of first and second order, in which all the three angles were measured,

b) auxiliary triangles of third and fourth order, in which only two angles were measured, while the third was determined by calculation.

The triangulation points of the previous period could in many cases not be used for protraction, nor could therefore astronomical measurements and connections be made. For this reason new measurements had to be made in many places.

The network covering the Monarchy consisted of 721 basic points of first order, which formed 1327 triangles. The basic points of first order were generally located on eminences 30—125 km from each other. These points were marked by carved stone columns above the ground, but were also marked under the ground. The place of the basic points was determined by 48-fold observation. The observation network of first order was rendered denser by triangulations of second and third order, in which the points were about 3 km from each other. Their determination was not quite perfect, but was sufficiently accurate for topographic surveys.

In the territory of the Monarchy 18, and abroad 5, base lines were measured for the derivation of the sidelines. These measurements were also very accurate: thus for instance in the case of the base of Versec the difference in the distance as measured there and back was only 2 mm, which is quite negligible in the case of the 4023-m-long base line.

The dates of the measurements of the base lines in Hungary are the following:

Budapest	1884
Brasso	1886
Versec	1885
Szatmár	1897
Szentanna	1840

The network was divided into 59 connected groups. The network, compensated for the purposes of protraction, made it possible to calculate accurately the geographic or polar coordinates of the points. It is characteristic of the accuracy of the measurements that the 2475-m-long base line near Sinj determined by calculation was only 3 cm shorter in reality, although the distance between the two points is about 700 air km.

In the third topographic survey only three triangulation points were given for each section, the size of which was 24—280 km^2. Similar was the case in the fourth survey: later on, after 1900, 8—10, and even later 15—20 points were needed.

The Institute had no extra personnel for carrying out the work connected with the international protraction, and thus tnese tasks became secondary owing to the urgency of the national survey. At the same time it is well-known that thə majority of the points were in the Alps and the Carpathian Mountains where the building of marks and observation were very difficult; many points were located in the world of eternal snow and ice, so that the workers were exposed to severe hardships. In such places nem liking their work and nature and enthusiastic about the idea were needed.

The third triangulation was of great scientific and practical value and represented an important step forward in comparaison with earlier work. Under the conditions of that time the earlier results were also remarkably good, but not good enough to meet the requirements of a technically advanced age. As we have said, the new main and auxiliary networks of the Hungarian cadastral triangulation are based on the points of the third triangulation.

2. Accurate Leveling

When the international committe was formed, it declared the principle that each participant nation should carry out level determinations of first order besides trigonometric measurements of altitude that connect the levels of the European seas. At the same time the committee decidede that in each state of the continents accurately leveled places should be determined which would serve as a basis for further measurements of altitude.

The work of leveling began in 1873 and ended in 1898. The basic level was the sea level which is 3.3520 m lower than the bench mark in the wall of the customs house of Molo Sartorio in Trieste. The bench mark in Trieste was determined by the teacher

Dr. Farolfi of the Academy of Navigation in Trieste. Regarding the accuracy he said, that as the annual mean of the wind directions, winds, barometric conditions, and the peculiar shape of the Adriatic had to be taken into consideration — and the place wasin the northwestern corner of this sea — it was understandable that the sea level in the harbor of Trieste changed every year. As the mean values are not the smae every year, owing to objective causes, the determined level can be considered to be only within an accuracy of 1 cm. In order to narrow precision to 1 mm, at least 10—12 years' observation is necessary. The lengt of the levelings made in the territory of the Monarchy is 22 935 km, the number of basic points is 16 652. The grouping of the basic points can be summarized as follows:

a) The cardinal base points or original marks are in places where their position cannot be changed by external conditions. Original marks in Hungary are:

1. at Máramarossziget, in the upper valley of the Tisza River, made in 1887,
2. in the pass of Vöröstorony, made in 1887,
3. near Zsolna and Ruttka, in the upper valley of the Vág River, made in 1888.

b) There are marking points — bench marks — in places where the marking points are not exposed to damage, built in the walls of churches and schools.

c) Secondary marking points are placed on fixed objects of the terrain, where the positioning of the leveling rod is ensured, as on rocks' bridges, kilometer stones, etc.

In spite of the great accuracy that can be achieved in leveling, mean errors must always be reckoned with. The average order of magnitude of the mean errors per kilometer is 2—3 mm. The error measured from the starting point is proportiona to increasing distance; for instance, if Trieste is the starting point, then the error is already ±6 cm at Vienna, and ±8 cm at the marschaling yard of Rákos in Budapest. The length of one of the mountain ranges on the border of the Monarchy is 5526.7 km, and its error of closure 737 km.

These errors — even if they are considered small enough — could be diminished considerably, if the levelings could be connected to points, the data of which are perfectly accurate. The leveling points of the neighboring states could be similar. As, however, these points also have errors of closure, no exact control is possible by using these. Therefore only the seas can come into consideration for the purposes of control. As the seas are in balance all over the Globe, their surface is perpendicular to the direction of gravitational acceleration. Consequently, their surface can on all coasts be used for leveling. At the same time we know that the seas are never in a perfect state of blance and rest because the external and internal inflences, such as wind, salt content, currents, the waters of the rivers falling into the seas, and the atmospheric pressure, all cause changes. Therefore the sea level can be used for control only with relative accuracy, although the magnitude of the variations in most cases in only a few cm. This is how a relatively accurate determination of the average level of the Adriatic was achieved, for the control of which a point was chosen in Ragusa, which is 500 air km from Trieste. Measurement work and observations lasting nearly two and a half years determined the altitude of the level of the Adriatic Sea with such accuracy, that it could be used for controlling.

3. Astronomical Measurements

Astronomical observations began in 1862, and ended in 1892. The measurements comprised: the latitudes,

determinations of the azimuths of the sides of the triangles, measurements of the differences in longitude.

According to the types of work undertaken by the different stations, we can distinguish:

a) second-rate astronomical stations, at which determinations of latitude and azimuth were carried out,

b) first-rate astronomical stations, at which, besides the above-mentioned things, differences in longitude were also measured.

Thus the differences in longitude between Budapest-Cracow,-Vienna,-Pola,-Sarajevo, and -Brassó were determined.

Polar height, i.e. latitude and azimuth determinations were carried out at 102 points in the territory of the Monarchy, and differences in longitude were measured on18 lines.

In Hungary there were second-rate stations on Cserháthegy (Mount Cserhát) near Szekszárd, on Magoshegy (Mount Magos) near Győr, on Sághegy near Kiscell and on Zoborhegy near Nyitra.

4. Measurements with Pendulums

These measurements were intende to determine the deviation of graviation from the normal with a view to obtain suitable data for the determination of the shape of the Earth and to find out how far gravitation infleunces the results of leveling.

The observations began also in 1882 and ended by 1901. Measurements with pendulums were carried out at 600 stations. After 1901 the measurements in the countryside were finished; further measurements were made only in the modernly equipped cellar room of the Geographical Institute.

The occupation of Bosnia-Herzegovina took place at that time. The administrational activity was almost paralyzed by the lack of cadastral and other maps, because this territory had not been surveyed under Turkish rule. At the beginning of the 70's the surveyors carried out only astronomical place-determinations. After the termination of the occupation, triangulations of first and second order were immediately carried out. Triangulations of third and fourth order could be carried out only partially because of the roughness of the terrain and the lack of roads. This geodesic work was completed in four years.

Geodesic Work during World War I

Wars have always influenced the development of the sciences and technique. In the World War geodesy and topography were instruments in the hands of the army headquarters. Before the War it had become customary to call up the geodesist officers to their old divisions. This curtom changed during the War, since the surveyors remained at their posts, and so the surveys could go on. The existing maps could not meet the requirements of standing warfare; at the same time the great battles changed the terrain and preparation of new maps became necessary or the old ones had to be corrected. In September 1915 military surveying was organized, the task of which was to make the necessary corrections, measurements and registration, and to survey the occupied territories. Therefore military surveying and mapping departments began to operate in the army.

Military Surveys

This work was always adjusted to the needs and possibilities of the War. In moving campaigns the work had to be done rapidly, or the surveys lost their purpose and value. In such cases any means could be used. The surveys were made so as to help the work of the artillery. At the same time triangulations were also made, in the course of which not only smaller battlefields and artillery emplacements, but also the essential enemy positions were marked.

In territories where no triangulation points were found, 240—400-m-long base lines were measured, or sometimes two suitable triangulation points were used as a basis of calculation. The basis of control was the new basic line established at 30 km's distance. The existing networks were constantly being completed. These surveys were a great help also in the working up of air photos.

Military Cartography

In the 18th century in each European state there arose the need for preparing accurate maps of their territories. The Balkans, however, remained enterely ursurveyed. It was the endavour of the Turks to make exploration of the territory by foreigners difficult. Mapping began here only when the political power of the Turks was broken and they were obliged to defend themselves. in their own territories.

At the end of the 1860's, when the Military Geographical Institute decided to publish 300,000:1 -scale maps, mapping of the Balkans was already included in the program. On the rough terrain of the Balkans the surveyors made first of all astronomical placedeterminations, barometric altitude measurements, and topographic photographs. This work went on for nearly a decade. The result was the determination of 500 astronomical points, 400 triangulation points, and, 4,000 barometric altitude points. A comparison of the earlier and later results showed perplexing discrepancies. From this time on military and civilian experts worked hard to correct the inaccuracies. At the same time they found that the most difficult task was the representation of the relief, which had to be made on the basis of hasty sketches and photographs. With such inexact data it was impossible to prepare accurate maps of the Balkans. Thus accurate surveying could be carried out only in the wake of military maneuvers and occupation.

The first survey in the Balkans was made by the Russians during the Russian-Turkish war of 1828—1829. This work was similar to the cartographic work carried out in Siberia because proper surveys were made only along roads and watercourses, while the surrounding areas were drawn lon the basis of visual estimation. About 30 years later, in the newer Russian-Turkish war, the occupation armies of the Monarchy stayed in Wallachia for nearly 3 years; this provided the opportunity to carry out systematic topographic surveys. During the Russian-Turkish war of 1877—1878 the Russians carried out surveys in the eastern part of the Balkans. There were no more surveys in the Balkans in that century.

New cartographic work in the Balkans started only in the fall of 1919. This was made urgent by the First World War. The first task was to create trigonometric basis of the topographic survey. The work was limited to a territory of nearly 90,000 km^2, comprising Bosnia-Herzegovina and the areas of Nis, Pristina, Ohrid, Vlora south of Hungary. At the same time the geodesic work covered also the territories of Macedonia, Albania, Montenegro, and Serbia. Most important was the mapping of the territory of Serbia. After half a century of Turkish occupation, it regained its independence only by the decision of the Berlin Conference in 1878. From this time on, Serbia tried to catch up with the more advanced nations in both military and economical respects. The natural consequence of this was the quick replancement of the unsatisfactory maps. Triangulation of the inner area was impossible owing to objective obstacles; therefore the surveyors had to take the triangulation points of the neighboring states for a basis. Near the triangulation points close to the border a 1,000-m-long base line was designated, which was then developed further. Orientation was carried out by means of compasses. Besides the survey of 1883—1887, triangulations by drawing were also made, and the results of both these surveys were in almost complete agreement with the survey results of Bosnia-Herzegovina obtained in 1880—1884.

The starting point of the altitude determinations was the water-gauge at the mouth of the river Sava, which at that time was found to be at 73.3 m altitude. The altitude measurements were made with barometers. As base points for level deeterminations the Rusian triangulation points were chosen, the altitudesof which represented the altitude points of first order. It should be noted that the bench mark on the first floor of the Military Academy in Belgrade is also calculated on the altitude of the water-gauge. The altitude of the mark-ball of the Military Academy is 91.6 m. In each center of the geodesic working-places a barometric station was established during the surveys, and the altitudes of these points were calculated by means of a mercury barometer in Belgrade. These points became the altitude points of second order, while the altitude points of third order were the observation points of the topographers. The details of the planimetric drawings of the 50,000-scale surveys were determined by intersection and resection, while the relief was represented by contour lines. On the basis of the surveys 50 m main, and 25 m and 12.5 m auxiliary contour lines were drawn. The Cyrillic alphabet was used for the insriptions.

Triangulations were made in Montenegro and Albania in connection with the border demarkations in 1878 and 1913. The data of these measurements could later not be found. Later the triangulations were based on the points of first order in Cattaro. On the occasion of the planning of the Saloniki-Sarajevo railroad, a base line was measured near Mitrovitsa and Novi-Pazar, and at the same time triangulations of first, second and third order were made, which were later linked to the Serbian network.

Surveying the Balkans must have been very difficult because of deterior ting public security, worsening food supply, and lodging conditions toward the end the First World War. The recurring epidemics made frequent replacement of the personnel necessary. The fall of the Monarchy in 1918 meant also the end of the military geodesic work. The Military Geographical Institute accomplished its task of surveying the Balkans with more than a century of hard work.