The Cartographic Journal

The World of Mapping

ISSN: 0008-7041 (Print) 1743-2774 (Online) Journal homepage: https://www.tandfonline.com/loi/ycaj20

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To cite this article: László Zentai (2018) The Transformation of Relief Representation on Topographic Maps in Hungary: From Hachures to Contour Lines, The Cartographic Journal, 55:2, 150-158, DOI: 10.1080/00087041.2018.1433475

To link to this article: https://doi.org/10.1080/00087041.2018.1433475

Published online: 09 Jul 2018.

THE CARTOGRAPHIC JOURNAL
2018, VOL. 55, NO. 2, pp. 150–158
https://doi.org/10.1080/00087041.2018.1433475

BRITISH CARTOGRAPHIC SOCIETY
Taylor & Francis
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REFEREED PAPER

The Transformation of Relief Representation on Topographic Maps in Hungary: From Hachures to Contour Lines

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ABSTRACT
Although the maps of the Third and Fourth Military Surveys of the Austria–Hungarian Empire were classified, after its dissolution the new countries had access to the topographic maps covering their own territories. Lehmann's slope hachures were used for representing relief, both at the survey scale and the derived scales. Contour lines were used to plan the hachures, which were the primary method of relief representation; therefore, most of the contour lines were removed from the final map. Following the political and administrative changes, a new organization, the independent Military Mapping Group was established in Hungary in 1919. After developing it into an institute, Hungary started a new topographic survey revising the former Austro-Hungarian 1:25 000 scale topographic maps. The revision changed the relief representation from hachures to contour lines and the language of the map lettering from German to Hungarian.

KEYWORDS
topographic maps; hachures; contour lines; relief representation

Historical background

The first systematic topographic surveys began and were completed in the eighteenth century. It is important to establish the historical circumstances of the time in Europe in order to fully understand the increasing importance of map use. Following the end of the War of the Austrian Succession (1740–1748), Maria Theresa plotted revenge on the Prussians. The Seven Years' War (1756–1763) split Europe into two coalitions led by the Kingdom of Great Britain (including Prussia, Portugal, and other small German states) on one side, and the Kingdom of France (including the Austria-led Holy Roman Empire, Russia, Spain, and Sweden) on the other. Austria was exhausted by the end of the war, which allowed the enemy side to gain territories from the empire (Yonan, 2011).

Maria Theresa (1740–1780) was succeeded by her son, Joseph II (1780–1790). Josephinism (as his policies were called) is notable for the very wide range of reforms designed to modernize the Austrian Empire in the times when France and Prussia were rapidly upgrading. Joseph II set about building a rational, centralized, and uniform government for his diverse lands; a pyramid with himself as supreme autocrat (Kohn, 1961).

The first topographic surveys

The sophistication of the methods of topographic mapping led to contradictions in the representation of map content by the mid-seventeenth century. The representation of planar elements of the terrain had improved, but the relief, which determines the image of the land, was only shown in side view. Although there were attempts to show the relief in oblique view from higher positions, the technical literature took up the problem of showing the terrain directly from above only in the second part of the eighteenth century.

The development of the profession was driven by the new methods of topographic mapping, first of all in France. In the second half of the seventeenth and first part of the eighteenth century, France was the European model of establishing professional institutions and making topographic map series. Great Britain followed the practice of France and by the end of the eighteenth century, Germany and the Austrian Empire led the development. The turn of the eighteenth century brought changes in the military: the representation of relief became a more important, or, rather the primary concern, of military cartography.

The reigns of Maria Theresa and Joseph II was the era when the First Military Survey was completed in Austria (1763–1787). This survey used hachures for relief representation. Hachures represent an early attempt to portray not only the general lay of the land, but also to give more detailed information on relative slopes as well. While in the earlier times only smaller scale maps were made to gain an overview of a land, the 'invention' of topographic

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maps led to the direct use of maps for terrain navigation and to the growing importance of terrain knowledge for military purposes. This was the main reason why these maps were generally classified.

The Cassini Survey of France (1756–1789) at the 1:86 400 scale used a very similar method of hachures, although this is not considered to be a military survey. Hachures were also used for other 'civil' maps at the time, like Samuel Mikoviny's county maps (scales between 1:100 000 and 1:200 000) of Hungary. This kind of relief representation is called *swing hachures* in Hungarian, which term refers to the lack of rules on how to use/draw the hachures. During the Second Military Survey (1806–1869), the representation of relief did not change, although in the second part of the survey the Lehmann hachures were implanted replacing the swing hachures (Jankó, 2007).

Relief representation on topographic maps

Several relief representation methods had already been invented by this time, but for military purposes it became more and more important to adopt methods which were suitable for printing and reproduction. The most common reproduction techniques of the time were lithography and chalcography (copper plates); both methods were perfect to reproduce thin lines.

With the development of topographic maps, methods for how best to represent relief became more complex. Hachures are lines of varying width and length, sometimes even in colour, used just to give the impression of the relief in the early era, later to depict slope steepness. When many hachures are drawn, they together show the forms of the surface configuration giving emphasis to relative gradient and distribution of shape.

Hachures

The first German language summary of the modern contemporary surveying methods was published by Johann Gottlieb Tielke (1731–1787) in 1769. These techniques did not include real geodetic measurements, just the so-called à-la-vue method. He dealt with the drawing techniques and suggested concentrating on representing the slope relations from a military point of view; he preferred the positioning of the light source at the top and emphasized the importance of expressing the heights. He properly defined the needs but had not identified the cartographic solution (Figure 1).

The optimal representation of the relief became the most important theoretical and empirical problem of German topography and cartography at the end of the eighteenth century. They still tried to find a method where the slopes and the height relations could be represented simultaneously by hachures. Johann Georg Lehmann (1765–1811) established the first theory of cartography in his famous book, *Darstellung einer neuen Theorie der Bezeichnung der schiefen Flächen im Grundriss oder der Situationszeichnung der Berge*, published in 1799, and in his last

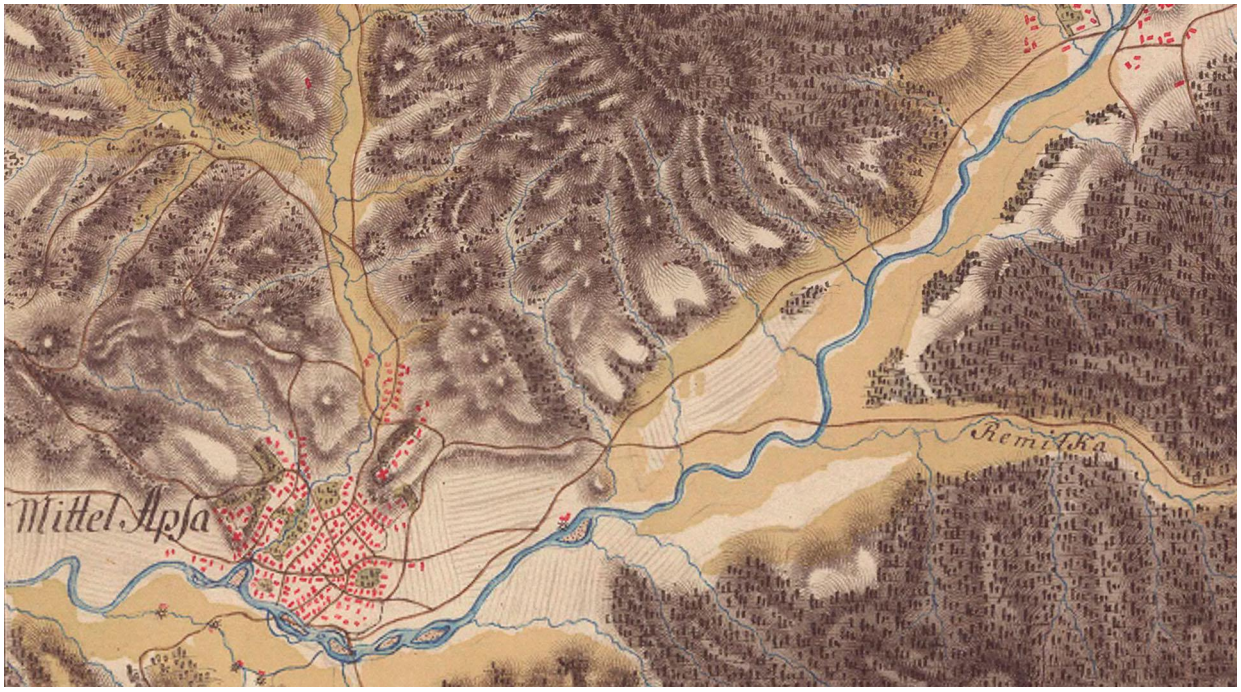

Figure 1. Hachures of the First Military Survey, Coll. XXXIV, Sectio VI. Scale: 1:28 800. By courtesy of the Institute and Museum of Military History, Budapest.

book, *Die Lehre der Situation-Zeichnung*, in 1812. Lehmann developed a mathematically derived slope hachure system, which undoubtedly had a paradigmatic effect on the theory of the cartographic relief representation. The new method was adopted soon in the neighbouring countries as well as in France and soon thereafter in England, the Netherlands, and Russia. The Second Military Survey started to use Lehmann hachures around 1820. The representation of the landforms in the late maps of the Second Military Survey was accomplished by spot heights chosen mostly from points of geodetic control. The depiction of relief in large- and medium-scale topographic maps was dominated throughout the nineteenth century by the more-or-less strictly applied Lehmann hachures (Klinghammer, 2017). It is easy to sketch and understand Lehmann's basic idea (Koch, 2013):

- 'The steeper, the darker' – assuming vertical illumination of the landscape.
- The hachures are set perpendicular to the contour lines.
- The hachure density is mainly dependent on the scale of the map.

Contour lines

The theory of contour lines was well-known for the military cartographers at the time: even the Lehmann hachures refer to contour lines (hachures run perpendicularly to contour lines). Because absolute heights did not have any relevance for military aspects, it took time to implement the proper geodetic (triangulation) methods. Therefore, the relief representation by contour lines remained a theoretical method until the beginning of the twentieth century (Dainville, 1958).

The first Hungarian map using contour lines as the only relief representation method was drawn by a student of Institutum Geometricum in 1843. The map of Dániel Braxatoris, Planum Montis Aquilae, was a large-scale piece of work (Figure 2). Braxatoris mapped the same area with hachures in 1842 (Jankó, 2007). Ágoston Tóth (1812–1889), the most notable Hungarian cartographer of the nineteenth century, created the relief model of the Karakas Hill area in 1846, near Pétervárad (now Petrovaradin in Serbia) in order to present the advantages of contour line relief representation (Klinghammer, 2002). The scale of Tóth's work was similar to Braxatoris's map. Since the Hungarian Kingdom's sheets of the Second Military Survey were made in the last decades of the survey, we can be sure that the creators of those sheets were trained to understand both contour lines and

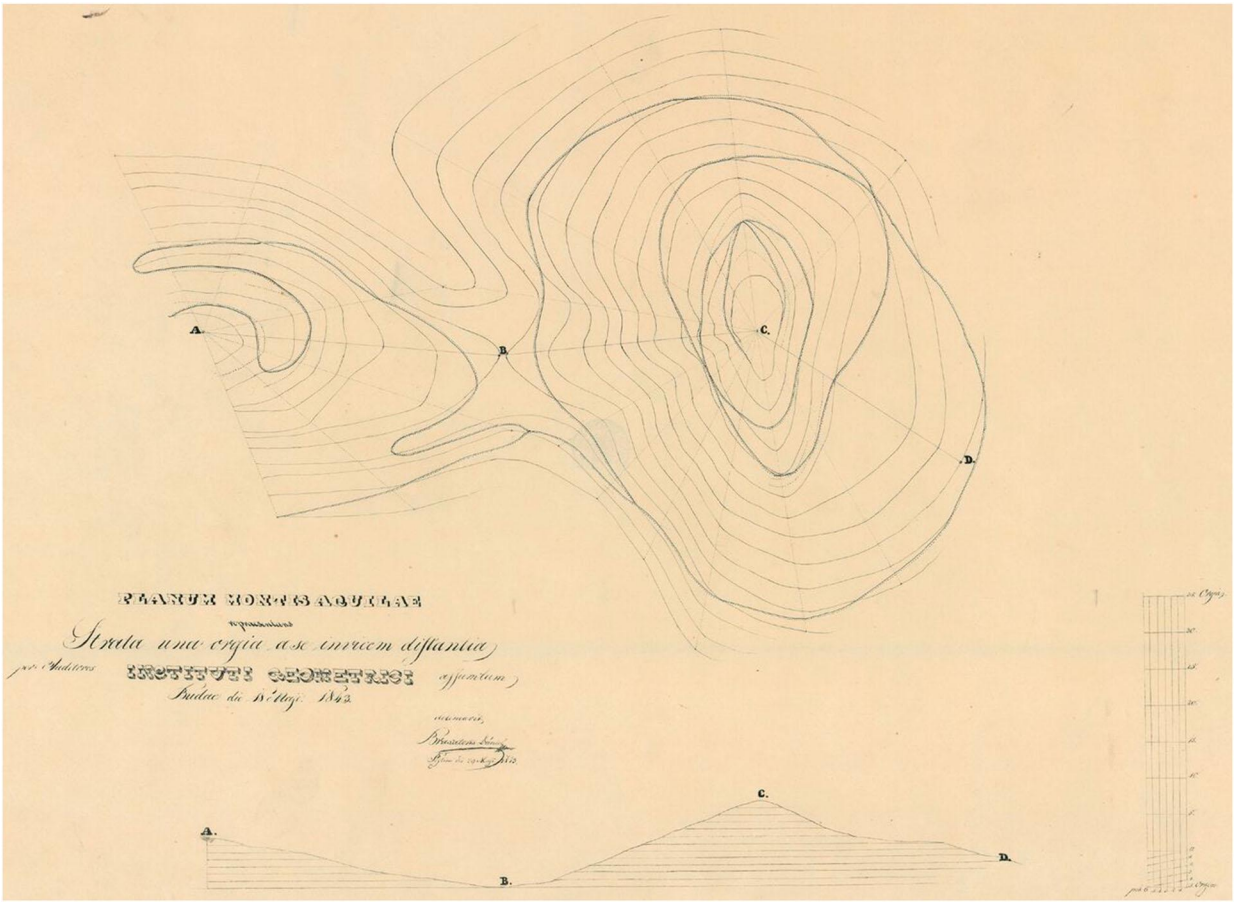

Figure 2. The first Hungarian map by contour lines (Planum Montis Aquilae, Dániel Braxatoris, 1843). Scale: ca. 1:6 650. Source and permission: Budapest History Museum.

Lehmann hachures. In addition, both methods were part of the curriculum in the Militärgeographisches Institut in Vienna (Klinghammer, 2002).

The third and fourth military survey

Transylvania was the last part of Austria–Hungary which was mapped in the Second Military Survey. Researchers are still discussing whether the survey of this area belongs to the Second or the Third Survey, but the area was surveyed only once (around 1870). The method of combining Lehmann hachures and contour lines (100 metres equidistance) became the 'official' relief representation method of the next surveys:

- Third Military Survey (1869–1887) – 1:25 000 scale.
- Fourth Military Survey (1896–1915) – 1:25 000 scale.

The Third Military Survey was based on a new framework of horizontal and vertical control points, which met European level measurement standards (Hungary counts the Third Military Survey as the country's first accurate, systematic survey). The method of relief representation was Lehmann hachures, 100-metre contour lines (on the 1:25 000 scale survey sheets), and schematic rock drawing (where it was necessary). Both these base maps and the derived maps of this survey (1:75 000; 1:200 000; 1:750 000 scales) were reproduced by black-and-white photolithography, that was begun in the early 1900s, but the smaller scale maps were reproduced in colour.

The Fourth Military Survey introduced precision surveying techniques, such as tachometric distance measurement and altitude measurements based on trigonometrical observations, to revise the interpolated contour lines. Having more precise contour lines required more and much more accurate altitude measurements, and this was the reason why the Fourth Military Survey was originally planned to be completed in 100 years.

After 1890, the use of photogrammetry for topographical survey in mountainous areas was also introduced (following experiments in 1891 near Vienna) by using balloon photography. In 1893–1894, photogrammetric surveying was tested also in the Tatra Mountains (these were the only sheets of the Fourth Military Survey covering the area of the Hungarian Kingdom). Experts recognized the superiority of photogrammetric surveying in mountainous areas, even though transforming the data for drawing was time-consuming (Jankó, 2007).

After 1910, stereophotogrammetry was permanently adopted in Vienna for topographical surveying. Experts also investigated the optical transformation of aerial photographs, taken by balloons, into orthophotographs. This greatly increased the geometric accuracy of large-scale topographical maps. After World War I, airplane-based stereophotogrammetry became the main method of the survey.

Implementation of the international system of units in Hungary

The Metre Convention (Convention Internationale du Mètre) is an international treaty that was signed in Paris on 20th May 1875 by representatives of 18 nations (including Austria–Hungary). In Hungary, the convention was immediately implemented by a law in 1876. In 1921, the convention was extended to permit the promotion of standards relating to any physical quantity, which greatly increased the scope of the International System of Units (Quinn, 2012).

The 1876 law provided respite to the Hungarian cadastral institutions, but at that time nobody has imagined that this favourism had to be extended for decades by additional laws later in 1928 and 1948 and even in 1974, when a decree abandoned parallel area accounting (both in m^2 and in square fathom) in land administration. However, the military cartographers immediately implemented the new measurement units; the scales of the Third Military Survey were adjusted, 1:25 000 became the new basic scale of the military surveys (Mélykúti, 2010).

The delayed implementation of the International System of Units in cadastral maps slightly influenced the change of relief representation from hachures to contour lines, but after the dissolution of the Austro-Hungarian Monarchy the newly established Hungarian mapping authority abandoned the use of hachures immediately. Nevertheless, the original idea was to use hachures on the first survey of the independent Hungarian Military Mapping Institute after World War I, but the lack of experts and the time-consuming process of hachuring quickly changed the original idea; since September 1921, contour lines became the primary relief representation method, which reduced the production time to 20% (Balla and Hrenkó, 1991).

The role of civil maps

Maps of military surveys did not influence the everyday map use of citizens in the Hungarian Kingdom, because maps were not widely used or known by them. The use of maps in the primary or secondary education was not

Figure 3. Part of a wall map for schools (Hungarian Kingdom) published by the Hungarian Geographical Institute in 1895. By courtesy of the Map Collection of the Department of Cartography and Geoinformatics, Eötvös Loránd University, Budapest.

common until the decrees (state codes of the Hungarian education) of Maria Theresa and later Franz I were issued (Ratio Educationis, 1777 and 1806). The Ratio greatly extended the field of cultural subjects and broadened the curriculum upon an encyclopaedic basis. However, the basic language of education was still Latin and German, which meant that only upper-class members had access to it (Mason, 2013).

One of the most important historical events of Hungary was the Austro-Hungarian Compromise of 1867. The Compromise (Ausgleich in German) recognized the sovereign equality of the two states and brought them together under a common ruler as a real union (Franz Joseph). After the Compromise, the Hungarian Kingdom partially re-established its sovereignty and gave more freedom in nearly all areas of public life and administration. The Elementary Education Act of 1868 regulated the entire system of public instruction. It stipulated general compulsory school attendance from the age of 6–15, subject to a penalty for disobedience. This law stipulated that pupils shall be instructed in their mother tongue if that tongue was generally used in the parish (Kohn, 1961).

The minister of education (Baron József Eötvös) provided basic school sets for nearly 500 public schools. As there were no Hungarian language maps available for elementary and secondary school education, the ministry ordered a series of maps and atlases. Manó Kogutowicz established a firm (Hungarian Geographical Institute) around 1870 to produce such maps, wall maps, and atlases. Manó Kogutowicz was already a well-known cartographer, when he managed to convince the minister of education to establish a Hungarian cartographic institution. Kogutowicz established his institute as a subsidiary of the Hölzel Company (based in Vienna) in the same year with the support of the minister. By 1892, his institute became an independent firm under the name Kogutowicz and Co. By the millennia (1896), his company produced numerous excellent atlases, wall maps and earth globes, and he was awarded the Great Medal of the Millennia.

His company operated for more than 60 years and all Hungarian people used these maps. In the last decades of the nineteenth century the Lehmann hachures were widely known and used by cartographers, and thanks to the colour printing technologies the paler colour of hachures (brown) eliminated the disadvantages of these relief representation methods (Figure 3). The popularity of Kogutowicz's maps made the Lehmann hachures method also well-known for civil map users.

Military mapping at the turn of the century

The end of the nineteenth century and the beginning of the twentieth century was the time of rapid development in cartography:

- War tactics and techniques changed. The nineteenth century was the time of far-reaching technological change that totally altered the scope of tactics and strategy. Railroads and steamships increased the volume, range, and speed of mobilization and of conscription. The growth in range and accuracy of rifle firepower created new tactical problems: artillery had to be placed further behind the lines, and troops began to fight from trenches and use grenades and land mines (Dupuy and Dupuy, 1970). Cartographers had to support these new

challenges: detailed and accurate topographic maps were necessary, even high mountainous areas were surveyed. Only contour lines were able to provide the necessary information for special weapons, like mortars.

- After 1900, great innovations in map reproduction also occurred. The Militärgeographisches Institut of Austria–Hungary had the first offset lithographic rotary press in Europe. Its output was quadruple that of flatbed mechanical presses, so printing colour maps became more common and affordable. The drawing of hachures was a time-consuming process, but due to the similarly time-consuming process of map printing it was not previously an issue. The invention of rotary and offset press speeded up the printing process, made the map production cycle much shorter and this also motivated cartographers to change the relief representation method to the well-known contour lines (Monmonier, 2015).
- Some countries already changed their relief representation method. On the topographic maps of the Prussian Survey, the contour lines replaced hachures since 1846. Even the Institut Géographique National (National Geographical Institute of France) adopted contour lines for relief representation, and relied upon 8 (initially) to 14 colours (Monmonier, 2015).

Independent Hungarian topographic mapping

Upon the dissolution and break-up of Austria–Hungary after World War I, the Hungarian Democratic Republic and then the Hungarian Soviet Republic were briefly proclaimed in 1918 and 1919, respectively. From 1919 to 1920, the country went into a period of civil conflict with Hungarian anti-communists and monarchists. Hungary's signing of the Treaty of Trianon in 1920 ratified the country's dismemberment, limited the size of its armed forces, and required reparations payments (Cornwall, 1990). The territorial provisions of the treaty, which ensured continued discord between Hungary and its neighbours, required the Hungarians to surrender more than two-thirds of their pre-war lands. Romania acquired Transylvania; Yugoslavia gained Croatia, Slavonia, and Vojvodina; Slovakia became a part of Czechoslovakia; and Austria also acquired a small piece of pre-war Hungarian territory. Hungary also lost about 60% of its pre-war population, and about one-third of the 10 million ethnic Hungarians found themselves outside the diminished homeland (Romsics, 1999).

Very soon after the dissolution of Austria–Hungary, the first independent Hungarian cartographical organization, the Hungarian Military Mapping Group was established in 1919. It was soon transferred into the Royal Hungarian State Mapping Institute (Magyar Királyi Állami Térképészet) in 1922 and was renamed the Institute of Military Cartography (Honvéd Térképészeti Intézet) after 1938 (when the restrictions of the Trianon Treaty were partly unregarded).

These new Hungarian authorities retained the map scales that were established by the Austro-Hungarian Monarchy. The 1:25 000 scale sheets of the Third and Fourth Military Survey were accurate enough from geodetic point of view, but their data had to be refreshed. The 1:25 000 scale map sheets of the Third Military Survey were perambulated (by re-surveying based on field-working) between 1920 and 1926 (the Fourth Military Survey did not cover the after-WWI-area of Hungary). Altogether 106 sheets were published, but due to the difficulties (outdated cadastral maps, restriction on air-photographing), it was practical to start a new survey. It is not easy to conclude the number of sheets that would have covered the whole of Hungary, because due to the revisionist politics of the country only the index sheet map of the 'large' Hungarian Kingdom was used; it is certain that a little more than 1000 sheets could cover the country. The most important outcome of the re-survey was the replacing of hachures by contour lines and the changing of the occurring German geographic names to Hungarian (Balla and Hrenkó, 1991).

A new survey was started in 1927, which was planned to fit to the different characteristics of the terrain types using air photographs. The first sheets fully supported by stereophotogrammetry were published around 1932 (Figure 4). Altogether 86 sheets were published and additional 17 sheets were field-worked before World War II. As a result, in 1940, a little less than 50% of the actual area was re-surveyed and published (Jankó, 2007). Further local corrections of the sheets of the southern and eastern borders were initiated by 1939–1940. The supervised sheets were circulated in multi-colour versions, while those not refreshed were issued as reprints of the Third Military Survey in black and white editions. The results of the supervisions were transferred onto the 1:75 000 scale maps as well.

The 1:50,000 scale survey

In 1938, the First Vienna Award separated largely Hungarian-populated territories in southern Slovakia and southern Carpatho-Ukraine from Czechoslovakia and awarded them back to Hungary. The area of Hungary increased by more than 10,000 km^2. Together with the Second Vienna Award (northern Transylvania) altogether 43,492 km^2 were awarded back to Hungary. (All these areas were returned after World War II.)

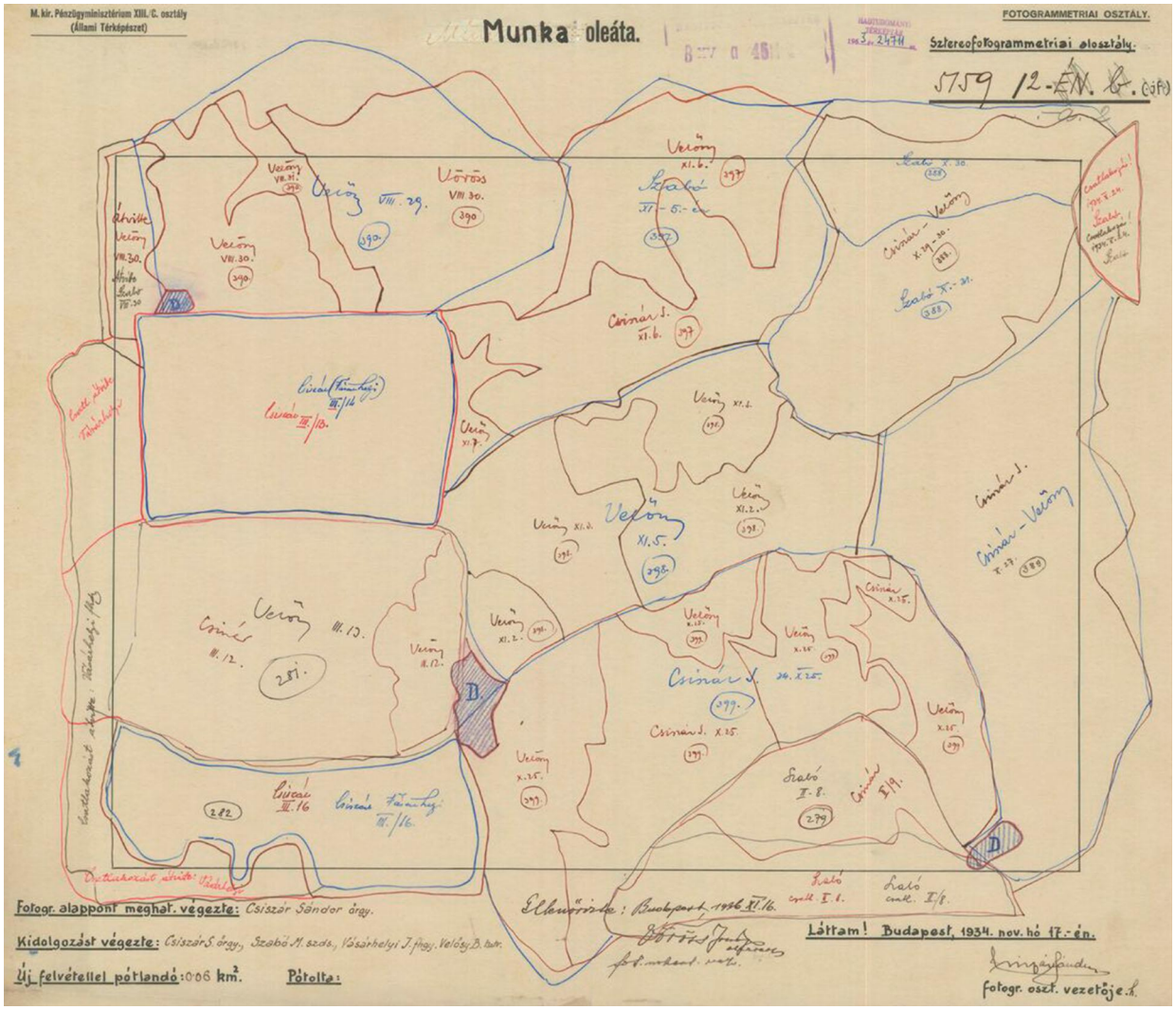

Figure 4. Worksheet of an early 1:25 000 scale Hungarian map sheet made by stereophotogrammetry (1934: sheet number 5159/2). The red/blue lines show the areas covered by aerial photographs. Hatched areas were not covered by stereophotogrammetry. By courtesy of the Institute and Museum of Military History, Budapest.

Due to the increased area of the country, a professional discussion started on the proper scale of military topographic maps: whether to continue the map publishing in the scales applied in the Third Military Survey or publish maps in a scale which is more appropriate for military use. Using the 1:50 000 scale was considered for the first time already when the scale of the Third Military Survey was fixed around 1870. After World War I, in the first stage of the operation of the State Cartography, experimental tests were carried out (one sheet was published in 1932). The final decision on using the 1:50 000 scale was supported by the following factors:

- this scale would be ideal for general military purposes;
- the scale would replace both the former 1:25 000 and 1:75 000 scale maps, so it would be cost-effective;
- the calculations would be easier, which is essential in war conditions; and
- it would also be suitable for administrative purposes and tourist maps.

According to the original plan, the whole survey would have taken 10–15 years for the whole increased area of Hungary. Due to World War II, the demands for updated maps continuously increased, especially for the returned areas. In comparison with the former map sheets (1:25 000 and 1:75 000 scales), the following principles were used in the production:

- the contour interval was 10 or 20 metres, depending on the relief characteristics of the area, but the equidistance was not even listed on the map sheets;
- dispensible features and details were discarded;

Figure 5. Different relief representation method in one sheet (sheet 5269 NY). By courtesy of the Map Collection of the Department of Cartography and Geoinformatics, Eötvös Loránd University, Budapest.

- the most important features were emphasized to improve the legibility and usefulness, and speed up the map drawing process;
- the out-of-frontier areas were reproduced according to the Third Military Survey (including the hachures, although this method was not used in the Hungarian cartography after 1921); and
- fine lines were not ideal for the off-set printing process.

This method was so well-organized that the first 17 printed sheets were already published in spring 1942. Later, when it was evident that the survey had to be speeded up, the process was changed. As the war extended, Hungarian military mapping had been progressively made to serve the Germany forces. It was essential to complete the 1:50 000 scale maps as soon as possible. In 1943, the Hungarian Royal Army Chief of Staff ordered to complete the survey by April 1944. About 150 sheets were not ready at that time, so the whole Royal Hungarian Cartographic Institute had to concentrate on this work. Non-stop photogrammetric preparation was necessary to create the base maps for the fieldwork. Since November 1943 nearly all available officers of the institute worked on the terrain in difficult circumstances.

Finally, most of the sheets (about 180) were simple photographic enlargements of the original 1:75 000 maps. The Lehmann hachures remained intact, and the approximate position of the forest areas was drawn (Slovakia, Carpatho-Ukraine, Northern Transylvania). This was the last time when hachures appeared on newly printed topographic maps (Jankó, 2007). Altogether 401 sheets were published (112 sheets represented Transylvanian areas). Though the mapmakers tried to do their best, the overall result could not be a homogenous set of sheets (Figure 5). The first 1:50 000 scale survey of Hungary is the last map series where the old-fashioned hachure method was used. In war conditions, this was the only possible way to complete the whole survey (mostly used on the returned areas) in the given time. Military officers had to execute the orders: the mappers of the Royal Hungarian Cartographic Institute managed to create a method to complete the survey.

It is apparent that the result was not homogenous, but if the order and the circumstances did not respect the cartographic needs, then the cartographers had to find makeshift ways to fulfil the order and provide maps for military operations. The five-colour, contour line maps of this survey aptly represent the outstanding level of the Hungarian topographic mapping at the time. However, these maps did not affect at all the following surveys of Hungary, because these later surveys were supplanted by Soviet mapping.

Conclusion

Contour lines appeared for the first time on the very late sheets of the Second Military Survey in systematic topographic mapping. In the Third and Fourth Military Survey, hachuring was still the main method of representing relief, though contour lines were also added. Austria–Hungary was probably the first country to

adopt the systematic use of photogrammetry for mapping, derived from balloon and aircraft photographs. Although the process was very time-consuming, this method was suitable to fulfil the precision requirements of the Fourth Military Survey. When Hungary became independent, Hungarian topographers no longer used hachures (except under the special circumstances of Word War II). Stereophotogrammetry from aerial photographs was introduced in Hungary at around 1930. The procedure was very complicated because of the early stage of the technology, but the overall manpower time was less and the quality was improved. Since that time this technology continuously developed, so this early introduction and implementation of stereophotogrammetry helped the Hungarian cartographers to manage the mapping of the enlarged area of the country during World War II.

Notes on contributor

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