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The georeferencing method of the 1:5000 scale Danube maps

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Summary

The 1: 5000 scale Danube maps were surveyed and drawn by the Hungarian civilian hydrological engineers in 1908. The map sheets show the river and the riverside between Dévény (now Devín, in Slovakia) and Gombos (now Bogojevo, in Serbia). The hydrological objects of the riverside (banks, sluices), the crossing places (bridges, pontoons and ferries), the type of the riverside, the streets of towns, and the land-use are represented in detail on the map sheets along the river. The triangulation points, established by the civilian engineers in the 1820s are represented too. The drawings of the map sheets are very simple; they are black curves and labels.

The geodetic system is identical to the system which was established by the civilian flood-control engineers in the first decades of the 19th century, although the stereographic projection was used in the other civilian surveying projects in the Hungarian Kingdom. The used projection was the Cassini–Soldner projection, the centre of which was the old observatory on Gellért Hill in Buda. The used ellipsoid was the Zach–Oriani combined ellipsoid. The dimension of one sheet is 2000 × 1600 Viennese fathoms on the ground. The coordinates of the four corner points can be calculated with this information and the sheet labelling system for every map sheet.

The georeferenced map sheets were compared to modern databases, such as the Google Earth satellite images and modern Hungarian topographic maps, and the average error is between 5 and 10 m due to the large scale mapping.

This paper gives a general overview of the maps and describes the possible projection systems, the georeferencing method and the final results.

Introduction

In the territory of Hungarian Kingdom, the major flood-control projects were carried out during the 19th century. The size of the projects is demonstrated by the large number of canals and cut-offs planned by the engineers and the areas protected from flood. According to the contemporary written records, the size of the area was the same as the territory of the Netherlands (Fodor 1952). The proof and preserver of the projects are the old flood-control maps that were made before the start of the actual work. They served as the basis for planning. Several maps were made after completing the project, which means that these maps were the graphical summary of the results. One of these flood-control maps is the 1: 5000 scale Danube map, which gives us a detailed view of the riverside along the Danube river.

The 1: 5000 scale Danube maps

The Hungarian Directorate of Water Management declared the necessity of new flood-control maps about the Danube River at the end of the 1800s, because the previous maps, surveyed between 1823 and 1845, became outdated and unusable. The new geodetic surveying and the duplicating of map sheets was completed in 1908.

The directorate established a new map system: the topographic survey was carried out at 1: 2880 scale on the field. This was originally the scale of the cadastral mapping in the civilian projects.

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As these survey map sheets were not copied, the originals were lost. The 1: 5000 scale maps derived from the survey sheets served for the water-engineering plans and constructions. The final scale was 1: 25 000 within the map system. These sheets served for general purposes such as giving a general overview of the river, or helping the identification of the 1: 5000 scale sheets.
The part of the river which lied within the borders of the former Hungarian Kingdom was divided into three parts. The upper section ran between Dévény (now Devín, in Slovakia) and Budapest, the middle one between Budapest and Gombos (now Bogojevo, in Serbia), and the lower section originally between Gombos and Orsova (now Orşova, in Romania). However, in the preface of the 1: 25 000 map sheets there is a short note saying that the topographic survey had been carried out only to Ómoldova (now part of Moldova Nouă, in Romania), because the bed of the Danube River was not changed in this section after the last surveying. The map sheets of the upper and middle sections are available in archives in Hungary. Unfortunately, the map sheets of the last section were perhaps lost or lay in various archives abroad.
Due to the large scale, the sheets represent the river and its riverside in great details. They represent the settlements, their road-networks and the flood-control works in the river (e.g. dykes, sluices, bridges, ferries) as well as the fundamental horizontal and vertical points. The type of the land-use is labelled with symbol and text (plough-land, meadow, pasture, vineyard, forest, reeds, swamp).
The drawings on the sheets are very simple; they consist of curves and labels in black only (Fig. 1).

Figure 1: Part of a map sheet

The upper section consists of 106 sheets; the middle consists of 155 sheets, but there is no any available information on the number of the sheets covering the lower section.

The possible geodetic systems of the maps

At the time of the surveying, the Hungarian “Civil” stereographic projection system was used for civilian topographic surveys (Mugnier 1999, Varga 2002). Other previously established systems existed at the same time, like the projection system of the flood-control projects based on the Cassini–Soldner projection (Mészáros–Timár 2010).

The stereographic projection system

A new projection system was established for the civilian surveying projects in the Hungarian Kingdom in 1863 (Mugnier 1999, Timár et al. 2003, Varga 2002). The stereographic projection was used to achieve the conformal property of the topographic surveys.
The central point of the projection was the fundamental point that marked the central point of the eastern dome inside the old observatory on Gellért Hill (destroyed in 1849). The ellipsoidal coordinates of the fundamental point were as follows (the ellipsoidal longitude from the Ferro prime meridian is in parentheses) (Homoródi 1953):

$$\Phi = 47° \; 29' \; 9.6380'' \; ; \; \Lambda_G = 19° \; 2' \; 56.9441'' \; ; \; (\Lambda_F = 36° \; 42' \; 51.69'')$$

The used ellipsoid was changed to the Bessel ellipsoid from the older Zach–Oriani ellipsoid. To achieve the best fitting to the geoid, the geodetic datum parameters of the Bursa–Wolfe transformation were used. These parameters consist of three shifts (meters), three rotations (arc-seconds) and the scale correction (parts per million) (Timár et al. 2003):

$$dX = 595.75 \text{ m} \; ; \; dY = 121.09 \text{ m} \; ; \; dZ = 515.4 \text{ m}$$
$$ex = -8.226'' \; ; \; ey = 1.5193'' \; ; \; ez = -5.541''$$
$$k = -7.371 \text{ ppm}$$

The Cassini–Soldner projection system

This system was based on the projection of the second military survey of the Austrian Empire, but this system was absolutely different. It was established at the time of the Danube triangulation in 1823 by the civilian engineers (Homoródi 1953).
The central point of this system was the same as the one in the previously described system. However, at this time the observatory was already established. The main difference is the ellipsoid: in this older system the Zach–Oriani ellipsoid was used. The ellipsoidal coordinates of the point on this ellipsoid were as follows (the ellipsoidal longitude from the Ferro prime meridian is in parentheses) (Homoródi 1953):

$$\Phi = 47^o \; 29' \; 10.4'' \; ; \; \Lambda_G = 19^o \; 02' \; 59.025'' \; ; \; (\Lambda_F = 36^o \; 42' \; 45'')$$

The datum parameters were calculated. In this case, the datum parameters of the Molodensky–Badekas transformation are sufficient to reach the required accuracy. These parameters consist of only three shifts (meters) (Mészáros–Timár 2010):

$$dX = 1599 \text{ m} \; ; \; dY = 370 \text{ m} \; ; \; dZ = 684 \text{ m}$$

Georeferencing the map sheets

To determine exactly the projection of the map sheets, one sheet (Paks settlement and its outskirts) was georeferenced in both projection systems. As the distance between Paks and the central point of the projection is almost 100 km, if the map sheet was georeferenced in the wrong projection, it would generate a significant error.

For georeferencing the map sheets it is necessary to identify control points on the sheets and their coordinates too. In this case, the control points are not significant ground points (church towers, bridges), but the four corner points of the sheets. A small program was developed, which computed the coordinates of the corner points for every sheet and saves the data into a textfile that is easily importable into several types of GIS software.
The results of the georeferencing of the pilot-sheet are shown by Figure 2. In this case, the georeferenced sheet was compared to the modern Hungarian topographic map at 1: 10 000 scale.

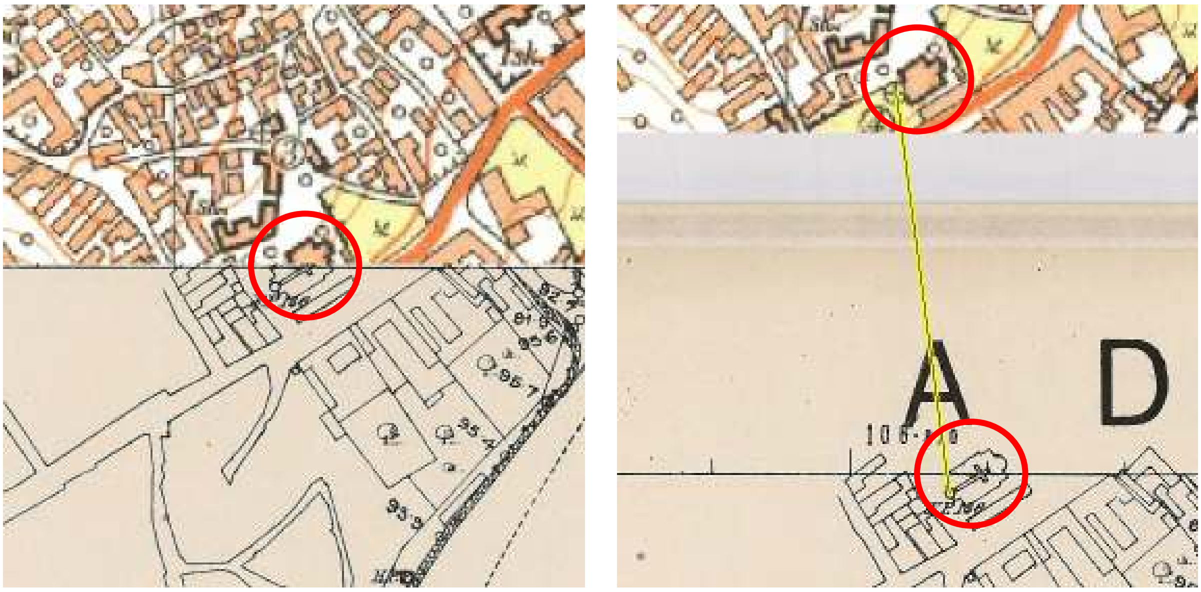

Figure 2: The error of the georeferenced map sheet: Cassini–Soldner projection (left) and stereographic projection (right)

Several easily identified buildings (for instance, the Roman Catholic church in Paks) were used to check the accuracy. The difference between the location of the church on the modern map and on the old map georeferenced in stereographic projection was very large (almost 300 m) compared to the map sheet that was georeferenced in the Cassini–Soldner projection. This fact showed that the 1: 5000 map sheets were surveyed in the older, almost 80 year old projection system, which was based on the Cassini–Soldner projection and the Zach–Oriani ellipsoid established in the 1820s.

Results and accuracy

After completing this research it became possible to georeference every map sheet and to compose the entire mosaic. Due to the large-scale mapping, the average error is minimal: 5-10 m only.

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