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RECTIFICATION OF THE ROMANIAN 1:75 000 MAP SERIES, PRIOR TO WORLD WAR I

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The labelling system, the projection and the datum parameters of the sheets of the 1:75 000 scale Romanian topographic map series completed prior to World War I, are described in order to integrate them to GIS databases. The series has two zones, eastern and western, both on the Bonne projection with different parameters. The sheets from each zone should be handled in a slightly different way in order to rectify them. The eastern sheets can be rectified using the grid coordinates computed from the sheet labels of the corner points. In the case of the western zone sheets, the geographic coordinates are computed from the sheet labels or directly from the graticule corners reprojected on the respective Bonne projection. The abridged Molodensky-parameters for the datums of the two zones are also given. The rectified sheets integrated to a GIS database provide an interesting source of the natural and built environment of the early 20th century Romania.

Keywords: Bonne projection; historical maps; map projections; rectification; Romania; World War I

Introduction and historical background

In the 19th century, many European countries completed the topographic mapping of their territories. During the second half of this period, most of the newly independent states were involved in this process, including Romania from 1870.

In Central Europe, the Habsburg Empire (the Austro-Hungarian Monarchy after 1867), established the standards and specifications for topographic mapping. The 1:75 000 scale maps of its Third Military Survey (Molnár and Timár 2009, Čechurová and Veverka 2009), were issued in the 1880s. The Austrian authorities made significant efforts to extend this series beyond the borders of the monarchy. As surveying in the territory of foreign countries was usually forbidden, it was supposedly carried out in the frame of the International Arc Measurements, thus providing geodetic control point sets for most of the Balkan Peninsula (Kovács and Timár 2009). In Romania, the Habsburg survey was completed using the occupation during the Crimean War (Timár 2008), which resulted in first- and second-order geodetic control point sets, covering Wallachia.

The following is a précis of the steps of Romanian independence. In the middle of the 19th century, Wallachia and Moldova (henceforth referred to as Old Romania), were parts of the Ottoman Empire while the third part of the modern-day country,

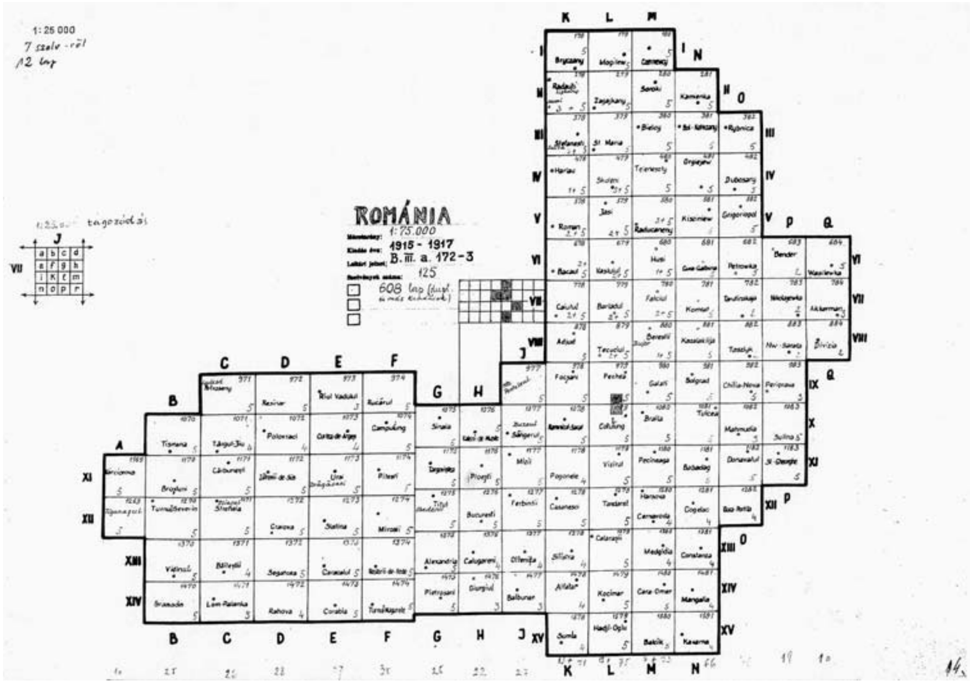

Fig. 1. Sheet system of the Romanian 1:75 000 scale topographic series

Transylvania, belonged to Hungary in the Habsburg Empire. Bessarabia, now the Republic of Moldova which is the land between the Prut and Dniester rivers was under Russian rule. After the Crimean War (1853–1856), the electorate in both Moldavia and Wallachia chose the same person as prince in 1859. Thus, Romania was created as a personal union. In a 1866 coup d'état, Prince Karl of Hohenzollern-Sigmaringen, known as Prince Carol of Romania was raised to power. During the Russo-Turkish War (1877–1878), Romania fought on the Russian side, and in the 1878 Treaty of Berlin, Romania was recognized as an independent state. In return, Romania ceded the three southern districts of Bessarabia to Russia, and in turn acquired Dobrogea. In 1881, the principality was raised to a kingdom and Prince Carol became King Carol I (Wikipedia 2005–2009).

The map series concerned in this paper, was initiated around 1870 (Dragomir 1975, Osachi-Costache 2000, Rus et al. 2007). According to Mugnier (2001), the projection used for the series was selected in 1870, when Romania was not yet a fully independent state. In spite of the quite early start of the map compilation, the printed sheets that can be found at the Institute and Museum of Military History, Ministry of Defense, Budapest, Hungary (Jankó and Bánfi 2009), are dated to the period of the World War I (Fig. 1). The sheet descriptions are in the Romanian language but the map legends are in German. The 1:75 000 topographic series was later obsoleted by the new, 1:20 000 scale Romanian maps on the Lambert-Cholesky projection (Bartos-Elekes et al. 2007, Rus et al. 2010).

Table I. Origin of the Bonne projection in the two zones of the map system. Scale factor is unity

Zone	Latitude of projection center			Longitude of projection center		
	degrees	minutes	seconds	degrees	minutes	seconds
East	27	20	13.35	46	30	0
West	26	6	41.18	45	0	0

Cartographic details of the Romanian 1:75 000 series

The sheets were made as very simple monochrome prints. The elevations are given in meters. The relief is represented by altitude contours, which was a very modern method at the time of the map compilation. The vegetation, especially the forests are indicated by surface signs.

It is interesting that not all of the territories of Old Romania were mapped. The western parts of Moldova (not mentioning Bukovina, which was under Austrian rule), adjacent to the Translyvanian borders are not covered by the sheets (Fig. 2). In the north and the east, the map system covers the whole of Bessarabia. Although the sheet system is different from the Austrian one (Molnár and Timár 2009), the overlapping areas are indicated in the Romanian series (Fig. 3).

The map system is divided into a western and an eastern zone. Columns A-F are the western zone, Columns G-Q belong to the eastern one. The projection of Bonne was selected for both zones, with different projection parameters (Table I). The coordinate descriptions are completely different in the two zones. Grid coordinates are indicated neither in the western, nor in the eastern zone. Geographic coordinates in the eastern zone are indicated (not in all sheets), in degrees, the longitudes are given from the prime meridian of Paris. In the western zone, in the F Column, the geographic coordinates are indicated in grads (where $90° = 100^{G}$), and the longitudes are given from the prime meridian of Bucharest ($26°06'41.18''$ East of Greenwich).

The sheet size is not only different but also follows a different system between the eastern and western zones. In the east, the system is similar to the modern ones; the sheets are 40 kilometers both in north-south and east-west directions, the projection center is the NW corner of the 779 (Column L, Row VII) sheet. In the western zone, sheet boundaries follow the longitude and latitude graticule. In north-south direction, the extent of the sheets is 0.4 Grads, which is precisely 40 kilometers. Along the meridians, the sheets are 0.6 Grads wide. The exception to this is the F Column, which is wider to the east in order to fill in the area to the zone boundary. The northern boundary of the Row (Seria) IX, is at 50 Grads and the western boundary of the Column (Coloana) F is at 1.5 Grads west of Bucharest.

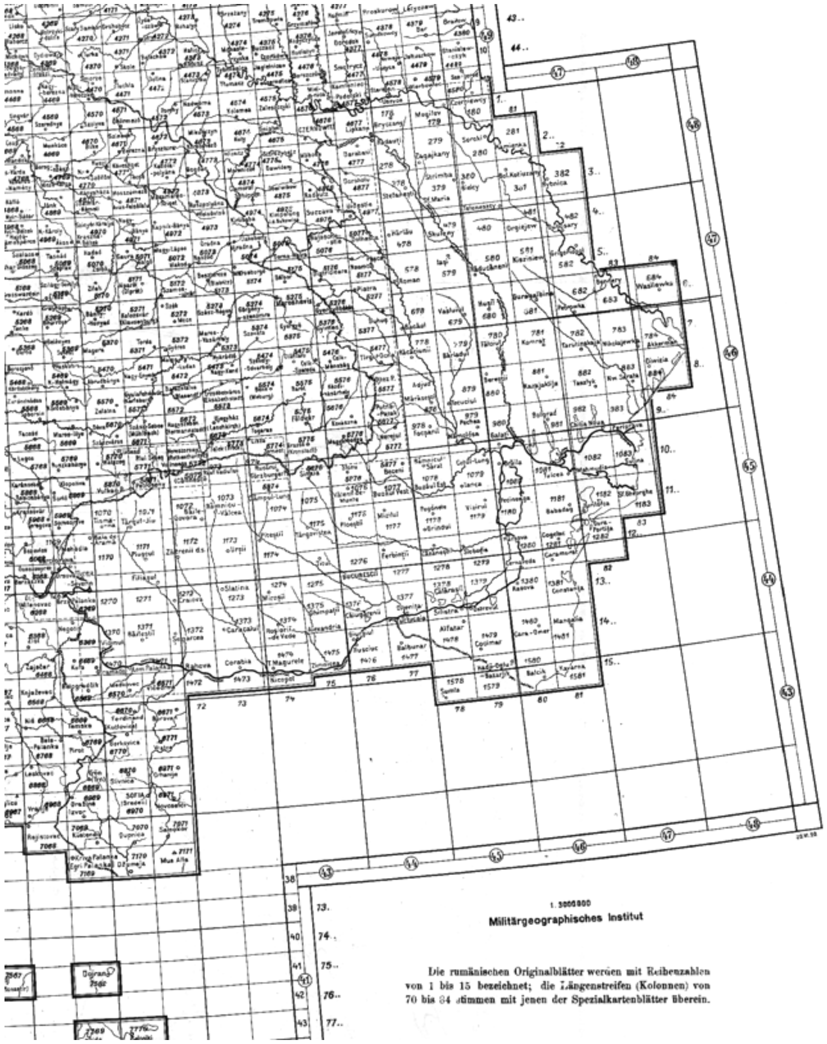

Fig. 2. The sheets system of the series, together with the system of the 1:75 000 scale Austrian series, printed to a backpage of a Romanian sheet. Note the different size and shape of the sheets in the two systems

Parameters of the geodetic datum and their accuracy

"The triangulation consisted of a net of the first order, supplemented by auxiliary nets of the second- and third-orders. In respect of the Moldavian district, the Dobrudzha, and Muntenia as far as the meridian of Zimnicea, was calculated on Bessel's ellipsoid; whereas for computing the triangulation westwards of this meridian, Clarke's ellipsoid of 1880 was employed" (Memorandum on the General State of Geodetic Work in Romania – Brief Historical Review, by General Radu Bodnârescu and Colonel Virgil Joan, translated by the U.S. Army Map Service,

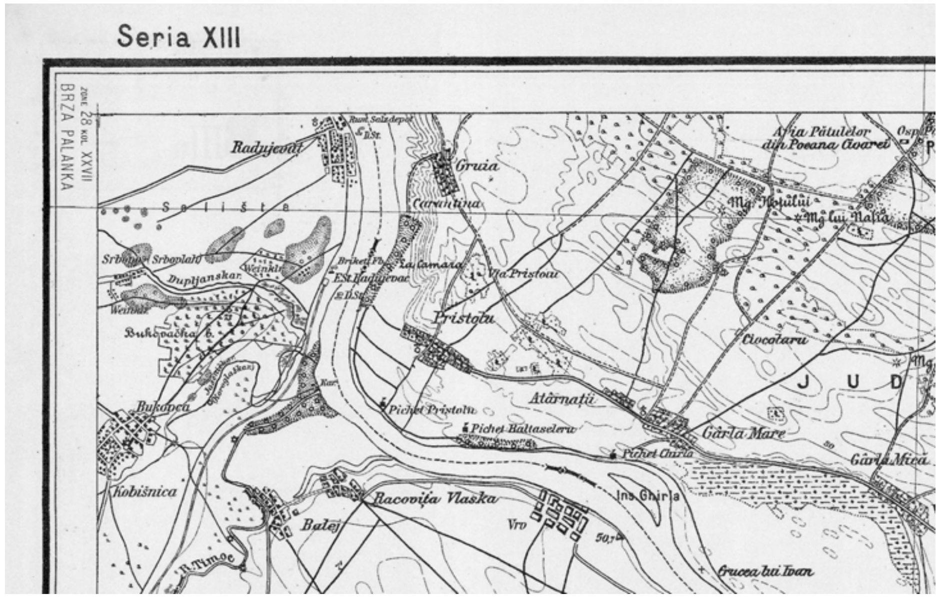

Fig. 3. Indication of an overlapping Austrian 1:75 000 sheet on a Romanian sheet (in the map frame, at the upper left corner)

Table II. The geocentric datum shift parameters in the two zones of the map system

Zone	dX m	dY m	dZ m
Eastern	+875	–119	+313
Western	+793	+364	+173

RHO/AMS Memo 318, 7 October 1960). For the earlier Habsburg survey of Romania, the Walbeck ellipsoid was used (Timár 2008). The ellipsoid of Clarke, used later for the Lambert-Cholesky series (Bartos-Elekes 2007) was introduced later. We have to mention that in case of systematic usage of any ellipsoid however incorrect, (both for the GIS definition and the determination of the datum location parameters), results in an error that is below the accuracy margin of the scale of this map series. The geocentric datum shift parameters from the local datum to the WGS84 datum were computed using control points coordinates scaled from both the old and from the modern maps, in vicinities near the zone centers. The results are shown in Table II.

The most notable difference in magnitudes of the components occurs between the dY values between the two zones. This may be attributed to the usage of different prime meridians used in the two zones (see the previous paragraph). The error of the datum difference changes from place to place and the maximum value is around 200 meters. A possible origin of this high error range can be similar to the errors of the datum of the Austrian 1:75 000 system. It might have been adjusted only partially, and again quoting from Bodnârescu and Joan, "one side of the Russian triangulation for Bessariabia was taken as the basis for calculating the Moldavian triangulation. This had been taken as far as one side of the Austrian triangulation in Bukovina. Simultaneously, i.e., in 1874, an Austrian and a Romanian officer surveyed the difference in longitude between Iaşi and Czernowitz. The triangulation work was continued southwards, without attempting to fit in with a side of the Austrian or Russian triangulation, and without measurement of a geodetic baseline". An interesting idea to handle these errors is to compute the deflections of vertical from a modern global or regional geoid model (Jekeli 1999), and to correct the base point coordinates by them (Molnár and Timár 2009).

Method of rectification

The GIS integration of the map sheets is based on their rectification; that is, the fitting of the maps to a well-defined coordinate system. The best way to do it is to fit to their own projection coordinates. So the first step is to define the two Bonne zones and their geodetic datum in the GIS software.

In case of the eastern sheets, the sheet labels bear the information for the rectification (similarly to the Austrian Second Military Survey, see e.g., Timár 2009). Knowing the position of the projection origin in the sheet system (see above) and the extent of the sheets, the sheet corners can be used as control points and the projection coordinates derived from the sheet labels. The situation is a bit complicated in the western zone. In the Columns A-E, where there are no coordinates indicated, the geographic coordinates of the sheet corners can be computed in Grads. These coordinates should then be converted to the Bonne grid coordinates for the rectification. In the sheets of Column F, coordinate grid ticks can be used as control points with their reprojected Bonne coordinates.

Reprojection to modern systems, e.g., to UTM or to Romanian Stereo-70, can be done in GIS software, by simple map-to-map reprojection.

Summary

Using the above described projection and datum parameters and methods, the sheets can be rectified with an average error of 100 meters and maximum error of 200 meters. Further improvement in horizontal accuracy can be achieved:

— locally by shifts according to one control point;

— globally by deflections of vertical derived from global or regional geoid models.

The rectified sheets, especially when they are integrated with other datasets (e.g., see Fig. 4), are suitable for analyses of the natural (Székely 2009, Brůna et al. 2010; Crăciunescu et al. 2010, Constantinescu et al. 2010) and built environment,

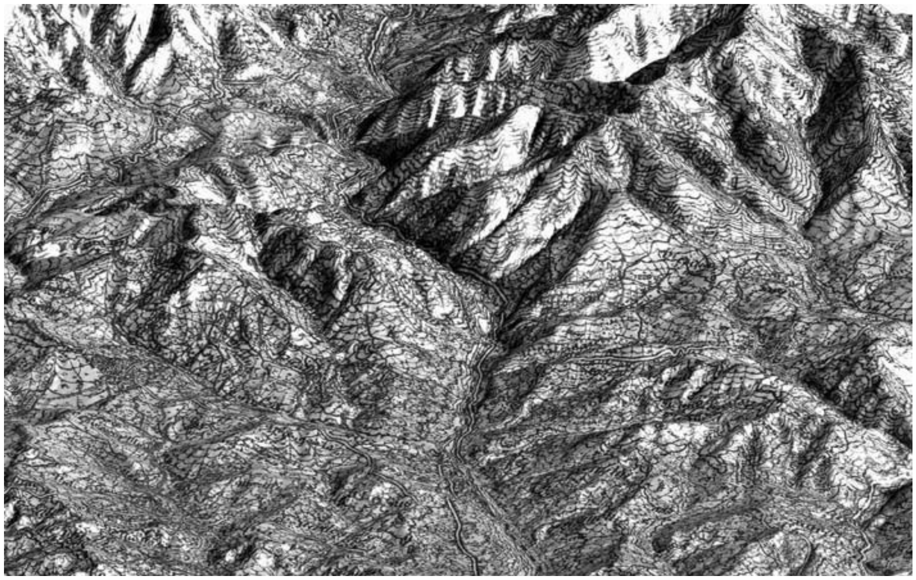

Fig. 4. Result of the rectification: 3D view of the mountain area south of Sinaia, with the railroad line between Predeal and Ploieşti; combination of the historical Romanian sheet and the SRTM elevation dataset (Farr et al. 2007)

especially for the analysis of the transportation network (Podobnikar 2010). Rectification is also a base of the mosaicked version of the map series (exportable to web-portals, see e.g., Crăciunescu et al. 2008) that provide an excellent overview of Old Romania at the very beginning of the 20th century.

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