DATUM AND PROJECTION PARAMETERS FOR THE TRANSYLVANIAN SHEETS OF THE 2ND AND 3RD MILITARY SURVEYS

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ABSTRACT
The Second Military Survey of the Habsburg Empire was carried out in Transylvania around 1860-1872. The survey had no geodetic basis; therefore the maps lacked a projection system. To rectify them with the current maps can be done only by using some landmarks. The study presents a method for rectifying these maps, the precision of the rectification being enough for GIS and cartographic purposes thus providing a useful instrument for the spatial analysis of the natural and anthropic environment of the 19th century Transylvania.
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1. INTRODUCTION

Prior to WWI, Transylvania was part of the Habsburg Empire, thus the first land surveys were carried out by the Austrian Military Geography Institute. The First Military Survey was carried out at the end of the 18th century, resulting in the production of some 1:28800 plans (Hofstätter, 1989). This survey had no geodetic basis; therefore the maps could not be seen as having a projection system. For this reason, rectify them with the current maps can be done only by using some landmarks (easily identifiable on both sets of maps).

The Second Military Survey of the Habsburg Empire was carried out in Transylvania around 1860, lasting until 1872 (Jankó, 2001). During this period, the Transylvanian administration functioned differently from that in Hungary. It is maybe for this reason that a different geodesic fundament with a different origin was applied in Transylvania than the other parts of the historical Hungary. It is also important to state that the current border between Hungary and Romania does nor correspond to the old one; the following counties: Maramureş, Satu-Mare, Bihor, Arad, Timiş şi Caraş-Severin did not belong to Transylvania, as they were still considered Partium.

The Third Military Survey was carried out on the basis of the International *Gradmessung*, in the 1880s. The coordinate system of these maps was different from the other parts of Hungary and also from the older Transylvanian surveys.

2. CARTOGRAPHIC AND GEODETIC BASIS OF THE MAPS

The triangulation network of the Second Military Survey was developed on a hybrid ellipsoid of Zach-Oriani (Bod, 1982). The origin was set to the observatory that functioned in that time North-West of Sibiu, on Hill of Vízakna (Mugnier, 2000; Varga, 2002; Kovács and Bartos-Elekes, 2007). The scale of the survey sheets was 1:28800, with a field extension of 9600 * 6400 Viennese fathoms (18206 * 12137 meters). The scale was a standard for the entire Empire (Jankó, 2001; Timár et al., 2006). The sheets situated west

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from the Sibiu meridian were considered „westliche”, and those situated eastward were „oestliche” ones. The projection system is considered as the Cassini-Soldner projection (Snyder, 1987: Varga, 2000), whose origin was set at the observatory described above, situated in the north-western corner of the plan „Section 19 oestliche Colonne I”. There is no coordinate system marked on the plans; the georeference is given by the sheet numbering and the planar extension, and by the setting of the projection origin. In Partium, both the geodetic base, the projection center and the sheet numbering was different (Timár and Molnár, 2003; Timár, 2004; Timár et al., 2004).

Between 1867 and 1918 Transylvania was part of Hungary, and for this interval a new land survey was carried out starting with 1880. Considering the large extension of Hungary in that time a special system was used for the Transylvania region called „Marosvásárhely (Târgu-Mureş) System”. The geodetic origin of the projection was the Kesztejhegy (Dl. Cîstei) Hill situated 15 km west from Târgu-Mureş. The Bessel 1841 ellipsoid was selected as reference.

In the Second Military Survey the maps were created without a projection system which could be compared with the Cassini projection, but was not identical (Varga, 2002). In case of the Third Survey, this was followed by a stereographic system, but only for those territories part of Northern Transylvania that belonged to Hungary during the Second World War. After 1935 the kilometric grid corresponding to the Târgu-Mureş system was also drawn on the border of the plans which were created without a projection system. The coordinates of the origin point are 600 000 m and 600 000 m, and the new system has a north –eastern orientation. The maps were created at a scale of 1:75 000 and 1:25 000. The plans for the Partium are created in the Budapest system and they have different parameters (Timár et al. 2003a).

In order to establish a correlation between points GPS measurements, the datum and projection parameters were computed for both systems. A check was also carried out on correlating the basic plans of the two land surveys.

3. COMPUTATION OF THE GEODETIC DATUM PARAMETERS OF THE SURVEYS

Once the GPS technology available it is possible to determine the position of the points in comparison with the mass center of the Earth (Montag et al., 1996), (Chirila and Dumitrascu 2006), thus to define Earth-centered geodetic datums. WGS84 (*World Geodetic System 1984*; DMA 1986) is such a system. In the GIS practice the local ellipsoids (with a relative position) are defined through their spatial position with respect to the WGS84 ellipsoid.

In the case of the study systems the ellipsoid coordinates of the geodetic centers were known both on the named ellipsoids, as well as on the WGS84 ellipsoid, as they were determined based on simple indirect calculus. For this reason, computing the parameters was done according to the Molodensky-type (3-parameters) transformation method. The Molodensky transform formulas are (Molodensky et al., 1960; DMA, 1990):

$$\Delta\Phi'' = \frac{-dX\sin\Phi\cos\Lambda - dY\sin\Phi\sin\Lambda + dZ\cos\Phi + (a\cdot df + f\cdot da)\sin 2\Phi)}{M\sin 1''} \quad (1)$$

$$\Delta\Lambda'' = \frac{-dX\sin\Lambda + dY\cos\Lambda}{N\cos\Phi\sin 1''} \quad (2)$$

$$\Delta h = dX\cos\Phi\cos\Lambda + dY\cos\Phi\sin\Lambda + dZ\sin\Phi + (a\cdot df + f\cdot da)\sin^2\Phi - da \quad (3)$$

where $M(\Phi) = a \frac{1-e^2}{(1-e^2 \sin^2 \Phi)^{3/2}}$ is the curvature in prime meridian;

$N(\Phi) = \frac{a}{\sqrt{1-e^2 \sin^2 \Phi}}$ is the curvature in prime vertical; ΔΦ” and ΔΛ” are the latitude and longitude differences defined between coordinates on the two datums in arc seconds; Δ*h* is the difference of the altitudes above the datums; *a* and *f* are the semimajor axis and the flattening of the original ellipsoid; *da* and *df* are their differences between the two datums. Unless the heights on the ellipsoid are known, they can be estimated by using some local or global geoid models, or formula (3) can be skipped during the calculation.

The Molodensky-type *dX*, *dY* and *dZ* parameters, expresses in meters describe the position of the ellipsoid in respect to the center of the Earth. For determining them we have transformed the coordinates of the origin point in rectangular coordinates using the following formulas:

$$X = (N+h)\cos\Phi\cos\Lambda \quad (4)$$

$$Y = (N+h)\cos\Phi\sin\Lambda \quad (5)$$

$$Z = [N(1-e^2)+h]\sin\Phi \quad (6)$$

First on the original datum and then on the WGS84 datum. After that, we calculate the differences:

$$dX = X_{WGS84} - X_{local} \quad (7)$$

$$dY = Y_{WGS84} - Y_{local} \quad (8)$$

$$dZ = Z_{WGS84} - Z_{local} \quad (9)$$

The coordinates of the basepoints on the local datums were given by Varga (2002). We could use the Gauss-Krüger coordinates of the basic points of the Pulkovo datum, of which (with the aid of the parameters published by DMA, 1990) we could determine the WGS84 coordinates. In the case of the local datum we considered the height to the ellipsoid equal with the heights to the geoid. For the WGS84, we increased the heights above the geoid with the values of the geoid undulation given by the global EGM96 geoid model (NIMA, 1997) for the given points. The results are presented in table 1.

Using this method, the small orientation difference between the local and WGS84 datums is not taken into account. Such simplification for a territory of Transylvania results an error of maximum 25 meters in the case of the second and maximum 10 meters in the case of the third survey.

The computed parameters were tested in practice: we correlated the sheets of the surveys with the current maps on global basis. For the Vízakna datum we noticed a constant deviation of 40 m which although it can be corrected manually, by assuming an unsuitable placement of the basic points then and now we could define the parameters which eliminate the error. (Vízakna corrected, cf. Kovács and Bartos-Elekes, 2007).

Table 1

Datum	Vízakna	corrected Vízakna	Kesztejhegy	Pulkovo 1942 (Romania)
dX (m)	1722	1734	604	27
dY (m)	376	399	-143	-121
dZ (m)	595	595	528	-78
ellipsoid	Zach-Oriani	Zach-Oriani	Bessel 1841	Krasovsky 1940
a (m)	6376130	6376130	6377397.155	6378245
b (m)	6355562.258	6355562.258	6356078.963	6356863.019

The Molodensky-type transformation parameters between the old Transylvanian datums and the WGS 84.

It is worth mentioning that although defined on the same ellipsoids, the translation parameters for the Kesztejhegy and the Hungarian Gellérthegy (+571 m; -174 m; +572 m; Timár et al. 2003a) systems are slightly different. The cause for this value can be the fact that the triangulation systems used were created and compensated on different territories.

4. THE PROJECTION PARAMETERS OF THE MAPS

The Transylvanian plans of the second land survey:

The type of projection: Cassini. This is just an aproximative projection, but the recording error of mostly 10 m is enough in the case of GIS applications.

- Reference ellipsoid: Zach-Oriani
- Point of origin in respect to the surface of reference (Marek, 1875):

Φ=45° 50’ 25.13”

Λ=24° 6’ 46.69”

(The above values in the case of longitude were initially give for the meridian of origin Ferro. The Ferro-Greenwich difference was considered of 17° 39’ 46.02”).

Due to the fact that no coordinates are given on the plan, we are free to define the point of origin. A simple solution would be to consider it zero. In practice georeferencing the plans is done in the following stages:

- defining the datum and projection parameters in the GIS software;
- computing the Cassini coordinates for the corners of the studied plan by using its extension in the field and also its system;
- defining the corners point by point using the coordinates calculated in point 2.;
- transforming the first plan in Casini then in any other projection;
- if necessary, for correcting the possible errors, the content of the map can be manually moved without rotation with the aid of a single landmark.

The Marosvásárhely (Târgu-Mureş) System

The type of projection: stereographic oblique (*„oblique”* or *„extended” Stereographic*)

- Reference ellipsoid: Bessel 1841
- Point of origin on the reference ellipsoid (Fasching, 1909):

Φ=46° 33’ 8.85”

Λ=24° 23’ 34.935”

The translation values of the origin:

False Eastings =False Northings=600000 meters

Conversion factor =1.0

In the case of this system for integration in GIS systems we skipped the double projection (projection from the ellipsoid to the aposphere then to the plane). The resulted error is in the order of centimeters which is negligible in comparison with the error of the datum definition.

5. **RESULTS**

The result of the georeference of the maps is illustrated in Figure 1. This figure represents Cluj city in the Second Military Survey (Section 10 westliche Colonne III), a sheet that was converted to UTM, and a three-dimensional image of it was achieved with the use of SRTM (Timár *et al.*, 2003b) elevation dataset. Another example in presented on the color cover: the same territory is presented in a correlated manner – with green the second survey and in black the third survey. It can be noticed on one hand the precision of the correlation inside the city, on the other hand the changes in the meanders of Someşului Mic (Kis Szamos) River in the interval of 30 years between the two surveys. The precision of the rectification is enough for GIS and cartographic purposes thus providing a useful instrument for the spatial analysis of the natural and anthropic environment of the 19th century Transylvania.

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