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Danger doesn't vanish with the dikes: Comparison of the inundation pattern of the 2006 Danube floods and the historical topographic map of 1864 of South Romania

Keywords: Danube Floods; Szatmáry; 1864, 2006; georeference; inundation map

Summary: Some sheets of the 1864 topographic map of South Romania were geo-referenced in order to be co-analyzed with satellite-based 2006 flood inundation map of the Bechet area (Dolj County, Romania). The rectification was based on the corners of the old map sheets as control points, using the previously gathered metadata (geodetic datum and map projection parameters, map sheet structure and labelling) of the historical cartographic material. The horizontal accuracy of the geo-reference of the old map was well below the pixel size of the MODIS imagery. The historical map reveals that a considerable part of the croplands along the Danube River was a regularly inundated area and the result gave a hint that an old village was forced to move to a new place after 1864 because of the floods.

Introduction

All maps contain a huge amount of information about the natural and artificial environment of the shown area. This statement is valid at all maps, drawn anytime. If we aim to incorporate this information into a modern GIS database, we shall be able to follow two different steps:

- decode the legend of the map, with respect to our goals of database compilation, and
- rectify correctly the map into the selected, common coordinate system of our GIS database.

In case of historical maps, both steps assume a lot of *a priori* knowledge. The interpretation of the map legends seems to be the less difficult exercise. The legend is often given with the map, the only complication is that the real terrain is much more complex than it is shown on the map, and sometimes the legend items are in contradiction with each other (e.g. is a swamp-forest a swamp or a forest? – in military maps of the infantry warfare time, till the end of the 19th century it is shown as swamp, as impenetrable by infantry).

The interpretation of the old coordinates, or, in more practical terms, the geo-reference of the old map is a more exact exercise – however, if we want to accomplish it with good accuracy, it needs a lot of metadata before starting (Zlinszky & Timár 2013). If the task is done, the result is sometimes striking, showing that the nature – e.g. during floods – follows hidden, 'secret' ways, which can be revealed by information of really old maps (Timár & al. 2008a; Székely 2009).

In the present paper, we aim to show an example – how can the 1864 topographic map of Southern Romania predict the flood inundation pattern of 2006, almost one and a half centuries later, along the Romanian Danube.

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Meteo-hydrological situation of the 2006 Danube flood

The 2006 spring flood on the Danube River was a classic snowmelt one. The amount of water, stored in snow on the catchment reached a historical maximum at mid-February. At the catchment belonging to the Budapest gauge – mainly in the core mountains of the Eastern Alps – this amount of water reached the 20 km^3, raising the danger of an elongated, big flood. The snowmelt occurred in two steps, first below the elevation of 500–800 meters, then up to 2000 meters. Historical gauge maximums occur in the middle and lower sections of the river. The most catastrophic dyke ruptures occurred in Romania, causing inundation of some 100 square kilometres in the southern part of the country.

The Romanian authorities followed the inundation pattern. When the clouds did not cover the area, the MODIS satellite images (Salomonson et al. 1989) provided the best solution of mapping the flood extents; its 250-meter horizontal resolution, coupled with the daily return interval gives a good data resolution both in space and time. Inundation maps were derived from the satellite imagery (INHM 2006; Crăciunescu et al. 2010). Satellite images can be combined with historical maps, bearing additional data of the paleo-environment of the area (Timár et al., 2008a). Here we show an example of the coupling of the old topographic map and the 2006 inundation pattern. This work was made earlier by Crăciunescu et al. (2010), combining the flood data with the 1916–59 topographic series of Romania. Now, we step forward to the past, to do the same combination with an earlier, 1864 map of South Romania.

The historical dataset: the 1864 „Szatmári” map

The historical background of the investigated old map set is quite interesting. It was originated in the Crimean War of 1854–56 between Russia and the anti-Russian coalition: Turkey, Britain, France and Piedmont, almost a decade earlier that its issue date. Before the war – and according to the international law and treaties, formally even after that, up to 1870 – the region of Wallachia, the present Oltenia and Muntenia, forming Southern Romania was under Ottoman rule. However, it was a primary direction of the Russian territorial ambitions, as it was used as Russian base during the failed Hungarian Independence War in 1849 as well as later in 1878 against again the Turks. To avoid its Russian occupation, the troops of the Habsburg Monarchy occupied Wallachia and kept occupied during the war (Timár & Mugnier 2010).

During this operation, the mapping capacity of the Habsburg Empire was concentrated in Wallachia, thus slowed the still ongoing Second Military Survey (Kretschmer et al. 2004; Timár 2006; Jankó 2007). The whole Wallachia was surveyed; geodetic points were set up, first astronomically determined ones along frame lines following the Danube, the Jiu, the Olt and the Ialomița Rivers, then triangulated ones from the first point set (Kovács & Timár 2010). The resulted point set is stored in manuscript in the Austrian Military Archive (Österreichsche Staatsarchiv, Kriegsarchiv), Vienna. According to this document (MGI 1859), the geodetic network was derived from the already started – but not yet finished – Transylvanian part of the Second Military Survey, using this fundamental point, the former contemporary observatory of Hermannstadt / Dealul Sibiului (Timár & al. 2008b) as a base point as well as the base line of St. Anna near Arad. A new fundamental point was set up at Movila David near Slobozia, Eastern Wallachia during the operation, as well as a new baseline south of it.

Upon this geodetic basis, a new map series was compiled by the Austrian mapping authorities about the region, between 1856 and 1858. Its scale was 1:57,600, which is the half of the scale of the Second Military Survey, however the cartographic style is obviously the same. The sheet structure follows the one of the second survey of Transylvania; the meridian dividing the western (’westliche’) sections from the eastern (’oestliche’) ones lies through the Hermannstadt observatory site, which is also an imaginary sheet corner, however it lies out of the mapped area.

According to our research (Bartos-Elekes et al., 2013), the Szatmári map was compiled as a replica of the Austrian map. Its sheet system, thus the geodetic and projection parameters are the same. The cartographic style is dominantly different, which does not mean that the original terrain accuracy was retained. The texts, that were dominantly in German and partially in Romanian in the original Austrian maps, were all translated to Romanian, and so was the map legend.

GIS integration of the data: from old maps to satellite images

To integrate any digital map into a GIS database, a coordinate system should be defined. The most convenient way, which avoids any systematic distortion, is to define the native coordinate – projection – system of the map. If it is done, we still need ground control points (GCPs) to fit the map content to the coordinate system.

The projection system can be given by two parameter sets and a projection type. One parameter set describes the geodetic datum (the base ellipsoid and its location in the three-dimensional space), while the other one realizes the projection, giving its necessary parameters, according to the projection type.

The coordinate system of the used historical map series is – similarly to the original Habsburg Second Military Survey datasets – the Cassini, or Cassini-Soldner projection. Its geodetic datum is interpreted on the Walbeck 1821 ellipsoid (MGI 1859), however using the datum of the Transylvanian survey with the Zach-Oriani hybrid ellipsoid is also a good solution, causing no detectable horizontal error. The projection center, to be given for the Cassini projection, is the Hermannstadt observatory. We shall handle, however, its coordinates systematically: using the Transylvanian Zach-Oriani datum with the coordinates of the observatory – as the projection center – in this very datum (Timár et al. 2006), or choose the Walbeck one with the different observatory coordinates, given in (MGI 1859). The map sheets are of the same size. They all cover the territory of 19,200 * 12,800 Viennese fathoms (36,412.5 * 24275 meters). The sheet boundaries follow the lines parallel to the coordinate axes of the given Cassini grid.

The most basic way to define GCPs is to seek identical points that can be identified both in the old map sheets and in modern ones, thus having coordinates in a modern grid. This procedure, however, has two main hindrances. First, it is not systematic, providing a lot of GCPs in built-in regions, especially in the towns and sometimes giving none in the lands between them. Second, if we use GCPs that are not in the native projection of the old map, it causes a systematic error; the bigger the terrain extents of the rectified sheet, the higher this systematic error is. Moreover, neighbouring sheets, rectified this way, are seldom fit at their boundaries and keeping them fitting requires difficult mathematics (Molnár 2010).

Instead of this, we can use sheet corner as GCPs, if the sheet system is well known and follow the grid lines of the projected coordinate system. However there are no coordinates given neither in the Austrian nor in the Szatmári versions of this topographic map, we know the positions of all sheet corners, according to the information discussed in the above paragraphs. All we need to do is to give the sheet that has the Hermannstadt observatory (the projection center with zero coordinates both to East and North) in the NW corner. Afterwards, the map sheet labels bear the georeference, giving how many steps are to be taken in east-western and north-southern directions to reach the GCP in a sheet corner and multiply the number of sheet steps by 36,412.5 meters in EW and 24275 meters in NS direction. These coordinates are defined in the native coordinate system of the topographic maps, thus avoiding the above mentioned error of the incorrect projection use. In practice, we use a map reading accuracy of 0.5 millimeters in the map. At a map with a scale of 1:57,600 half map millimeters refers to 28.8 meters on the field, so a theoretical horizontal accuracy that is better than 25–30 meters is well acceptable. The resulting horizontal accuracy is influenced by different error sources:

- The errors of the original survey (according to our results, these errors are far lower than 25–30 meters);
- The errors of the local surveys, in the area between the well-defined geodetic base points;
- The errors of the map drawing, and – in case of hand-drawn replica – the error of the copy;
- Folding and drying of the paper, and;
- Scanning errors.

In the present case, the errors of the local surveys and the paper should be acknowledged as the main sources. Especially the local survey can cause errors up to 130 meters – within one sheet. This can be handled by a solution using GSB or correction grid technology (Molnár & Timár 2011), however this is not yet applied to the discussed dataset.

The inundated area in the historical map

As an example we show a part of the Bechet-Corabia embayment of the Danube. Both the old map sheets and the satellite images reveal the obvious fact that the Danube River had a few-kilometre wide low floodplain in this area, bordered by an escarpment in the north. Before the flood control works and dyke constructions, this area was a water labyrinth with several reaches. Most of the low floodplain was regularly inundated (Fig. 1) – in the old map, it is shown by horizontal blue lines in the white regions, which refer to croplands. The new dykes are built along the Danube banks, trying to keep the old floodplain ’dry’ for agriculture.

Figure 1: The plan-draw of the old map mosaic (black) over the 2006 satellite interpretation map. The accuracy of the fitting is acceptable.

Interestingly enough, the 2006 inundation pattern covers some low mounds, that were shown in the old maps, and the old village of Pichettu is right in an inundation pond. This old village is now a part of the small town of Bechet, which is clearly built after the flood control works, in geometrical order – on the higher, not endangered terrain. Only its southern part, the old Pichettu was flooded in 2006. This shows that the 2006 flood was an extreme one (the old villages were seldom built in dangerous zones), or the downstream dykes and battlements banked up the water high enough to inundate an old settlement zone (Figs 2a & 2b).

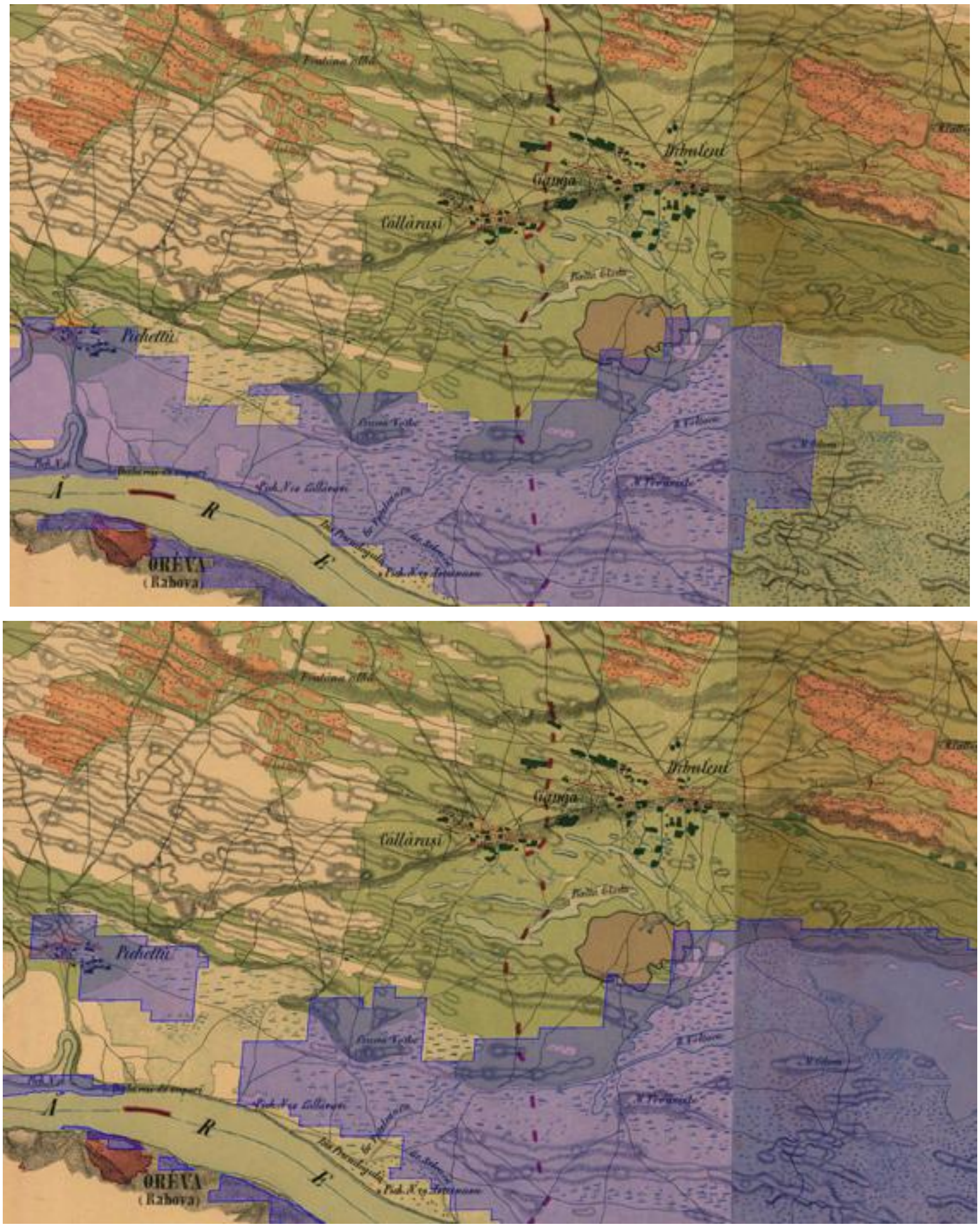

Figure 2: The 2006 flood inundation pattern on the 1864 historical map mosaic near Bechet. Note that the Danube did not reach all of the low floodplain. The extents of Figs. 1 & 2 are the same. (a) Inundation pattern of 27 April, 2006: the area on the west is inundated partly because of the banking up of a perpendicular dyke on the east, just giving through the water (b) Inundation pattern of 13 May, 2006: the old village site of Pichettu is still in an inundation pond, after the main water body left the area.

Fortunately, the ’common, community knowledge’ of the Danube floodplain is strong enough and we don’t see too many newly built objects in the low area – a much more fortunate case that the Tisza floodplain in Hungary (Timár & Rácz 2002).

Conclusions

Knowing the correct geodetic and cartographic metadata (the parameters of the geodetic datum and the projection, as well as the sheet structure) of an old map, the geo-reference can be accomplished with acceptable accuracy in a quite easy way, selecting only the sheet corners as control points. In case of the mid-19th century surveys, the main source of map distortions is the lower accuracy of the local, low-level mapping works.

When the geo-reference is accomplished, the information content of the old map can be integrated into a GIS database as a layer, to be co-analyzed with very different datasets, such as radar/lidar-based elevation and – in our very case – satellite imagery. They reveal the history and original status of the parts of the ’uniform’ croplands; we can build dykes but when they rupture because of the extreme flood, nature takes over what it owned before.

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