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SYSTEM OF THE 1:28 800 SCALE SHEETS OF THE SECOND MILITARY SURVEY IN TYROL AND SALZBURG

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The Second Military Survey of the Habsburg Empire (Franziszeische Landesaufnahme) was based on the first triangulation net of the Empire, ordered by Emperor Francis I in 1806. Eight horizontal control points were later used as projection centers for the different parts of the Empire. However, two provinces, mapped in the very early phase of the survey, have no real terrain objects as projection centers. In spite of the earlier literature items, mainly concerning the cadastral systems, the map sheet systems of the Second Military Survey of Tyrol and Salzburg do not follow the Soldner-Cassini projections centered at Innsbruck and Gusterberg, respectively. Indeed, the design of these sheets is similar to the one of the First Military Survey in cartographic point of view also with respect to their projection. The systems of the 1:28 800 sheets in these provinces are not centered at Vienna (St. Stephen) or Gusterberg as it was indicated in the literature. Projection analysis shows that for these provinces a unified sheet system was introduced. It can be connected to an Innsbruck-Pfarrturm-centered Cassini projection but the projection center is not at any distinct point (sheet center, corner or boundary halving point) of the sheet system. This Cassini projection, however, is not suitable for precise georeferencing of the sheets of Tyrol and Salzburg as it results errors up to one kilometer. The map sheets of these provinces can be rectified using quadratic formulae with remnant errors of maximum 220 meters (Tyrol) and 500 meters (Salzburg), which are much higher values than the fitting accuracy of the sheets in other parts of the Empire. According to the analysis, Liechtenstein is also without definite projection center but it is covered by only one extended sheet and its rectification can be done with an accuracy of 30 meters.

Keywords: Habsburg Empire; historical topographic maps; map projection; Salzburg; Second Military Survey; Tyrol

Introduction

The Second Military Survey is a masterpiece of the map tile series representing the territory of Austro-Hungarian Empire up to the 1860s. It is outstanding in quality regarding its data content, cartographic design and aesthetic appearance. Although the series is not uniform in its content and in its implementation due to the extended period of time of the mapping (1806–1869), according to recent experience in its present-day usage, its map sheets are fairly well applicable even today.

For a long time, the original map sheets treasured in the Austrian state archives (Military Archive) were only available for the closed group of professionals of military cartography and history. The excellent geodetic base of the map (Hofstätter 1989, Kretschmer et al. 2004) made possible to compare the recent and former topographic features in specific study areas with acceptable accuracy (e.g. Boltižiar et al. 2008).

Partly preceding its publication, but primarily after the appearance of the digital version of the maps (Timár et al. 2006), the users became interested to have the digital images in georeferenced format, i.e., rectified in present-day coordinate systems. Concerning several selected map sheets, numerous attempts of georeferencing were developed by various institutions. The rather varying results and accuracy of these attempts, depending on the demands and expertise of the specialists performing the rectification, demonstrated the imminent need of a uniform georeferencing solution, that is geodetically correct, takes the geodetic basis of the map system into account, and which generally minimizes the errors of rectification. As a result of our previous studies (Timár et al. 2006), the complete set of map projection and geodetic datum parameters of the Second Military Survey, used in the different provinces, are computed.

The triangulation system of the Second Military Survey offers a geodetic basis also for the early cadastral works of the Empire (Marek 1875, Hofstätter 1989). In case of most provinces, the cadastral and topographic surveys used the same projection center (see e.g. Maślanka, without date). However, in case of Tyrol and Salzburg, the situation is different. In the cadastral system, Salzburg (cadastral survey: 1823–1830) belongs to the Gusterberg-centered projection zone, similarly to Upper Austria and Bohemia (Marek 1875, Hofstätter 1989). Tyrol has its own cadastral projection system (cadastral survey: 1855–1861), centered at the Pfarrturm in Innsbruck (Marek 1875, Buffoni et al. 2003, Mugnier 2004, Kretschmer et al. 2004).

In a key publication about the Second Military Survey (Hofstätter 1989), it is indicated that in Tyrol and Salzburg, the framework of the 1:28 800 scale sheets are Vienna-centered, providing a contiguous system from Lower Austria (and even Hungary) to Vorarlberg (Fig. 1). As the original survey sheets were scanned and georeferenced in a project of a Hungarian company Arcanum, this statement proved to be false. In the present work, the author provides the correct description of the sheet system of these provinces and the way to georeference them.

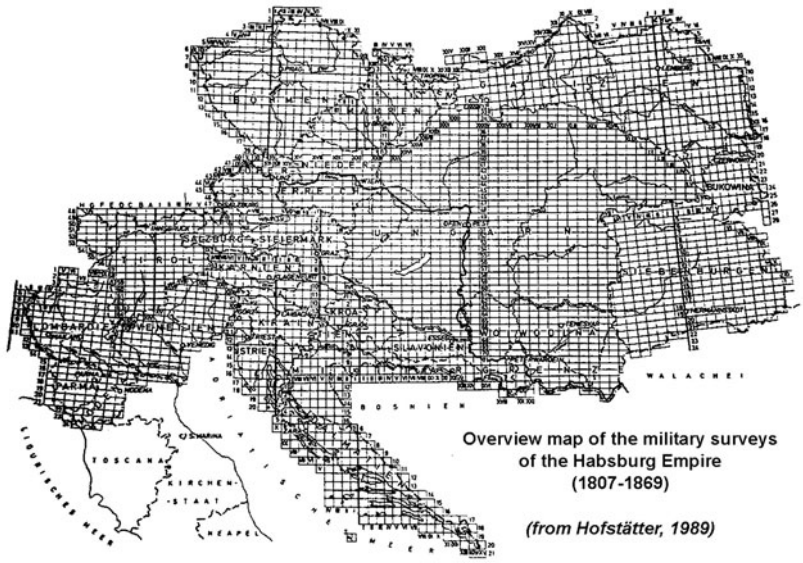

Fig. 1. The sheet system of the whole Second Military Survey of the Habsburg Empire (Hofstätter 1989). It indicates that the Vienna-centered system is valid even in Tyrol and Salzburg. As it is described here, this is incorrect

To make this description more reliable, it is worth to have a look on the history of Tyrol and Salzburg prior to the Second Military Survey. It is important that these provinces were not mapped in the First Military Survey (1763–1787) — Tyrol was was covered by the Atlas Tyrolensis (20 sheets from 1774; Kretschmer et al. 2004) and Salzburg was not even a part of the Empire until 1805. Emperor Francis I ordered the Second Military Survey in 1806 (Hofstätter 1989, Kretschmer et al. 2004). Salzburg was the first province mapped in this surveying campaign, in 1807–1808 but Tyrol followed it in only after the Napoleonic occupation (Kretschmer et al. 2004, Jankó 2007). The early compilation explains why the map symbol pattern of the Second Military Survey in Tyrol and Salzburg is similar to rather the First Survey in other parts of the Empire (Fig. 2).

The scanned sheets of Tyrol and Salzburg

The original, hand drawn color sheets of the Second Military Survey are archived at the Austrian State Archive, Military Archive (Österreichisches Staatsarchiv, Kriegsarchiv) Vienna. All of the available map sheets were systematically scanned by the Hungarian firm Arcanum in 2006, according to an agreement between this company and the Austrian State Archive. Although they have not been published, as a chief advisor of the georeferencing work the author had a full access to this material for scientific purposes, especially for developing the georeferencing procedures of the Second Military Survey.

There are 148 sheets of the 1:28 800 maps covering Tyrol and 68 ones covering Salzburg. The frame descriptions are similar to the other provinces of the Second

Fig. 2. Maps of the First Military Survey of Vienna (a); the Second Military Survey of Innsbruck (b) and Graz (c). Note that the texture of the cities are similar at the cases of (a) and (b) and different in (c). It indicates that the Second Survey in Tyrol was rather a transition from technology and design of the First Survey to the Second one

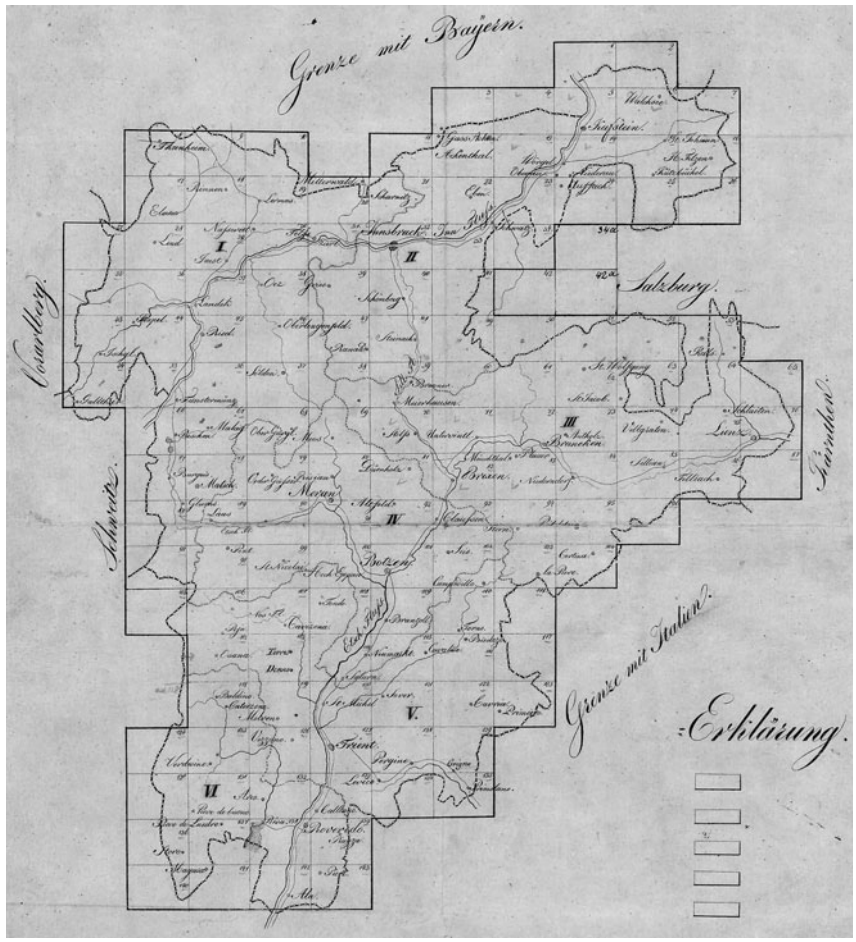

Fig. 3. The overview map of the 1:28 800 scale sheets of the Second Military Survey in the province Tyrol

Military Survey. However, the sheet numbering is different; instead of indication al columns and rows, each sheet has a unique identification number (Figs 3 and 4). The Salzburg sheets show also the Rupertigau, which is west of the Inn River. This area, now Part of Bavaria (Germany), was Part of the Salzburg province during the mapping campaign.

Sheet mosaics were compiled for each provinces of the Empire; the frames were cropped and the map content of each sheet was rectified using the four corner points (Veverka and Čechurová 2003, Timár 2004, Veverka 2005, Timár et al. 2006). In case of all other provinces, this process also provided the geodetic framework, as the coordinates of the sheet corners were known in the Cassini projection zone valid in the given province (Timár 2004, Timár et al. 2006). The mosaic of Tyrol and Salzburg was georeferenced after tiling. Around 50 ground control points (GCPs)

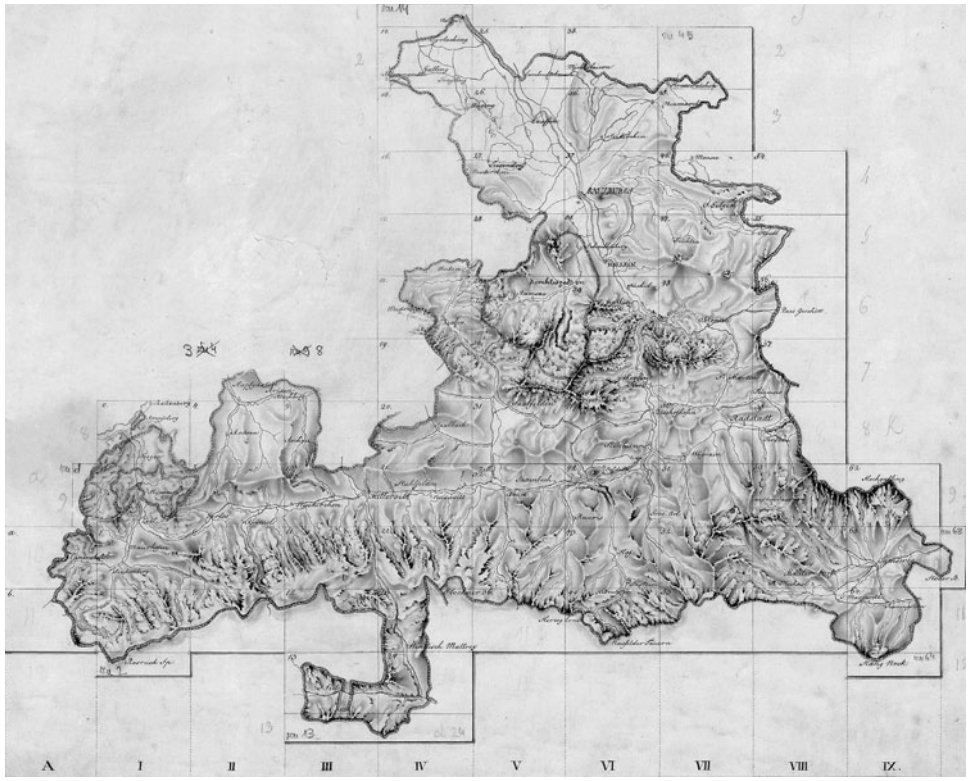

Fig. 4. The overview map of the 1:28 800 scale sheets of the Second Military Survey in the province Salzburg

were defined throughout each province by their image pixel coordinates and projected coordinates in UTM systems (UTM Zone 32 for Tyrol, Zone 33 for Salzburg). Parameters of the following quadratic formulae were estimated:

$$\begin{aligned} E &= a_0 + a_1 \cdot x + a_2 \cdot y + a_3 \cdot x^2 + a_4 \cdot x \cdot y + a_5 \cdot y^2 \\ N &= b_0 + b_1 \cdot x + b_2 \cdot y + b_3 \cdot x^2 + b_4 \cdot x \cdot y + b_5 \cdot y^2 \end{aligned} \quad , \tag{1}$$

where E and N are easting and northing values of any point of the mosaic in the UTM plane, x and y are the image pixel coordinates (column and row number) of the same point in the sheet mosaic. $a_{0\ldots5}$ and $b_{0\ldots5}$ are the 12 parameters of the quadratic transformation; a_0 and b_0 are obviously the UTM coordinates of the upper left corner of the image mosaic. The accuracy of this rectification is worse than the one used at the other provinces. The maximum error of 500 meters occurs in Salzburg at the upper Salzach valley. The maximum error in Tyrol is around 220 meters at the Trient/Trento area. The average accuracy is around 100 meters in both regions. Here the author has to mention that these figures are much smaller than the similar rectifying errors of the different provinces in the First Military Survey (1–4 kilometers).

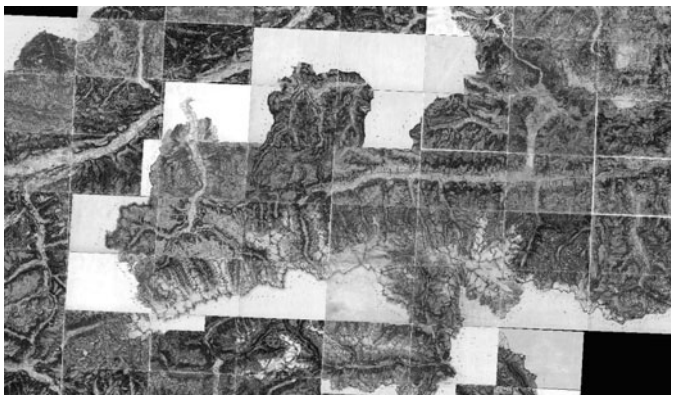

Fig. 5. The georeferenced border sheets in the border region of Tyrol and Salzburg refer to a unified sheet system of the two regions

Analysis of the sheet tiling system of Tyrol and Salzburg

This georeference makes possible to overlap the mosaic and any theoretic grid frame system, and also the mosaics to each other. The first observation is that the sheet system of Tyrol and Salzburg is more or less the same one, with accuracy better than half a kilometer (Fig. 5).

Overlapping the unified Tyrol-Salzburg mosaic and the theoretical frame system of the Vienna-centered Cassini zone (Fig. 6) it is obvious that these provinces have a different projection. It can also be detected at the frontier between Salzburg and Upper Austria. Moreover, in Fig. 6 the Tyrol-Salzburg georeferenced mosaic is reprojected to an Innsbruck-Pfarrturm-centered Cassini grid. In this system, the sheet boundaries are almost horizontal and vertical lines, indicating that both of the regions have this projection center.

A question arises immediately about it: what is the accuracy of this assumed projection? If it is better than the above described quadratic method, it makes the georeferencing of the individual sheets very simple. In this case the only thing we have to know is the position of the projection center in the sheet system, namely in what sheet it is and what is its position inside that sheet? In case of the other provinces, the projection center is at the center of a sheet (e.g. the Vienna – Stephansdom) or at a corner of four sheets (as the Krimberg, the observatory at Hermannstadt, the Lövenburg and Ivanić), or in a halving point of a sheet boundary (e.g. the Schöcklberg and the Gusterberg). The only exception is the Duomo San Salvatore, Milano, the projection center of the zone of Lombardy, anyway, its shift from the sheet corners can be expressed in round numbers in Viennese fathoms, the length unit used in the survey.

The situation of the Innsbruck-Pfarrturm is different. It is in the Section 32 of Tyrol, slightly southwest of the sheet center but the shift cannot be expressed in round numbers. Using this center and the known extent of the sheets (Hofstätter 1989, Kretschmer et al. 2004), Cassini-coordinates of all sheet corners can be computed and use them as virtual control points for the rectification. A quick check

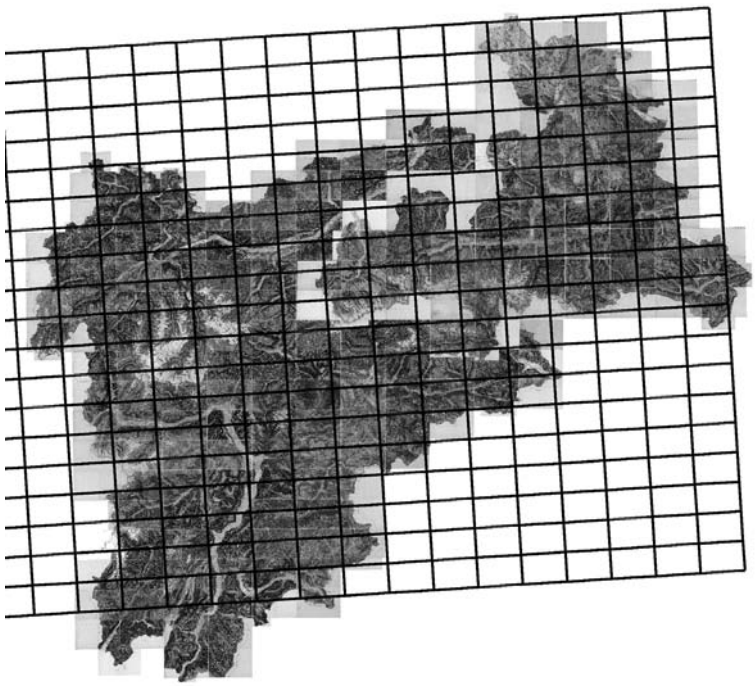

Fig. 6. The theoretical sheet boundaries of the Vienna-centered system (black lines) differ from the real sheet structure of Tyrol and Salzburg. Moreover, as the mosaic here is in Innsbruck-centered Cassini system and the real sheet boundaries are almost horizontal and vertical lines, they indicate that this can be a 'quasi-projection' of these sheets (see text)

at the southern edge of Tyrol shows an error on approx. one kilometer. This is considerably worse than the accuracy provided by the quadratic formula.

The archived documents of the military triangulations of Tyrol (Potier and Kielmann 1817), however, offer some hint to find the real geodetic network used in Tyrol. Figure 7 shows an interesting description of the not specified control point of 'Innsbruck'. First, it shows that this point is 1571 fathoms (almost 3 kilometers) west of the meridian of the fundamental point. Moreover, according to the description, the coordinates of this point are given with respect to a virtual point ('Abstand vom fingirten Merid.' = position with respect to a simulated meridian). The nothings value of this point is also given to a virtual center (fundamental point), which is 327 thousand fathoms (cca. 620 kilometers) north of Innsbruck.

The geodetic datum is another issue of this analysis. Using the coordinates of the Pfarrturm-Innsbruck used in the Second Military Survey ($\Phi = 47°16'14.1''$; $\Lambda = 29°3'25.9''$ from Ferro; Marek 1875) and the modern ones (Mugnier 2004, also readable from Google Earth) and taking the geoid undulation (NIMA 1997) into account, the following Molodensky-type shift parameters were used for the Zach-Oriani ellipsoid:

$$dX = +1756 \text{ m}; \quad dY = +354 \text{ m}; \quad dZ = +544 \text{ m}.$$

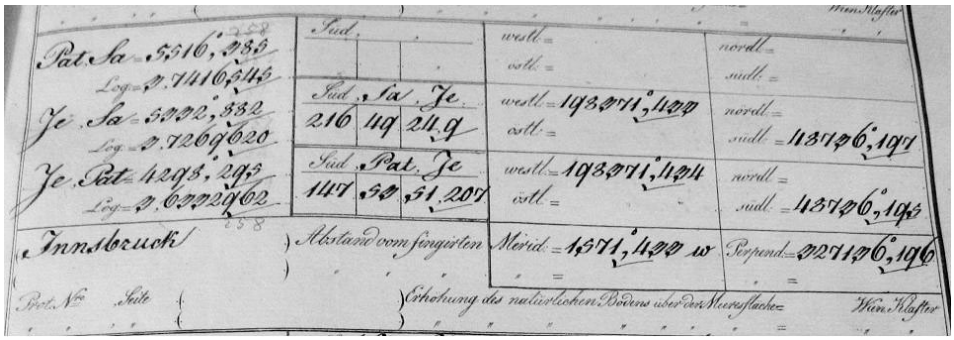

Fig. 7. The Cassini-type coordinates of the unspecified point of 'Innsbruck' are given with respect to a virtual (simulated) meridian and fundamental point ('Abstand vom fingirten Merid. und Perpend')

Conclusions

Analyzing the map sheet structures of the Second Military Survey in case of the provinces Tyrol and Salzburg, I made the following observations:

1. In spite of the map of Hofstätter (1989), the sheet system of these regions is not identical at all to the Vienna-centered one.

2. The sheet system of Tyrol and Salzburg can be interpreted as a unified one with an error of a few hundred meters.

3. According to archive triangulation documents, the Cassini-coordinates of the geodetic control points are defined with respect to a simulated fundamental point far north of Austria and a prime meridian near Innsbruck.

The georeference of the sheet mosaics of the regions can be made by a quadratic formula directly between the image coordinates and the projected ones on a selected map grid system, e.g. the UTM. The error of this method is around one hundred meters but extreme high values occur in Südtirol (approx. 220 meters) and at the upper Salzach valley (almost 500 meters).

As a conclusion in terms of the history of cartography, the author would characterize the sheets of the Tyrol and Salzburg as designed between the First and Second Military Surveys. It is true both from point of view of the map symbol system but also of the accuracy of the geodetic base. The rectification errors indicate a real transition between the accuracy of the First Survey (1–4 kilometers) and the Second one in the other provinces (around 50 meters). Based on the above statements the author suggests to refer these systems to as 'Survey Number One and a Half'.

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