

Gábor Timár¹, Előd Biszak²

Projection analysis and georeference of Russian Shubert's „3-verst” topographic maps (late 1800s)

Keywords: Shubert map, three-verst maps, Russia, historical topographic maps, georeferenced, Cassini projection

Summary

The historical medium-scale topographic map series of Russia (Shubert's 3-verst; 1:126,000 scale) series is analyzed, in order to make a geo-referenced mosaic to the MAPIRE map portal. Analyzing the geographic latitude and longitude lines, it is confirmed that the projection center is at the Pulkovo Observatory, near St. Petersburg. Digitizing around a hundred of ground control points, we analyzed the two concurrent projection types with this center, found in the literature: the Bonne and the Cassini. According to our analysis, the Cassini projection offers a much more precise mathematic model for the coordinate system of the map. Applying this, the geo-reference is suitable for the standards of MAPIRE.

Introduction

The Shubert map series covers the western part of the European Russia from the second part of the 19th century. The mapped area is the present-day Russia cca. west from the Volga River, with the notable exception of the Moscow region, Ukraine, Belorussia, the Baltic states, Moldavia and the Russian part of the historical Poland, more or less the central region of the present-day Poland. Of course, the mapped area is not extended to East Prussia, the present-day Kaliningrad enclave and the Polish Mazuria, which were parts of Germany. Besides, Russian topographic activity is known in the present-day Finland, which were an autonomous part of Russia between Napoleon and the WWI, however the analyzed 1:126,000 series covers just the northern foreland of St. Petersburg, more or less to the Russian-Finnish border drawn between the two WWs.

The name of the series refers to the author and initiator, Shubert, Fedor Fedorovich (1789-1865). He organized the survey of Russia in different scale topographic maps. Smallest scale product is referred to as 'ten-verst map', while the largest scale on is as 'half-verst map'. Since 'verst' is an obsoleted Russian length unit, a kind of 'mile' (1066.78 meters), and these scales expressed the ratio between the Russian inch and the 'verst', in decimal format of the 'ten-verst' maps is 1:420,000 and the 'half-verst' one is 1:21,000. In between of these extreme small and large scales, 'one-verst' (1:42,000), 'two-verst' (1:84,000) and 'three verst' (1:126,000) maps were also completed, with different map coverages, of course. Large scale maps were produced for important economic regions (e.g. for the largest city municipality area) and for potential battlefields, border zones to Germany and Austria. Also, large scale surveys are completed in the southern parts of Finland, acting as a basis of the Finnish Senate Atlas.

The '3-verst', or in our terms, the 1:126,000 scale topographic series provides the optimum target in the MAPIRE database. Relatively large scale, and almost full coverage of the European Russia together offer a good solution, which is coupled with the availability of the sheets in the Military Archive of the Austrian State Archive in Vienna, our cooperating partner. However, geo-reference of hundreds of sheets needs the knowledge of the map projection (or at least a good mathematical model of it). In map portals (e.g. the excellent Polish 'mappywig' database) gives the projection of the 3-verst series as the Bonne projection.

¹ Department of Geophysics and Space Science, ELTE Eötvös Loránd University, Budapest, Hungary

² Arcanum Database Ltd., Budapest, Hungary

It was the starting point of the analysis. We haven't analyzed neither the larger scale Shubert versions (which are thought to be polyhedral ones, own planar projections for each individual sheets), nor the small-scale one (which can be supposed to be in Bonne indeed), just the 3-verst series, later used in the MAPIRE.

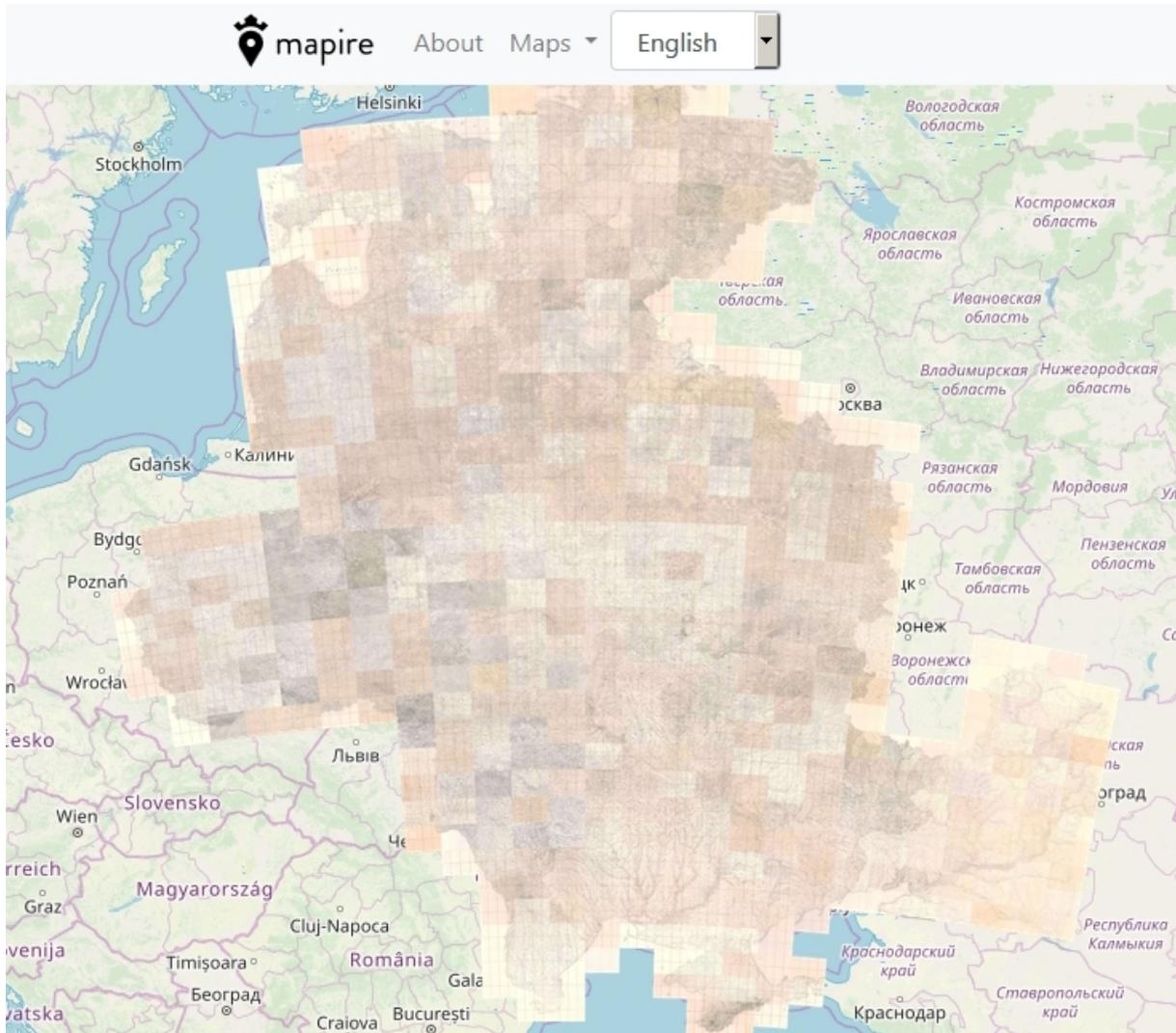


Fig 1. The mosaic of all scanned maps of the Shubert's '3-verst' topographic series in the MAPIRE portal.

Georeferencing process and the projection analysis

Since we had no exact initial knowledge about the geodetic datum and the map projection of the 3-verst series, first we compiled a virtual mosaic of all the sheets. In fact, it was done twice; first using scans from the 'grey web' for our training, simultaneously with the scanning process in the Vienna archive. As it can be seen in the MAPIRE, the final product is based on the Vienna files, where the originals are canvas-mounted with discontinuities along the folding lines. Of course, it mars the accuracy of the geo-reference, however for several hundreds of sheets, the reconstruction of the originals would be a tremendous work (for analysis of accuracy of canvas-mounted sheet georeferenced, cf. the paper of Galambos, 2019, in this very volume).

In the virtual mosaic, 254 ground control points (GCPs) were defined in perfectly identified points. WGS84 latitude and longitude positions were recorded for the GCPs using Google Earth, with their image

pixel position in the large virtual map mosaic. According to our knowledge about the 19th century Russian geodesy (Levitskaya, 2017; Mazurova et al., 2017) and also to the structure of the latitude-longitude lines in the sheets, the Pulkovo observatory was assumed to be the projection center.

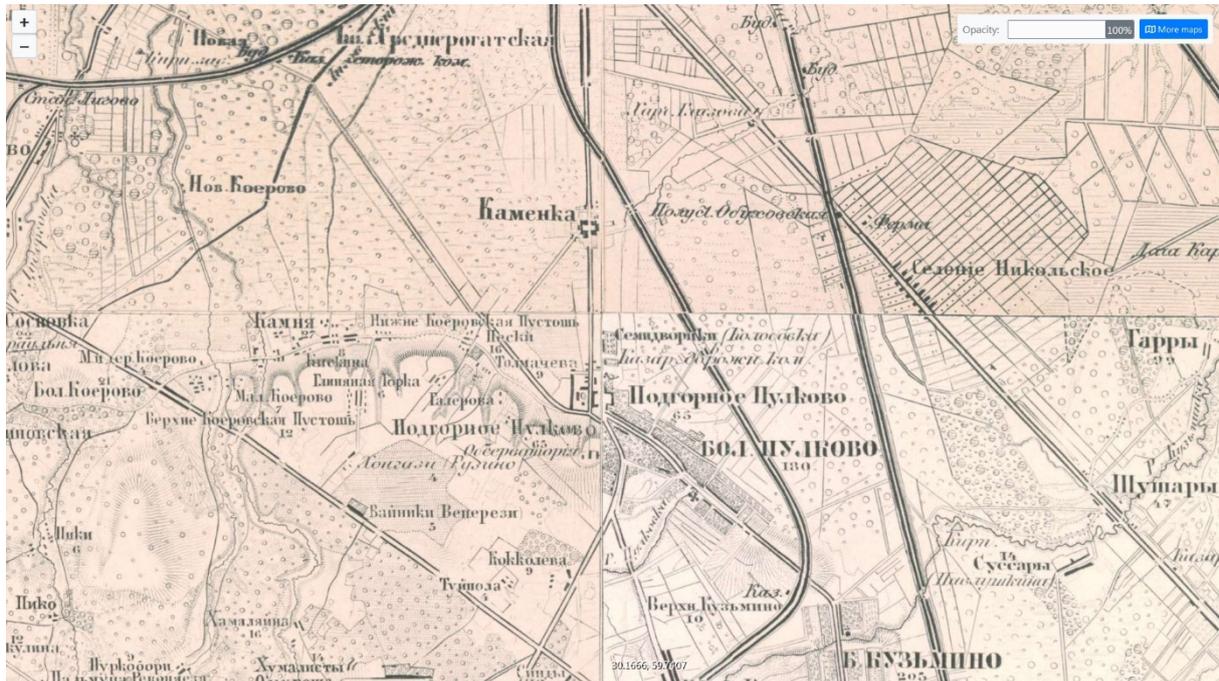


Fig. 2. The neighborhood of the Pulkovo observatory in the Shubert's 1:126,000 scale map.

Reprojecting the latitude-longitude coordinates of the GCPs to a Pulkovo-centered Bonne projection was accomplished with quite high RMS error (with more than a kilometer horizontal mean error), which is unacceptable. Since the Bonne projection is usually known as the one for smaller scale maps, we made an attempt to define a Cassini projection with the same center. As the transversal version of the 'unprojected' latitude-longitude grid, the Cassini is easy enough for an extent field survey. This pushed the remaining errors down to around 500 meters. In pure numbers, the average RMS error of the points are 1011 meters in Bonne and 565 meters in the Cassini plane, assuming the Pulkovo as projection center in both cases. Also, we made an estimation of the 'best resulting' projection center longitude (Cassini is latitude-independent), which provided a 0.05 arc degree shift to west for best GCP fit (516 m average error), however as Pulkovo was clearly indicated in the maps, we concluded to use the Cassini projection with the center of $\Phi=59^{\circ}46'18.71''$; $\Lambda=30^{\circ}19'38.55''$, interpreted on the Bessel 1841 ellipsoid, similarly to the S-32 system (Levitskaya, 2016). The final step of the georeferencing was the application of the correction grid (GSB or NTV2; cf. Molnár et al., 2014) compiled from the 254 GCPs. Thus, the final horizontal error was pushed down to 2-300 meters, most of it because of the effect of the canvas mounting.

For the scale of 1:126,000, the geodetic datum is less important, however it is well-defined for the 19th century surveys with the center of Pulkovo (Timár et al., 2004).

Results: the Shubert map in MAPIRE

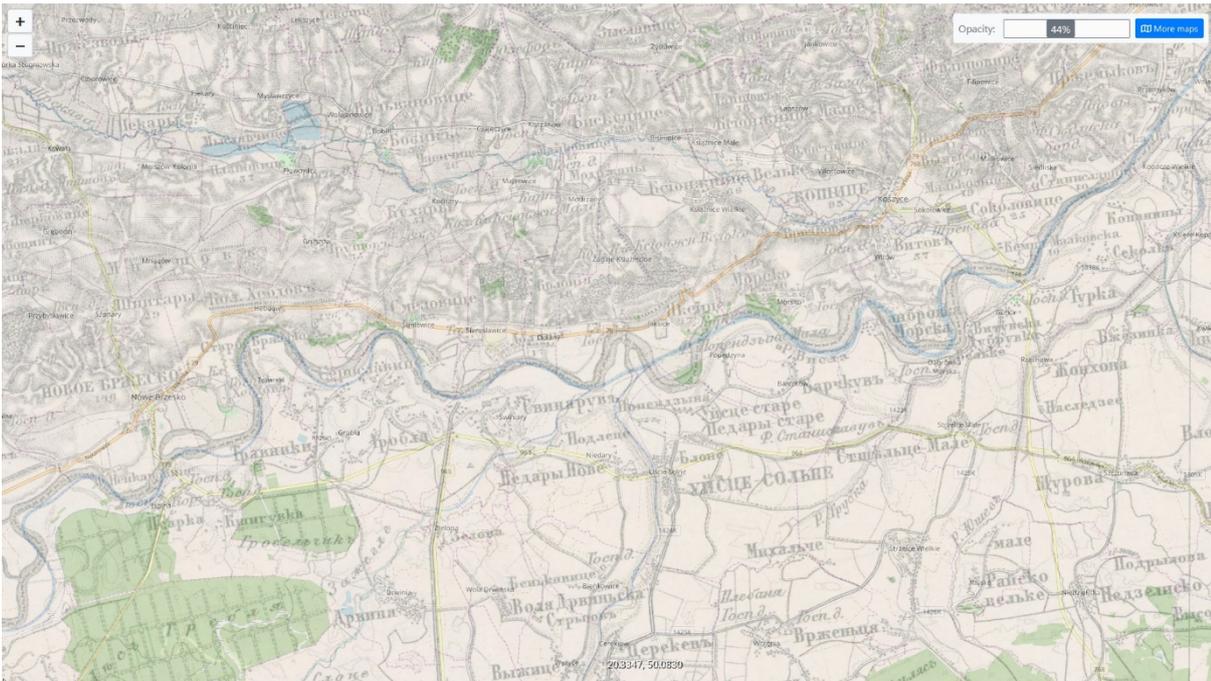


Fig. 3. Course changes of the Vistula River, east of Kraków (now Southern Poland). The Shubert's map is fit to the OpenStreetMaps layer in the MAPIRE.



Fig. 4. The area of Sevastopol in the Shubert's map in the MAPIRE. Note the obvious and not handled errors of the canvas mounting.

References

Galambos, Cs. (2019): Estimation of projection and datum metadata of the early country maps of Hungary (this volume)

- Levitskaya, T. I. (2016): History of the unified geodetic coordinate system selection in Russia (in Russian). *Izvestiya Glavnoy Astronomicheskoy Observatorii v Pulkove* 223: 353-360.
- Mazurova, E., Kopeikin, S., Karpik, A. (2017): Development of a terrestrial reference frame in the Russian Federation. *Studia Geophysica et Geodaetica* 61(4): 616-638.
- Molnár, G., Timár, G., Biszak, S. (2014): Can the First Military Survey maps of the Habsburg Empire (1763-1790) be georeferenced by an accuracy of 200 meters? 9th International Workshop on Digital Approaches to Cartographic Heritage Budapest, 4-5 September 2014; pp 127-132.
- Timár, G., Aunap, R., Molnár, G. (2004): Datum transformation parameters between the historical and modern Estonian geodetic networks. *Estonia – Geographical Studies* 9: 99-106.