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Habsburg topographic cartography of the Italian peninsula in the first half of the 19th century

Keyworks: historical maps, Italy, Habsburg cartography, 19th century, georeferenced

Summary: The geodetic point lists of the Habsburg survey of the Italian peninsula, carried out in several steps after the Napoleonic wars, were digitized and analyzed together with the modern coordinates of the identified points. Assuming the usage of the Zach-Oriani hybrid ellipsoid, the Burša-Wolf type datum transformation parameters were estimated between the local, historical triangulation Datums and the WGS84. The results show interesting accuracy differences in the Italian regions; since the points and coordinates in Lombardy, Piedmont and Lucca shows surprisingly high accuracy and consistency, the survey of Venice, Tuscany, the Papal State, the Adriatic coasts and the Kingdom of Naples is less controlled. The results enabled us to geo-refer the corresponding map series, stored in the Austrian Military Archives, in Vienna, in four different parts. Venice, Lombardy and Lucca (with other small regions at their southern border) were a part of the Habsburg Second Military Survey, with same scale and technology and legend. Part of the series of Piedmont was also found in the Vienna archives and geo-referred. South of these regions, Tuscany and the Papal State was mapped in 1:86400 scale, in a Cassini projection with the centre in the Duomo S. Salvatore, Milan. The southernmost systematic mapping work in the peninsula was in the Kingdom of Naples in the 1820s, with the same scale as used in mid-Italy, projection centre was in Capodimonte (Naples). Albeit the relatively high accuracy of the geodetic network, these map mosaics are refined horizontally applying a local correction grid (GSB) to keep the horizontal errors below 200 meters.

Introduction

Although only the northern Italy was a Habsburg possession for a longer period in the 19th century (after the Napoleonic wars till 1859 in Lombardy and till 1866 in Veneto), Austrian military assistance was asked several time in the first half of this period also in the central and southern parts of the Appennine peninsula. Military surveyors escorted the Austrian troops. As a result of their works, the first systematic geodetic network of the peninsula has been built. Based on this, to the half of the century, the whole onshore part of the later Italy was mapped by the Habsburg Empire but its enemy and the nest of the Italian independence, Piedmont. In the long-possessed northern parts, as well as the neighbouring Parma, Modena and Lucca, the scale of the

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topographic maps was 1:28,800 (one Viennese inch to 400 Viennese fathom, expressed in decimal units). In Toscana, the Papal State and in the Kingdom of Naples, the scale was 1:86,400. The whole survey followed the technology of the Habsburg Second Military Survey (1806-1869), in the northern regions; the works were a part of this survey.

Here we make an attempt to process the old base point dataset, stored in manuscript form in the Austrian Military Archive, Vienna, in order to provide a metadata control to georeference the Habsburg maps of the present-day Italy. These map are the followings:

- The 1:28,800 scale series of Lombardy, Venice, Parma, Lucca and Modena (around 1824-38), henceforth referred to as 'Lombardy region of the Habsburg Second Military Survey';
- The 1:28,800 scale sheets covering the south-eastern corner of Piedmont, around Alexandria;
- The 1:86400 scale series of Middle Italy, practically Tuscany and the Papal State (before 1842) and
- The 1:86400 scale series of the Kingdom of Naples (from around 1823).

The first item was discussed and its metadata given by Timár et al. (2006), also it was published by the MAPIRE initiative as a part of the Habsburg Second Military Survey (Biszak et al., 2014). We don't know about publication of the maps of the other three items and especially no web publication of them before the present development of the MAPIRE (Biszak et al., 2017). The present contribution gives the metadata that is behind the geo-referenced web publication of all of the above maps (Fig. 1).

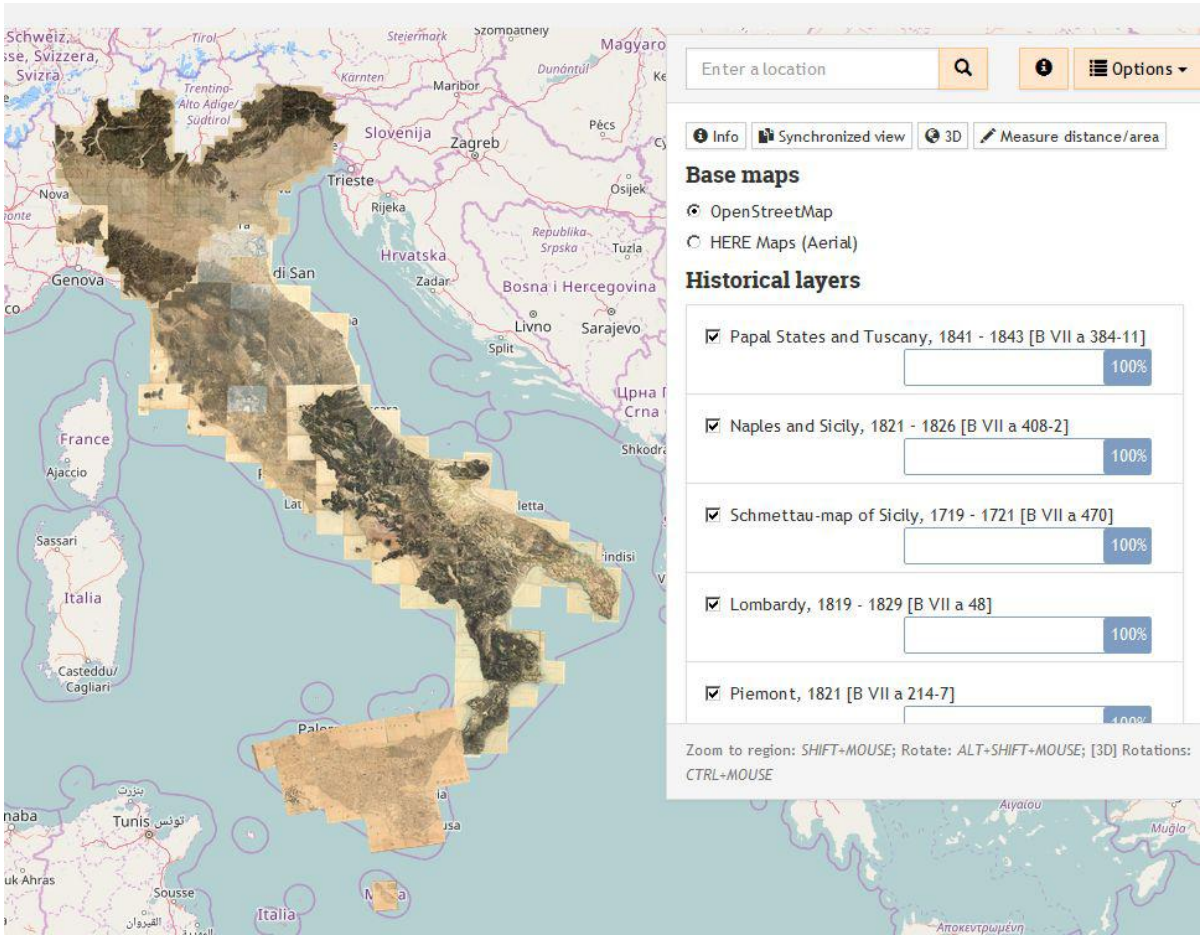

Figure 1: The overview of the processed and published Habsburg topographic map products of Italy in the MAPIRE web page.

Data and processing

As well as the map sheets, the reports and summaries about the geodetic/triangulation works carried out by the engineering part of the Habsburg military, are stored in the Vienna archives.
The manuscripts are organized in unique books, according to the specific tasks and regions (Fig. 2). Most of the work made by the Milan-based branch of the Habsburg military survey corps (Kretschmer et al., 2004) so that the documents are mostly in Italian language or, in some cases, they are written also in Italian and German. Some reports are in French, which was the 'international language' of the cartography of that time. The prime meridians used were Ferro (Timár, 2007) or Paris, however in practice they are the same as Ferro is nothing more than a theoretical meridian 20 degrees west from Paris, in round numbers.

Figure 2: The 'Italian shelf' in the War Collection of the Austrian State Archive (Österreichische Staatsarchiv, Kriegsarchiv)

In the manuscripts, base points of different regions are listed in different forms. Locations are partly given in latitudes and longitudes and partly in meridian and perpendickel values from

Duomo S. Salvatore (Milan) in Viennese fathom units. The latter ones can be interpreted as Cassini-type projection coordinates with the centre at the Milan cathedral spire (Fig. 3).
We haven't found any reference to the ellipsoid/sphere used, so we assumed it the same as used for the Second Military Survey: the Zach-Oriani hybrid ellipsoid (with the semi major axis of the Oriani ellipsoid: a = 6,376,130 m, and the flattening of Zach one: f = 1/310).
For some base points, both geodetic and 'projected' coordinates are given. Fortunately, there is one summary book, containing a collected point register from all Italian regions.[1]

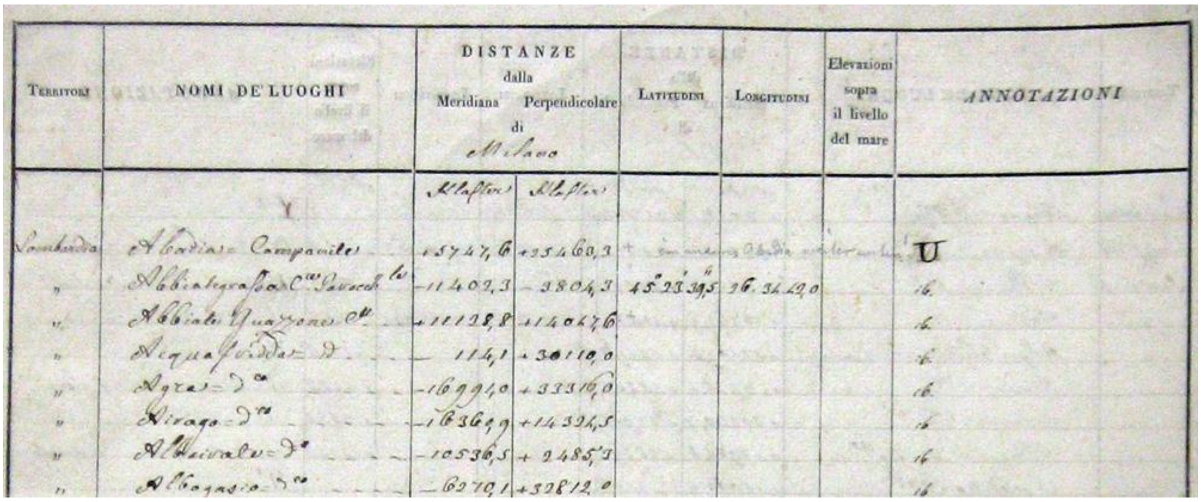

Figure 3: Alphabetical ordered collection of the base points. After the point name, the Cassini coordinates are following in Viennese fathom units, then the latitude, longitude (from Ferro) and altitude, if available.

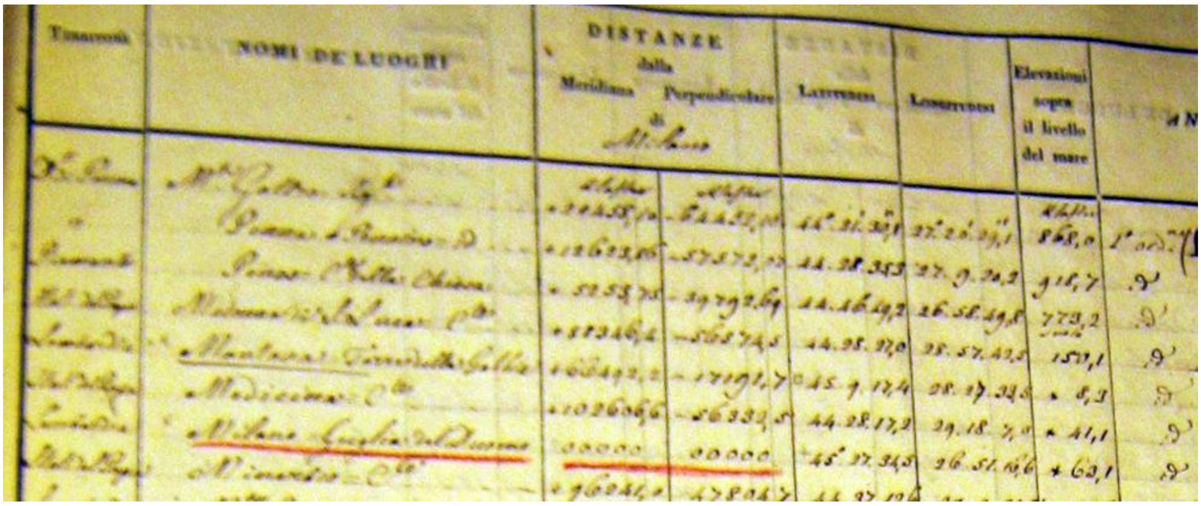

Figure 4: The record of the Milano base point in the base point register.

All points, around 4000 of them, were digitized and stored in an electronic table (Kocsis, 2015). They were systematically compared to the modern base point lists provided by the web page of www.fiduciali.it. We found these points identical ones in 200 cases. These points were used to make an estimation of the 7 parameters of the Burša-Wolf transformation (Burša, 1962; Wolf, 1963). The geodetic coordinates of the points in the old datum and in the WGS84 were used. For

[1] Prospetto Generale dei punti d'Italia… archive number: 395, in Österreichische Staatsarchiv-Kriegsarchiv, Vienna

vertical control, we set elevation of 'zero' for all old points and the geoid heights taken from the EGM96 model (Lemoine et al., 1998) were given for the modern ones. The results are shown in Tab. 1.

In Table 1, the most interesting result is the relatively low errors, compared to the technology of that time. The errors are surprisingly low in Lombardy, Piedmont and Lucca, while moderate in all other regions. Also, we made an attempt to estimate these parameters for all regions, using as many points as it was useful. The last row of Tab. 1 shows the result of this estimation, using all points but the ones from Tuscany and Naples.

Results and discussion: geo-reference of the Italian surveys

The results in Table 1 provide a good starting point for geo-referencing the four map products. Besides, analyzing the errors, we can make three statements:

1. The fine, quite low errors mean that these points are the results of pure triangulation and not by field astronomical observations. Distortions caused by the variation of the deflection of vertical would make much weaker horizontal control in case of astronomic data. Pure triangulation, based on only one astronomical control point might result a 'deliberate' network, but its control is far better. This is the case of the Second Military Survey of the core Habsburg territories, too.
2. The northern part of the points (except Venice) makes a unified and very well controlled network. The southern extreme, in Naples, is another network, while in-between, even drawn in a unified map, the Papal State and Tuscany show some differences, so the unified geo-reference might not be very accurate. It was later confirmed by the practice, too.
3. The low error occurring in Sicily is because of the low number of the base points, concentrated in a relatively small area around the Strait of Messina.

Region	**dX**	**dY**	**dZ**	**scale**	**rX**	**rY**	**rZ**	**avg**	**max**
Venice	887	55	107	1.48E-04	-63.1	-3.6	-65.5	***17.7***	***36.6***
Lombardy	1452	330	1088	-2.86E-05	-11.5	-2.2	-7.7	***2.4***	***6.5***
Piedmont	1624	-209	796	-5.49E-06	-4.9	7.6	-25.3	***2.7***	***7.4***
Parma	2237	225	521	-5.01E-05	1.3	30.8	-0.4	***1.2***	***2.5***
Tuscany	2848	523	1218	-1.99E-04	-11.8	-5.5	12.5	***16.9***	***36.9***
Papal St.	770	28	-435	2.21E-04	32.3	25.1	33.0	***13.4***	***35.3***
Adriatic	2713	942	1892	-2.68E-04	4.2	-19.6	17.8	***8.1***	***31.6***
Naples	1578	518	617	7.87E-06	109.9	13.1	137.1	***15.5***	***32.3***
Sicily	-3737	-1313	-3455	1.10E-03	-7.0	-16.9	18.1	***12.2***	***18.9***
Italy	**1483**	**250**	**732**	**9.49E-06**	**-24.2**	**4.3**	**-22.6**	***21.7***	***111.0***

Table 1: The Burša-Wolf Datum transformation parameters (the shift parameters are in meters; the rotation parameters in arc seconds according to coordinate frame rotation convention; the scale factor is dimensionless) and their average (avg) and maximum errors (in meters) from the old Habsburg surveys of Italy to WGS84. Note the extreme low error in Lombardy, Piedmont and Parma. In the last row, the unified data set without Naples, Sicily and Tuscany was used.

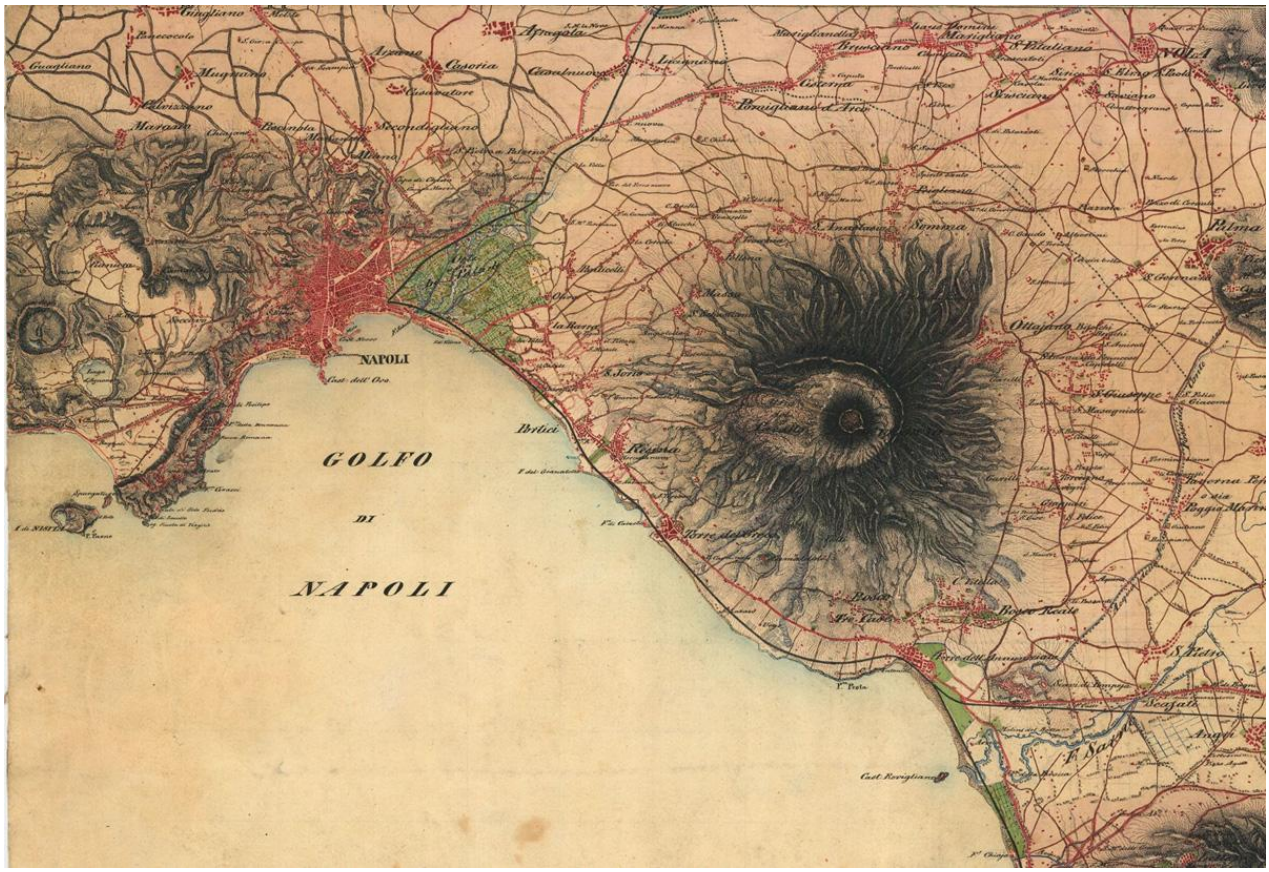

Figure 5: Naples and Mt. Vesuvius in the map of Kingdom of Naples, scale: 1:86,400.

The geo-reference of the Lombardian part of the maps were made similarly to the Habsburg Second Military Survey: coordinates of the map corners were computed from the sheet labels and the geodetic datum and projection were clearly defined (Timár et al., 2006). However, because of the above experiments, the geo-referencing process was carried out in a more 'engineer-like' way: we compiled virtual image mosaics made of the sheets, one for Middle Italy and one for Naples. Around 100 ground control points were defined with their mosaic image pixel coordinates and geodetic coordinates, at landmark points. Using them, the parameters of the best-fitting Cassini projections were estimated, using the method of Molnár & Timár (2015). The projection centres occurred to be at Duomo S. Salvatore (Milan) for Middle Italy (Fig. 4) and Capodimonte (Naples) for the sheets of Kingdom of Naples. However, we could not define the sheet corners in round numbers, not even in the used length units, in Viennese fathoms. Moreover, the horizontal control with the best fitting parameters were also un-tolerable high, much higher than the errors of Table 1, in some places around a kilometre. It indicates that the sparse geodetic net provided weak horizontal control without the lower-order base point set. So, the geo-reference was finalized by the correction grid (GSB) fitting, based on our defined GCPs.

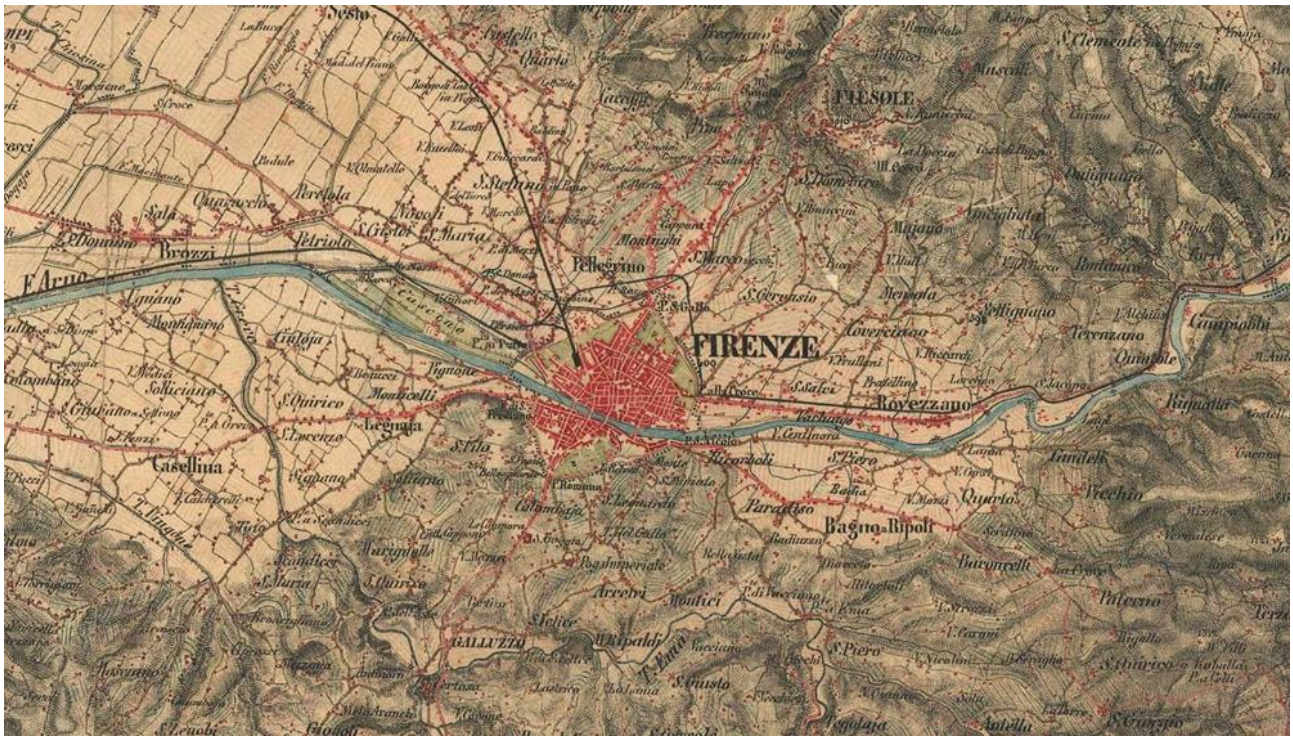

Figure 6: Florence in the map of Central Italy – note the railroad lines around the city.

Conclusions

The Austrian survey in Italy in the first half of the 19th century, between the Napoleonic Wars and the 1848 revolutions, have not resulted a really unified geodetic network. Their cumulative high point number (more than 4000 points) means a tremendous activity and it enabled to make high-scale topographic maps of the peninsula, according to Cassinian standards (Mastronunzio & Dai Prà, 2016; for their influence to Austrian cartography, cf. also Livieratos, 2011; Pazarli et al., 2011). The point list is a result of almost pure triangulation works, according to the high internal consistency. However, the internal horizontal control of the resulted maps is much weaker, which can be explained by the lack of a higher order geodetic network.

The whole cartographic datasets are published very first time in frame of the MAPIRE project (Figs. 1, 5 & 6): http://mapire.eu/hu/map/italy giving excellent opportunity to study the geography of the Italian lands in the first half of the 19th century. The maps of the Kingdom of Naples (from around 1823; Fig. 5) and Lombardy-Venice (1824-38) are the earlier ones, while the maps of Central Italy were completed to 1842, however some railroad lines, build later, are also found in the sheets in the Vienna archive (Fig. 6). The map styles show this time order: the southern sheets from Naples are similar to the earliest Austrian second survey maps (Tyrol, Salzburg) in symbols, while Lombardy and Central Italy reminds to the 'mainstream' second survey sheets of the Habsburg Empire itself.

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