The cadastral mapping system of Bukovina: from emergence to GIS integration

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ABSTRACT: In order to support the cartographic activities of the "Stable Cadaster" in Bukovina (Bukowina), the Habsburgs developed a local triangulation network, starting with the measuring of a geodetic baseline north of Rădăuţi (Radautz, Radovec) in 1818. Its western endpoint became the fundamental center of the coordinate system used by the cadastral map sheets of the province until the Second World War, and the monument placed here, in 1820, is nowadays the oldest geodetic monument in Romania. The established triangulation network in Bukovina also sustained the advanced of the modern geodetic activities in nearby areas, especially in Moldova. In contemporary times, precise definition of the Rădăuţi coordinate system, reconstruction of the cadastral index map and use of the geodetic transformation parameters allow the georeferencing and GIS integration of the map sheets without the need of ground control points.

KEY WORDS: Bukovina, cadastral survey, Habsburg geodetic activities, Rădăuţi baseline, geodetic monument, historical maps.

1. Introduction

Since the early 18th century, in the Carpatho-Danubian region maps became more than simple, graphical representations of certain geographical areas and played important roles in times of war and peace as a means of organization of economy, administration and political life. The process was related to the expansion of the Habsburg Empire in the former ottomancontrolled territories and the coeval systematic cartographic surveys, which consistently enriched the geographical knowledge of the historical Romanian provinces.

For strategic and financial reasons, the accurate description and mapping of the Empire crown-lands and various war theaters highly remained after 1758 (when the Imperial General Quartermaster Staff was established) in the hands of well-trained engineer officers, with good knowledge of geometry, trigonometry and geography. The quality of their works was in time subjected to the development of the main scientific ideas in the fields of cartography and geodesy or to the improvement of the survey instruments, therefore the need of better maps had never faded! The official topographical activities in the former Austro-Hungarian Empire may

consequently be divided into four periods having distinct features regarding the geodetic foundations, methods of survey and accuracy of maps produced (Imrek, 2014).

The first systematic military mapping of the Habsburg territories was ordered by Maria Teresa in 1763. During the next 22 years (1763-1785) all the Habsburg provinces, and in a short time, other regions of interest such as Moldova (between the Carpathians and Siret) or Wallachia (with the exception of ottoman territory of Brăila) were charted at unprecedented scale (Paldus, 1919).

From this early stage of cartographic descriptions, date also the first detailed (medium to high scale) representations and descriptions of a smaller part of the northwestern Moldavia and later of a larger one - namely Bukovina (Bukowina), after the Habsburg annexation in 1775 (Table 1; see also Iosep et al., 2013). These surveys were typically based on '*a la vue*' descriptions and only partially on local geometric measurements.

Table 1 Early medium and high scale maps of north-western Moldavia and Bukovina produced during the Josephine land survey**.**

Map title/description	Coordinator	Year	Scale	Details
General Charte deren Lisieres von der Moldau und Walachei, worinnen zu entnehmen ist, wie die Sectiones derenselben mit jenen der angränzenden Gross Fürstenthum Siebenbürgen zusammen zu setzen sind	v. Jeney	1773	1:57.600	103 map sheets; 1 index map
Brouillons der Bukowiner Aufnahme bestehend in 71 Sectionen (aufgenommen durch den k. k. Generalquartiermeisterstab unter der direction des Major Büschel in den Jahren 1773, 1774 und 1775	Büschel	1773 1775	1:57.600	72 map sheets; 1 index map; 2 versions
Plan des Bukowiner Districts bestehend in 72 Sections, welche in den Jahren 1773, 1774 und 1775 von einem departement des kaisl. königl. Generalstabes geometrisch aufgenommen worden	F. v. Mieg	1778	1:28.800	72 map sheets; 1 title page; 1 index map
Ökonomische Aufnahme von 40 Ortschaften in der Bukowina	J. Budinszky	1782-1783	variable; 1:4.800 and 1:14.400	117 map sheets
Topographische Bukowiner Kreis-Carte, welche aus denen unter der Direction des deutsch banatischen Gränz-Regiments Hauptmann Hora von Otzellowitz oeconomisch aufgenommenen original Grundrissen reducirt und zusammengesetzt worden, bestehend in 55 Sectionen, worinnen alle Dominien Abtheilungen und Grundgattungen ersichtlich	F. Hora von Otzellowitz	1789/1790	1:28.800	55 map sheets; 1 title page; 1 index map

In addition to the strategic causes of the military surveys, for the application of various tax reforms and the economic development of the monarchy, was decided an inventory and classification of land properties. On April 20, 1785, Joseph II ordered the implementation of a new land tax regulation system that would not take into account the social ownership of landowners, but land revenue. As a result, in the next years (1785-1789) were carried out measurements of productive land in over 200,000 km^2! The haste with which the study was conducted and the general estimation of each parcel yield based on the land use categories were significant deficiencies of the Josephine land tax system. Under the pressure of the great landowners, in 1790, Leopold II

would reintroduce in most provinces the differentiated taxation method of dominican and rustic properties, previously applied by Maria Theresa (Ungureanu, 2011).

The short-lived Josephine cadastral project was nevertheless of great importance in Bukovina. Since the land registers or land owner tables were uncommon in the former Moldavian region, the newly established authorities were forced to start the delineation of the properties and the land inventory since 1777. During this long and difficult process, the first high scale cadastral maps of several administrative units were drawn (1782-1783), under the coordination of the civil engineer Johann Budinszky, but the geometrical survey was shortly interrupted for cost reasons. It was resumed in 1786-1790, under the supervision of Capt. Hora von Otzellowitz and the result was the first economic (land use) map of the province in scale 1:28.800 (Iosep and Cristea, 2014).

Cartographic materials drawn up by the military personnel were strictly secret (in the Archive of the Aulic War Council), were accessible to a small number of senior officers and remained largely unknown to the public. Even less is known about their metadata, relevant for the assessment of the quality of the survey, displacement errors etc. The available time, trained personnel, topographical conditions or the political and economic factors were of great influence for the characteristics of the field measurements in various areas and we may assume that, in optimal conditions, were used the limited instruments of the epoch (plane-table, compass, lead wire, measuring chain etc.). From this point of view, the Otzellowitz's map of Bukovina, based on the plane-table geometrical surveys and local triangulation points (established especially in the main river valleys) is generally more accurate than the prior ones. However, like for the rest of the first military topographic surveys, we have no clues for a geodetic/projection background and the astronomic base for the field observations is missing.

2. The Franciscan surveys and the beginning of cadastral triangulations in Bukovina

The main flaw in the Josephine cartographic records was that the surveys were carried at the local level without a general framework. Consequently, when the provincial maps were attempted to be joined, in 1792, in order to obtain a general picture of the monarchy, the border areas were so distorted that concatenation was impossible (MGI, 1881).

This led the Austrian Emperor Francis I to order the General Staff in 1806 a new survey of the imperial territories with the use of scientific bases. The wars with Napoleon interrupted the process in 1811 but after their completion, in 1815, the works were resumed. Alongside the new military recognition, since August and October 1806, the Austrian Aulic Chancellery has been tasked with developing a new, uniform, system of taxation of land. The action was a sensitive one and required a long period of preparation, resulting in the introduction of the stable cadaster by the imperial decree of 23 December 1817 (Ungureanu, 2011). The act ordered the beginning of the cadastral measurements in all the German and Italian provinces of the monarchy, with the exception of the Hungarian territories (Hungary, Transylvania, Croatia, Slavonia, Vojvodina and Banat). In the latter the cadastral survey merely started in 1849 (K. K. Finanzministerium, 1907).

Since the two mapping activities have been carried out in parallel and have progressed independently, the question of their complementarity has been raised from the outset. In those regions where the cadastral records were already accomplished, the General Staff had to resort to the reducing of land use planimetry to military-scale instead of new topographic recognitions. Cartographers therefore only had to include relief details (using hachures) and make corrections where necessary.

A novel feature for the Franciscan surveys was the gradual development of a stable network of triangulation points (the geodetic foundation) using the laws of trigonometry and astronomical observations. This was to provide the skeleton of field measurements ("the graphical triangulation" with the plane table - a less rigorous and costly method) and, above all, the precision of the geographic positioning of details (rivers, roads, localities, forests, etc.).

The groundwork for the establishment of the grid of triangles was the precise measurement of a "baseline" (one side of the initial triangle) or more (for the cross-check calculations). This difficult operation had to be done with the utmost precision (each error is multiplied by the calculated length of the other two sides of the triangle), so the chosen terrain should be as uniform as possible. To measure this distance, the engineer officers used in the 19th century variants of the so-called Delambre's apparatus, consisting mainly of four standard iron rods on wooden stands (each of about 4 m length, about 13 cm wide and 4.5 cm thick), with indicators for thermal expansions/contractions (Figure 1). The other station points of the grid were determined with theodolites. The works were coordinated by the newly established (1806) Topographical Bureau of the General Staff and, since 1839, by the Military Geographical Institute (MGI) in Vienna. High-ranking officers also coordinated the technical work of the cadastral Measurements Bureau of the High Commision for the Land Tax Regulations (*Grundsteuerregulierungs-Hofkommission*), responsible for the implementation of the "stable cadaster".

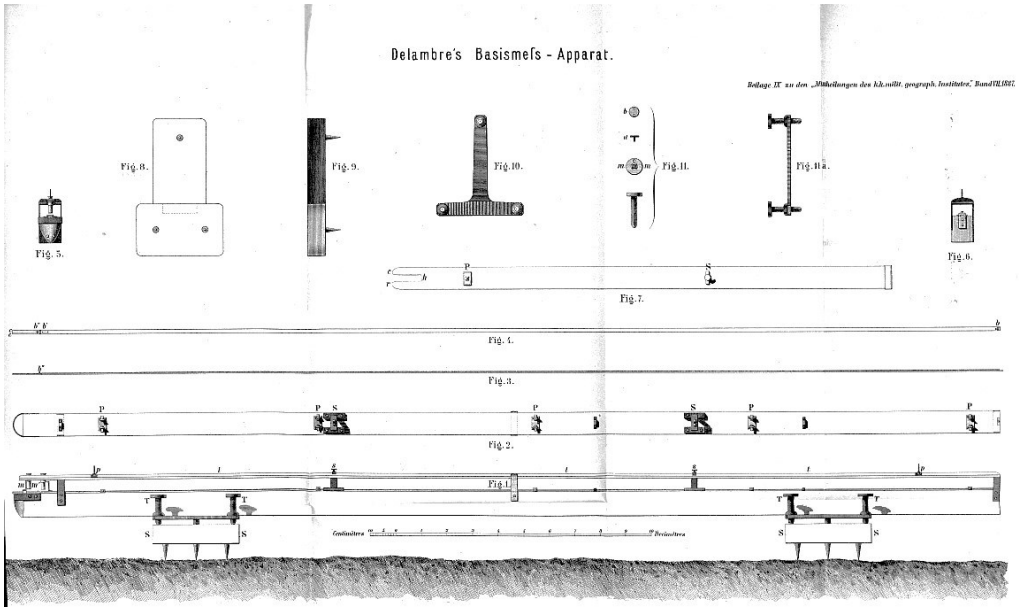


Figure 1 The system of a standard rod of the Delambre's apparatus, used for the geodetic baseline measuring since 1810 (Hartl, 1888).

Initially the origin of the mapping coordinate system was considered the tower of the St. Stephen's Church in Vienna, but soon it become obvious that large expansion of the monarchy in longitude will cause significant distortions at the periphery. Consequently, when the cadastral triangulation started in 1817, the territory has been divided into multiple zones; each one had its own, independent, Cartesian coordinate system with a center at a geodetically defined reference point. The military topographic survey in order to make use of the reduced cadastral planimetry commonly adopted the systems (Timár et. al, 2006), but this was not the case of Bukovina!

In 1818, when the geodetic works started, Bukovina was an administrative circle (Czernowitzer Kreis) of Galicia and the easternmost province of the Empire. Although subjected to the

coordination of the Galician military and civil leadership in Lemberg, since the beginning of the activities, in the province was developed an independent geodetic and cadastral mapping system.

For this purpose, it was deployed here the leader of one of the triangulation brigades on the Adriatic North Coast, first lieutenant Alois Hawliczek from the General Staff, and other officers (Hartl, 1888) such as first lieutenant Martin Nowak (Pioneer Regiment), first lieutenant Wilhelm Freiherr von Piers (15th Zach Infantry Regiment), lieutenant Joseph Pomo von Weyerthal (4th Kronprinz Regiment) and lieutenant Carl von Torry (3th Infantry Regiment). Field operations were supervised at the time by the colonel Ludwig August von Fallon, reviewer of the astronomy-trigonometric works in the Measurements Bureau of the *Grundsteuerregulierungs - Hofkommission* and director of the Topographical Bureau of the General Staff (MGI, 1881).

Table 2 Geodetic baselines used for cadastral triangulation of the Habsburg crown-lands (K.K. Finanzministerium, 1907).

	Baseline	Year of the measurement	Length	
			Viennese fathoms (klafters)	*meters*
1.	Neustadt – Viena (Lower Austria)	1763	6410,903	12158,175
2.	Wels (Upper Austria)	1806	7903,812	14989,453
3.	**Rădăuţi (Bukovina)**	**1818**	**5199,6**	**9860,958**
4.	Hall (Tyrol)	1851	2990,38	5671,215

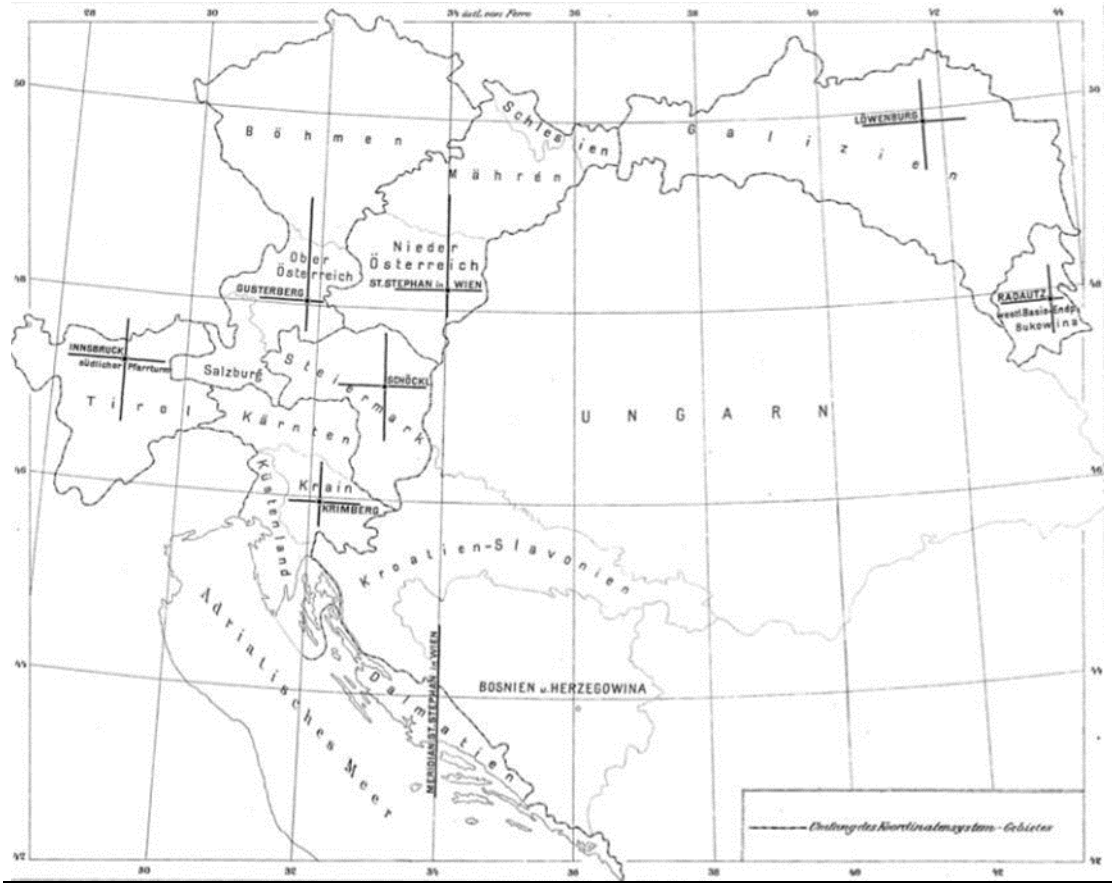
Hawliczek coordinated the measurement of a geodesic baseline north of Rădăuţi (Radautz, Radovec), a relatively extended flat region and centrally located within Bukovina. The determined base had its western end south of the village Gălăneşti and the eastern one south of Andrasfalva (nowadays Măneuţi). From the officer's report results that a metallic Delambre's apparatus, built in 1810 (Figure 1) was used for the baseline measurement between September 24 and December 30, 1818. This important result for the further triangulation works was hardly achieved in optimum conditions – the measurement was performed only once and under unfavorable temperature conditions, that could have affected the size of the standards (Hartl, 1888).

In the following years, starting from the Rădăuţi baseline, the initial triangles (with station points in Ursoaia Hill and Fundătura, north of Fântâna Albă) as well as other points of the network were determined. At the end of the works, in 1820, the endpoints of the baseline were marked by inscribed stone monuments - the first known geodetic markings in Romania! The western endpoint of the Rădăuţi baseline became the reference point of the cadastral mapping system in Bukovina (the origin of the Cassini grid). The eastern one was used for astronomical observations.

The station points determined by trigonometric methods (order I-III) backed the cadastral survey. According to the Cadastral Regulation, for each Austrian square mile (5754.6 ha) there should be at least three trigonometric points determined by theodolite. Based on these, other support points (of fourth order) were graphically determined by geometers using the plane-table, and, lastly, parcel detailing was made (K.K. Finanzministerium, 1824).

Since Bukovina was one of the Habsburg provinces in which cadastral measurements preceded the military recognition, the new maps drawn up by the Army General Staff were made using the reduced cadastral planimetry (1: 28,800) and associating topographical details. This operation began in 1828-1831, when only 28 map sections were made (under the coordination of Major Myrbach), and it will be concluded in 1863. Unlike the cadastral works, the mapping grid system

used by the military in Bukovina was the one of Eastern Galicia, with the fundamental point of the projection in Lemberg / Lvov (Timár et. al, 2006).



	Reference point	Surveyed crown-lands	Latitude	Longitude (from Ferro)
1.	Stephansdom - Vienna	Lower Austria, Moravia, Silesia, Dalmatia (with the exception of Zara)	48°12’31.54’’	34°02’27.32’’
2.	Gusterberg, near Kremsmünster	Upper Austria, Salzburg, Bohemia	48°02’18.47’’	31°48’15.02’’
3.	Shöcklberg, near Graz	Styria	47°11’54.87’’	33°07’59.9472’’
4.	Krimberg, near Laibach	Carinthia, Carniola and the Austrian Littoral	45°55’43.75’’	32°08’18.71’’
5.	Pfarrturm in Innsbruck	Tyrol, Vorarlberg	47°16’11.27’’	29°03’39.57’’
6.	Löwenburg in Lvov	Galicia	49°50’55.24’’	41°42’29.57’’
7.	**The western endpoint of the Rădăuţi baseline**	**Bukovina**	**47°54’22.47’’**	**43°28’56.92’’**

Figure 2 Reference points of the cadastral coordinate systems in the German and Italian provinces of the Austrian Empire (K.K. Finanzministerium, 1907).

Along with the emergence of the Military Geographic Institute (1839), triangulations continued in Hungary and Transylvania, in order to complete the joining of the interconnected triangles throughout the monarchy. On this occasion it became obvious the insufficiency and lower

accuracy of the prior works and supplementary activities were performed, including in the already mapped territories (measurements of new geodetic bases – e.g. Arad-1840, Tarnow in Galicia-1849, Hall in Tirol-1851, astronomical determinations – e.g. Arad-1840, Ocna Sibiului1841, Lvov-1844, Spalato in Dalmatia-1845, Ivanic in Croatia-1846, etc.). Moreover, the main astronomical observatories were connected to the geodetic network (MGI, 1881).

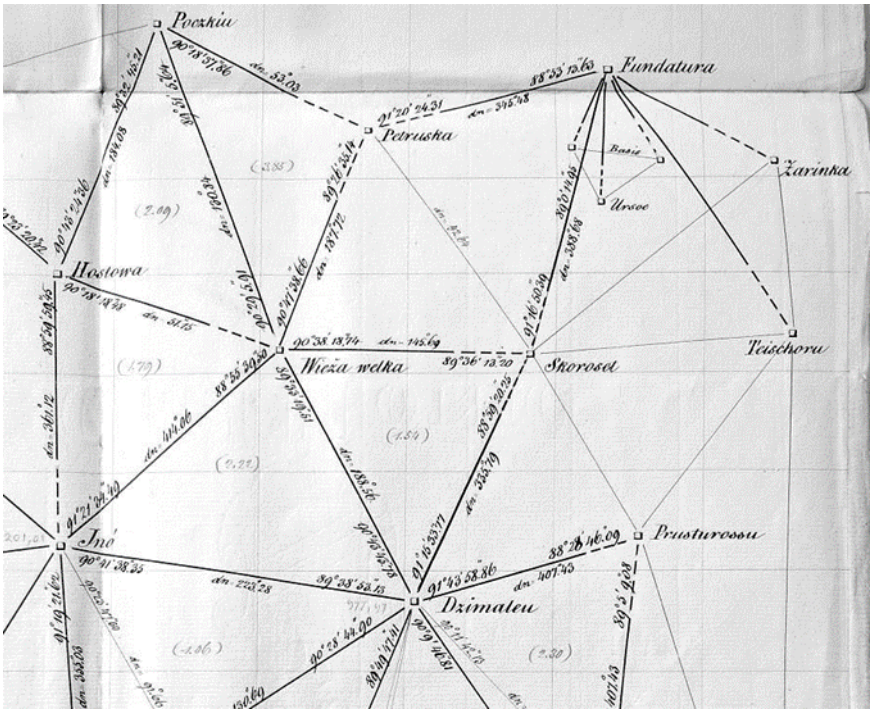


Figure 3 The network of first order triangulation points in southern Bukovina in 1844. The baseline near Rădăuţi is marked by the term Basis (MGI, 1844).

In Transylvania, the geodetic bases of the second survey were set up in 1841 (Timár et. al, 2008), when the first astronomical determinations were made in a small observatory on the Sibiu Hill (Vízaknai-hegy, near Ocna Sibiului) similarly by Alois Hawliczek (at that time Lieutenant Colonel). The point became the center of the Transylvanian coordinate system used by the military maps, mostly completed between 1869 and 1873. It is also worth mentioning that during this period (1855-1857), the Habsburg military triangulation institute coordinated the first triangulation of Wallachia and Dobrogea (Timár, 2008). In Bukovina, further geodetic works involved the connection of the local triangulation network with those from neighboring provinces and the stabilization/marking of the determined trigonometric points, chiefly by wooden pyramids - 1846-1858 (K.K. Finanzministerium, 1907).

Considering the accuracy of the established triangulation network, the chains were not observed uniformly (included local cadastral grids) and were never rigorously adjusted. No uniform astronomic orientation of the net was ever made and the geographic coordinates were computed from different datum points. These favored errors propagation from local to regional scale; such was the case of the Rădăuţi baseline where the error associated to the 1818's measurement - about 1 fathom (1.9 m), affected the scale of the lately developed triangulation chains in northern Hungary, Galicia and Transylvania.

3. The joint geodetic activities in Bukovina and Romania in 1874

A reference year in the history of European geodesy was 1864, when the first 'General Conference of the Representatives to the Central European Arc Measurement' took place in Berlin. The main purpose of the associated countries was a scientific one - to determine the shape and dimensions of the Earth by measuring giant arcs of meridians and parallel, which required the connection and improvement of geodetic triangulations from different parts of the continent. Under the aegis of this international association, to which almost all European countries eventually have joined, notable scientific advances have been made based on cordial relations and service exchanges at national level and unique standards for the geodetic activities and equipment used were established (Grandidier, 1882; Torge, 2005). From the very beginning, the Association advocated the use of the metric system in the measurement of the geodetic baselines and the standard rulers, a system that would be gradually introduced into the AustroHungarian Empire starting with 1871.

Consequently, in September 1872, a new military survey of the monarchy was decided. In comparison to the previous ones, the new instructions imposed the use of the metric system, precise determination of heights and representation of topography using contour lines, unification of the projection system and the use of the Bessel ellipsoid. For the new topographical maps, the 1:25.000 scale was adopted, while the cadastral plans were realized in scale 1: 2.500.

In Bukovina, the entire territory was surveyed according to the new standards in 18731874, partly using reduced cadastral planimetry. The process involved 32 cartographers (MGI, 1881). On the occasion of the new topographic survey, geodetic works were carried out to connect the Austrian and Russian triangulation networks (from Bessarabia) across the eastern part of Romania (Moldova).

Contrasting Wallachia, Moldova had not been mapped since the end of the 18th century (only partially at the time!). Moreover, it had no triangulation network to provide the scientific basis for the action.

In order to achieve the first modern map of Romania, the geodetic triangulations and topographic survey started in 1873. The lack of technical trained staff and funds determined the activity to begin in northern Moldova, where the construction of the network could be based on "precise and technical data of triangulation executed in neighboring countries" (Pârjolescu, 1908). Responsible for this project were "The Three Constantines" (Hepites, 1902) - col. Constantin Barozzi (Chief of the War Deposit), Captain C. Căpitaineanu (responsible for astronomical-trigonometric works) and Captain C. Brătianu (responsible for the cartographic part). In 1873, the three officers identified the probable triangulation points in the counties of Iaşi, Botoşani, Dorohoi and Suceava and analyzed the possibilities of connecting the Romanian network with those of Bessarabia and Bukovina. With this aim, the delegation first went to Bessarabia in order to identify the connection points, and afterwards arrived in Bukovina. Here, the Romanian commission, along with the Austrian one - led by the Czech captain Robert Freiherr Daublebsky von Sterneck, determined three connection points: Arşiţa - Ibăneşti, Zarincea - Bucecea, Korzan (Teişoara) - Tudora. By joining the three networks (Austrian, Romanian, and Russian), it was accomplished also the scope of the European Association for the Arc Measurement.

Since the Romanian part of the triangulation network did not have its own geodetic base and the War Deposit did not have the necessary means for the baseline measurement, the Austrian

baseline near Rădăuţi was used for the calculations. With this occasion the line was resurveyed in October 1874 by von Sternek, an operation that was also attended by C. Căpităneanu. Distinctive from the measurements of 1818, only a reduced base of 2416 Viennese fathoms (4566.24 m) was determined, from the old western endpoint near Gălăneşti to a new eastern endpoint near Frătăuţii Vechi (Figure 4).

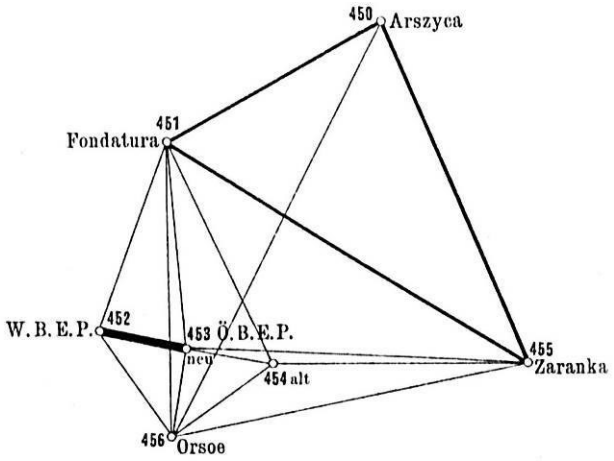


Figure 4 Triangulation sides of the Rădăuţi baseline (MGI, 1902.

From these station points and the adjacent stations Fundoaia and Ursoaia, Căpităneanu surveyed the connection points with the Romanian network. On this occasion, he compared the results with those of Sternek and had the opportunity to evaluate the precision of the instruments, which were found "very satisfactory" (Pârjolescu, 1908).

Căpităneanu had major contributions in the development of Romanian geodesy and astronomy, being considered the father of the geodetic triangulation in Romania and the author of the first highly accurate astronomical study in the country - determination of the longitude difference between Iaşi and Cernăuţi (made in 1875 and published in 1881). Robert von Sternek will become the director of the Astronomical Observatory of the Military Geographic Institute in Vienna (1880), and since 1882, the Austrian representative in the European Arc Measurement Commission (MGI, 1881).

With the occasion of the 1874's survey, an error of about 2 m was noticed for the previous measurement, as well in the baseline orientation. The latter affects the correspondence between the Cartesian coordinates of the cadastral map sheets and geographical coordinates, similarly with the case of the Gusterberg geodetic system (used in Upper-Austria, Salzburg and Bohemia; Nušl, 1909).

The progressive development of the Romanian geodetic network to south was the preamble of the topographic surveys (1875-1893) and the mapping of Moldavia (1: 20,000, 496 sections). In memory of the measurements carried out in 1874 north of Rădăuţi by the joint Austro-Romanian team, a second inscribed plaque was placed on the 1820 monument marking the western endpoint of the geodetic baseline, while the eastern, newer one was stone marked.

4. Monuments associated with the geodetic baseline in Bukovina

Subsequently to the measurements carried out in 1818 and 1874, three first-order geodetic points - the western endpoint (W.B.E.P., 1818), the older eastern endpoint (Ö.B.E.P.-alt, 1818) and the newer eastern one (Ö.B.E.P.-neu, 1874) were determined along the Rădăuţi baseline (Figure 4). These were marked on the ground by inscribed survey monuments, unique in Bukovina (MGI, 1905). Regrettably only one was preserved in time!

a. The monument from the western endpoint

It is located in the south-eastern part of the village Galăneşti, about 220 m east of the road 50A. The monument was described by O. Bâtă (2009) as a landmark of the cadastral works carried out by the Austrians in 1818-1820. It has the form of a parallelepiped made of sandstone blocks. The monument has a total height of about 3.50 m and consists of a square base (with sides of about 1.7 m), a square pillar (about 2 m high and with sides of 1.3 m) and a top made up of three plates of variable size. On the eastern and western sides of the pillar there were two rectangular plates that reminded the activities (of 1820 and 1874 respectively). Of these, only the oldest (made of limestone, 0.79 x 1.2 m) is preserved and have a Latin inscription (Figure 5). Besides its historical value - it remembers the first modern geodesic operations on the nowadays territory of Romania, the monument marks the fundamental point of the Habsburg cadastral geodetic system of Bukovina, therefore can be used for scientific purposes (e.g. georeferencing of the historical cadastral plans and assessment of the datum transformation parameters to modern geodetic systems).

b. The monument from the older eastern endpoint

According to the MGI, the eastern endpoint of the 1818 geodetic baseline was similarly marked by an inscribed stone monument. This supposed to be located nowadays at about 570 m southwest of the village of Măneuţi (Andrasfalva), close to the Măneuţi geodetic point (363.9 m) from the 1980s' topographic map. Unfortunately, the monument was demolished and the only trace of its previous location is the presence of the stone blocks in the foundation. The eastern endpoint was part of the second order astronomical network of the monarchy and astronomical observations were still made here in 1905. It is possible that a nearby building, marked on the Franciscan military maps as *Wächterhaus,* had served to this purpose.

Figure 5 The monument erected in the western endpoint of the Rădăuţi baseline (W.B.E.P): the reference point of cadastral coordinate system of Bukovina.

c. The monument from the newer eastern endpoint

It is located near an agricultural road in the south of Frătăuţii Vechi, about 600 m west of the county road 178C. It is a geodesic stone mark placed with the occasion of the baseline survey in 1874 (attended by the Romanian astronomer Constantin Căpitaneanu). According to the MGI (1905), it has an inscription which recalls the activity. As the pillar has been overturned from its

base, it is possible that the inscription is on the face that is currently not visible. The marker has the form of a parallelepiped with a sharp top and is about 1 m high, with 0.30 m sides. Its base, partially covered by vegetation, consisted of at least two stone plates. One of these has a semicircular cut-out side, which could have been used by a wooden tower (pyramid) erected for the survey. In fact, one of the protagonists of the measurements - von Sternek, extensively describes in one of his studies the construction and use of the survey pyramids for trigonometric observations, as well as the subsequently marking of the station points (Sternek, 1898).

5. The Rădăuţi coordinate reference system and the georeferencing of the historical cadastral maps of Bukovina

The Franciscan cadastral maps of Bukovina were produced between 1819 and 1823 and further updated/completed between 1854-1856 and 1860-1862. The subsequent changes (until 1913) were marked with red ink. A condensed presentation of the results is presented in Table 3.

The maps recorded in unprecedented scale accurate details for the properties taxation – property boundaries, buildings and land use categories, providing nowadays detailed and authentic information on the earlier state of the geographical environment and land use changes (Sipos, 2014). Presently are scatteringly preserved in the regional archives in Czernowitz and Suceava (Rumpler, Scharr and Ungureanu, 2015).

Similarly, with the rest of the crown-lands, the cadastral maps were assembled based on a Cassini projected grid of lines and columns, each cell covering an Austrian square mile (1 mile=

7585.94 m). The geodetic reference point (0) of the system corresponds to the western endpoint of the Rădăuţi baseline (Figure 5), in which the axis of the ordinates (y axis) perpendicularly intersected the central meridian (x axis) - (Table 2, Fig.5). From this point, to the east (negative coordinates) and west (positive coordinates), the columns were numbered with Roman numerals: from I to VIII, to the east, and I to IX, to the west. The rows were numbered from north to south with Arabic numerals (from 1 to 23), therefore the ordinate axis corresponded to the grid line between row 12 and 13 (Figure 5).

Table 3 Results of the Franciscan cadastral mapping in Bukovina and the Habsburg Empire - with the exception of the Hungarian crown-lands (K.K. Finanzministerium, 1907).

Indicator	Bukovina	Habsburg Empire (with the exception of the Hungarian crown-lands)*
Land area	10.450 km^2	300.082 km^2
Triangulation points	276 *(in 1818-1820)*	12.589
Mapped cadastral units	319 *(in 1819-1823 and 1854-1856)*	30.556
Number of the cadastral parcels	798.707 parcels (the fewest in the Empire*)	49.138.140 parcels
Number of the map sheets	4.821	164.357
Average annual performance of a geometer	6.531 ha (the best in the Empire*)	-
Cost of the survey (geodetic and mapping activities)	328.000 Austrian guldens (the least costly in the Empire*)	17.583.000 Austrian guldens

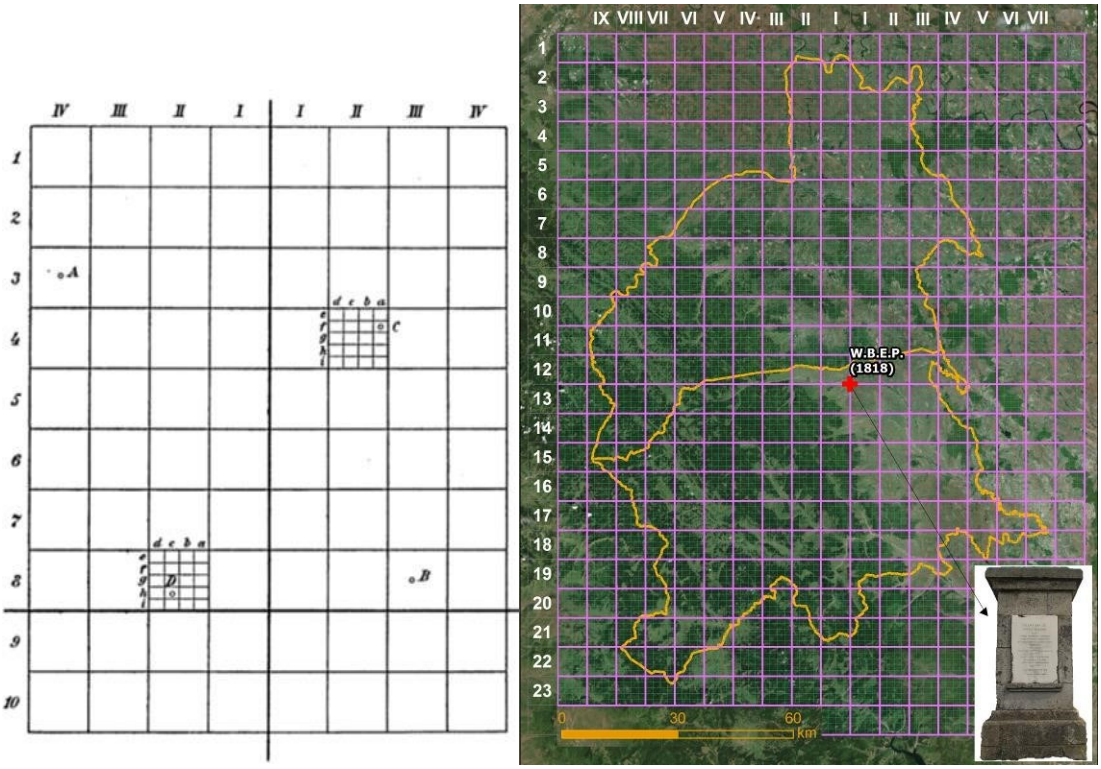


Figure 5 Labeling system of the historical cadastral system in Bukovina and the GIS reassembled Cassini index map.

For each grid cell there were 20 cadastral plan sheets at scale of about 1: 2.880, in the form of rectangles (4 columns x 5 rows, identified by letters) of 25x20 Austrian inches (zolls) (65,85*52,68 cm), corresponding to a geographical extent of 1000*800 Viennese fathoms (1896.48*1517.19 m). The labeling system is complicated enough; however, using the label of a sheet, one can easily compute the coordinates of the sheet corners from the origin point. The sheets were organized in files, according to the administrative cadastral units (cities and villages), each sheet is labeled by a single number in the file, and an overview map is given for each file to make a correspondence between these numbers and the general labels (Timar and Biszak, 2010).

The map datum of cadastral datasets of the 19th century is not available into GIS software by default, though these applications allow entering custom parameters - such as the characteristics of the ellipsoid (semi-major axis, semi-minor axis, inverse flattening), the prime meridian used and angular unit. According to the previous studies of Timar and Biszak (2010), Mastronunzio and Dai Prà (2016), the cadastral survey in the Empire used the Zach-Oriani 1810 hybrid ellipsoid (semi-major axis a=6376130 m; inverse flattening 1/f=310) and the Ferro prime meridian. For practical reasons the Ferro reference may be shifted to Greenwich subtracting the “Albrecht deviation” – 17° 39’ 46,02” (Timar, 2007).

After the definition of the ellipsoid, a Cassini-Soldner projection can be described using known geographical coordinates of the geodetic center (for the standard parallel and central meridian), a scale factor and a unit of distance.

Projection parameters used for Bukovina are related to the coordinates of the western endpoint of the Rădăuţi baseline, which can be found in the technical documentation of the K.K. Finanzministerium (1907). With the geodetic framework established, the index map providing the

four-corner coordinates of each single map-sheet can easily be reassembled and used for subsequent georeferencing (Figure 5). In order to improve the accuracy of the geographical positioning and to correct the orientation errors, a small rotation of 0.15° centered in the fundamental point of the grid is also required.

A further step entails the simple, geocentric translation of the historical datum to the contemporary global one - WGS84, using Molodensky-type parameters. The method applies a shift between the centers of the two geocentric coordinate systems based on the three components of the vector connecting the ellipsoid centers (dX, dY, dZ). However, these parameters are not available for the Rădăuţi coordinate system and required to be calculated using the inverse Molodensky equations.

Table 4 The coordinates of the western endpoint of the Rădăuţi baseline in the historical (from Greenwich) and modern geodetic systems.

Geographic coordinate	Historical local datum	WGS84
Longitude	25.81969	25.81335
Latitude	47.90624	47.90607

Using the known parameters of the historical ellipsoid, the coordinates of the geodetic reference point used for Bukovina (western endpoint of the Rădăuţi baseline) in the historical and WGS84 systems (Table 4) and taking the ellipsoidal height into account, the following Molodensky-type shift parameters were determined:

dX = +1722.48 m; dY = +306.78 m; dZ = +624.7 m

For the assessment of the contemporary ellipsoid height, the geoid undulations were considered (National Geospatial-Intelligence Agency Geoid Calculator) while for the historical datum ellipsoidal height equaled the mapped elevation (Affek, 2013). The resulted horizontal accuracy is less than 10 meters.

Figure 5 Georeferenced cadastral map sheet showing the position of the former Austrian fortifications in Gura Humorului.

Precise definition of the historical coordinate reference system, reconstruction of the grid lines and use of the datum transformation parameters allow the georeferencing and GIS integration of the historical cadastral maps without the need of ground control points. This could provide a valuable resource for the study of the changes of natural and built environment in Bukovina (Figure 5).

6. Conclusions

In the end of this review of the Habsburg geodesic and cartographic activities in Bukovina, it can be concluded that the geodetic baseline near Rădăuţi and the associated monument in Gălăneşti have been fundamental landmarks in the scientific description and cadastral mapping of province for almost a century. The stable triangulation network created here in 1818-1820 was the first of its kind in the present-day territory of Romania and allowed the cadastral mapping of the province in at least two chronological stages (1819-1823; 1854-1856). Bukovina was thus among the first provinces of the Habsburg Empire which benefited from the implementation of the stable cadaster, being advanced only by Lower Austria (1817-1824) and the Austrian Littoral (1818-1822). Through its central position within the local coordinate reference system used for the realization of cadastral plans, the monument in the western endpoint of the Rădăuţi geodetic baseline allows the reconstruction of the geographical position of the map sheets bridging the gap between the nowadays environment and the historical landscape of the 19th century.

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