Review of the Local Rectangular Plane Coordinates Systems Used in Polish Hard Coal Mines

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1.1 Introduction

The issues presented in the chapter are primarily related to legal regulations included in the Regulation of the Minister for the Environment of October 28, 2015, regarding surveyor – geological documentation, [11]. In accordance with Article 4, documents included in surveyor – geological documentation shall be prepared in compliance with the provisions of geodetic and cartographic law as well as the requirements specified in Polish Standards – Mining Maps. In paragraph 4 of the above-mentioned article, the possibility of creating documents included in the surveyor – geological documentation in the local geodetic systems was allowed, if the entrepreneur or an entity conducting activity not requiring a concession has the possibility of geodetic transformation of this system to the geodetic reference system, being an element of the state spatial reference system referred to in the provisions of geodetic and cartographic law. Relevant provisions in this scope are also include in the Polish Standard PN-G-09000-3:2002 [10], which requires maps to be made in the state coordinate system or in a local system, provided that all maps of the mining company should be prepared in one coordinate system. use this for the first paragraph in a section, or to continue after an extract.

Regulations regarding the mentioned state spatial reference system are contained in the Regulation of Council of Ministers of 15 October 2012, on the state spatial reference system [12], issued on the basis of the delegation contained in Article 3 of the Act of May 17, 1989, Geodetic and Cartographic Law [13]. It lists the following elements of the state spatial reference system. From the point of view of implementing the provisions of the Regulation, the PL-2000 system is important for running the surveyor – geological documentation. The spatial reference system, which should be used in Poland is the realization of regulation included in the Directive INSPIRE [8]. This directive is implemented in all European Union countries, which makes it possible to create databases that meet the interoperability condition of spatial data sets, which is particularly important to allow the full use of this data.

Taking into account the above, an important issue becomes the transformation of documents kept in the local systems into the state system. This issue was the subject of research carried out at the Silesian University of Technology in 2017 [7]. The issue was discussed partially in the paper [4]. As a part of their implementation, a review of the coordinate systems, used in hard coal mines in the region of GZW (Upper Silesian Coal Basin) was carried out. Archival materials and, made available by mining companies, mining cartographic materials were analyzed according to the state before the changes that took place in 2016. The coordinate systems used on archival mining maps as well as systems used in active mines in 2016 were distinguished. The elaboration in the following chapters presents a short description of the systems used in archival maps as well as the local coordinate systems, which were distinguished as the main ones.

In order to conduct research concerning the subject of this chapter, an analysis of available literature, technical and legal regulations as well as cartographic materials obtained from 29 hard coal mines operating in the region of the Upper Silesian Coal Basin were carried out in 2016. The analysis also included a comprehensive range of archival cartographic documents obtained from the resources of the Archive of the Higher Mining Office. The archive, in accordance with the applicable legal regulations in Poland, is obliged to collect the surveying and geological documentation of the closed mines. The analyzes were to separate the coordinate systems used on archival maps and those that were used in active mines in 2016, with the indication, in this case, of a system that was adopted as the main system. In the case of these last, characteristic of each of the systems was made with the determination of the ellipsoid, the used mapping and the method of determining the map section emblem for a rectangular sectional cut. Previous elaborations did not contain, in particular information on how to determine the emblem of the map section in the Sucha Góra system. Fig. 1 presented the location of analyzed hard coal-mines.

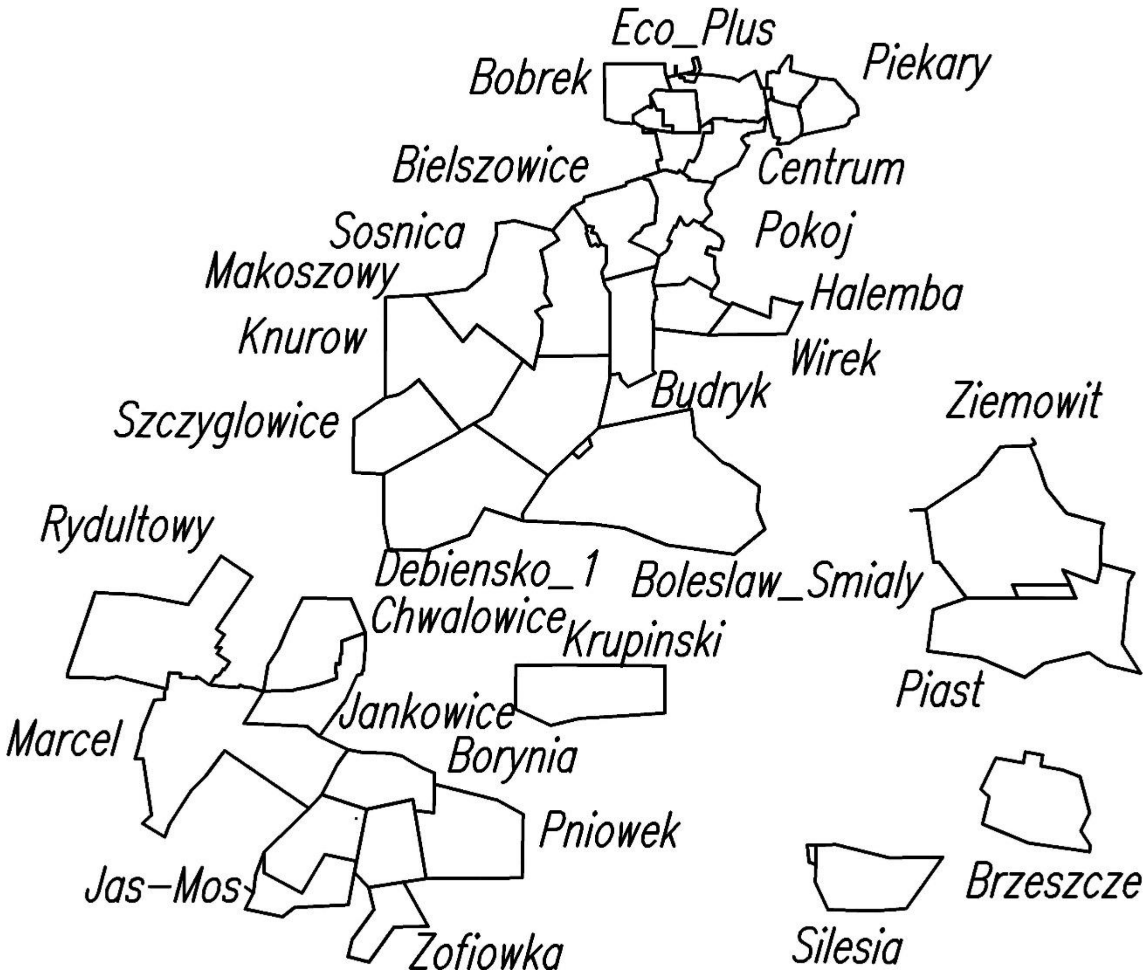

Fig.1. The location of the analyzed hard coal-mines; source: own elaboration.

1.2 The coordinate systems used on archival mining maps

Analyzes have shown that in the past, in Polish mining cartography over a dozen of coordinate systems of a supra-local and local importance were used. Mining maps created in the 19th century were made on the basis of geodetic control points, whose coordinates were determined in the systems that were in force on the territory of the partitioning countries.

Below is a brief overview of the most important ones:

(1) A system with the starting point in the Helmert Tower (German Helemertturm). Its former counterpart was the Raueuberg system. The reference surface was the Bessel ellipsoid. Its range overlaps with the former range of the German partition and includes the Recovered Territories, Western Pomerania and Silesia. The measurement campaigns

in those areas were conducted at different times, and in general, it can be assumed that at that time those systems were characterized by very good accuracy, comparable with the one being obtained on the basis of ongoing measurements, being performed with reference to the Borowa Góra system. The results of the triangulation, revealed in the form of coordinates in the Helemerrturm and Rauenberg systems, for the immediate practical purposes, were previously calculated in Soldner and then Gauss-Krüger projection. In general terms, their use consisted in incorporating those evaluations into the Borowa Góra system through appropriate coordinates transformation, and transition from the coordinates in Soldner projection to those in Krüger.

(2) The system with the Hermansskogel starting point. The range of occurrence of this system on the Polish lands coincides with the extent of the Austrian annexation. However, it did not present any practical value, as the triangulation points in this system were spaced far apart from each other (20 – 30 km). This system also used the Bessel ellipsoid.

(3) The system with the starting point on the Mount of the Union Lublin in Lviv. This system also included the areas of the Austrian partition, and its triangulation was made independently of the 1st order triangulation in the territory of Austria. The problematic issue was the fact that projection used in its case was unknown, although it showed many features in common with Soldner projection. This triangulation, even in the 1950s, was of considerable economic importance, as it was still used for cadastral purposes.

(4) The system with the point of application in Zegrze (Borowa Góra). This system was officially introduced for use in 1936 by the Military Geographical Institute (WIG). Maps in this system were created using the Bessel ellipsoid and the quasi – stereographic projection. A solution simplifying the introduction of mathematical formulas for Roussilhe projection was used. In 1947 a resolution was passed within the framework of the second session of the State Measuring Council, which stated that the country maps would be created in Gauss – Krüger projection while maintaining the Bessel ellipsoid and the point of its application in Borowa Góra. The Polish area was divided into the four three-stages meridional bands, each of which had an independent coordinate system. Analogously to the pre-war naming – also in this case, the largest cities located in a given area were used. As a result, the following systems were created: Szczecin system for a band with a longitude of 15°, Bydgoszcz system for a band with a longitude of 18°, Warszawa system for a band with a longitude of 21°, Białystok system for a band with a longitude of 24° (Kowalczyk 1959).

(5) Systems in the area of the Upper Silesian region – Pszów and Sucha Góra. The first of the considered systems, with the point of application in Pszów, was used for cadastral purposes. The second one, with the application point in Sucha Góra, near Tarnowskie Góry, was adopted for mining purposes. In both cases Soldner projection was used, and the considered systems were a part of the Helemertturm (Rauenberg) system. None of them, however, did not have any connection with the system of Borowa Góra that was obligatory in Poland, neither in the Upper Silesia area nor in its vicinity [1]. The Sucha Góra system is characterized in detail in the subchapter 3.1.

(6) The system with the point of application in Pułkowo – ‘1942’. The system 1942 was introduced for use in Poland by a resolution of the Presidium of the Government in 1953. It was realized on the basis of Gauss-Krüger projection, in three or six-stages bands (depending on the scale of elaboration). The area of the country was divided into four zones for large-scale elaborations (1:5000 and larger) and for two zones for small-scale elaborations. It survived in the civil service slightly over ten years and was replaced in the mid-sixties by the 1965 system, but military elaborations were being realized using it until the 1990s [14].

(7) The system ‘1965’- A flat rectangular coordinate system used for civil works from the moment of its introduction in 1968, until its replacement by the system ‘2000’, in 2010.

(8) In addition, it should be emphasized that there were a number of coordinate systems applied locally or regionally. A perfect example is the use of the GOP I, II, III and SG-ROW systems for a properly divided area of the Upper Silesian Industrial District and the Rybnik Coal District. In the Lublin Coal Basin the LZW system was used [2].

1.3 The coordinate systems currently used in the underground hard coal mining companies

Researches on the currently used local coordinate systems in the mining companies exploiting hard coal, including 29 mines according to the state before the restructuring changes in 2016, revealed that they run cartographic documentation basically in the Sucha Góra, Borowa Góra, and 1965 coordinate systems, and due to the obligatory legal regulations, in the PL-2000 coordinate system. For forming of the specific systems for running surveyor-geological documentation in the mines concerned, affected both the period in which they were created and organizational changes. The main systems used in almost all analyzed companies are the Sucha Góra or Borowa Góra local systems. At the same time, it should be emphasized that the most common Sucha Góra system, in each of the analyzed cases, occurs in a variation using Cassini-Soldner projection, which determines turning the abscissa axes to the south [9]. In some cases, the subject companies adopted the *X* axis, directed to the north, despite the above-mentioned projection. It can be assumed that it was dictated by practical reasons. The figure 2 shows the number of mines in which the above-mentioned systems are used, and the number of mines, in which these systems are used as the main system.

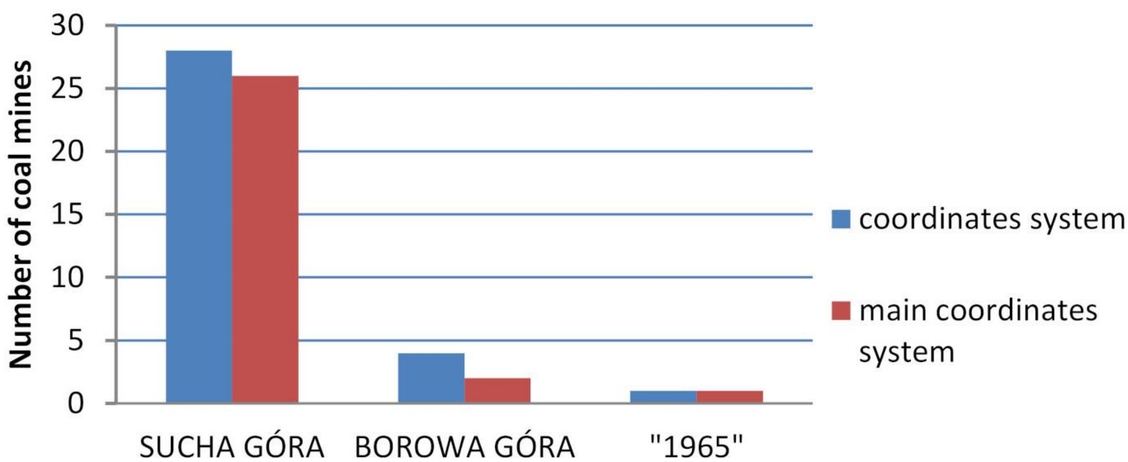

Fig.2. A distribution of types of flat rectangular coordinate systems used in the analyzed mining enterprises as at the end of 2016; source: own elaboration.

The results are particularly important, because as it was mentioned earlier and due to the obligatory legal regulations, it is necessary to ensure, by mining companies, the possibility of transforming rectangular flat coordinates from the local system to the PL-2000 coordinate system.

1.3.1 The Sucha Góra System

General information on the Sucha Góra system, indicated only its occurrence on the Upper Silesia area, but what is more important from the point of view of objective elaboration - indicated that it is used by hard coal mines [1]. It also appears in literature as a local system, generally used in Silesia [6]. This system is available in two versions. In the first place it should be indicated that this system can be characterized by two different reference surfaces. In the initial period, the surface of the sphere was adopted using the modified Cassini- Soldner equidistant projection [2,3]. In this version, the radius of the sphere was taken as the average radius of curvature of the Bessel ellipsoid at the starting point [3], whose coordinates are: φ_0 =52024’42,89”, λ_0=36032’39,97”.

In addition, the sphere and ellipsoid are characterized by a common parallel which passes through the starting point of the system [2]. Originally considered projection was designed by Soldner in such a way that the flat rectangular coordinates system resulted directly from the spheroidal system on the ellipsoid, which was expressed in dependencies (1, 2):

$$\xi = X_s \quad (1)$$

and

$$\eta = Y_s \quad (2)$$

where:

ξ, η -spheroidal coordinates of the point,

Xs, Ys- the coordinates of representation of the point on the plane.

What is important in the case of the Sucha Góra system, is the question of the axes of the system. The axis *X*, which is the representation of the meridian passing through the beginning of the system, is directed to the south – the coordinates calculated from the starting point take positive values southward [2,3]. When considering the *Y* axis, it is important to indicate different descriptions of the authors. Both Rajnich [3] and Maciaszek [2] indicate that it is the realization of a geodetic line perpendicular to the *X* axis at the starting point. However, in the first case there is an indication that the coordinates calculated from the starting point take positive values eastward, while in the second case, westward. The Sucha Góra system, using this projection, was used on the mining maps of mining companies conducted ore mining in the region of Piekary Śląskie and Bytom, and also hard coal mining in the area of Rybnik and Bytom [2].

The second variation of the subject coordinate system characterize the application of Gaussian conformal projection with the use of a reference surface in the form of an elliptic cylinder, tangential to the Bessel ellipsoid at the starting point of the system. This case is complicated enough, because it works on an already existing coordinate system and introduces the new one, i.e.:

- the current system that uses the spheroidal coordinates in the Soldner projection system, discussed above (X_S, Y_S),
- a new system that uses flat coordinates in Gaussian projection (X_G, Y_G).

Conversion between the discussed coordinates can be made on the basis of the following dependencies:

$$X_G = X_S \qquad (3)$$

and

$$Y_G = Y_S + \frac{Y_S}{6N^2} \qquad (4)$$

where:

X_G, Y_G– flat coordinates in Gaussian projection,

X_S, Y_S - spheroidal coordinates in Soldner projection,

N -the radius of curvature of the meridian of an ellipsoid in the first vertical [2,3].

This version of the Sucha Góra system was used, among others, in the vicinity of Sosnowiec and it resulted, among others, from the fact that a triangulation of the Zagłębie Dąbrowskie area was conducted by using it in 1926 [2]. What is important, the system using Gaussian projection is also characterized by differently directed axes - the X axis is calculated northward, and the axis Y eastward [2,3]. This is tantamount to a different numbering of quadrants, which together transfers to the occurrence of slight coordinate differences in both systems, what at the accurate measurements was leveled with the use of corrections to each corner of the map sheet. The corrections came from the Beyer ‘s tables.

The authors did not find any indication for a sectional division for the Sucha Góra system among the available literature and other source materials. However, the analysis of currently used maps and cartographic elaborations, which are in use both in mining companies and in some Geodetic and Cartographic Documentation Centers, allows to distinguish one of the many systems of marking the sections in this system. It was chosen to be shown due to the unified form.

According to it, the 1:10000 scale section is marked, for example, as -25 -8, which means a negative value of 25 kilometers from the beginning of the vertical layout, and a negative value of 8 kilometers from the beginning of the system in the horizontal layout. This indication directly translates to the coordinates of the lower left corner of a given section. The sheet in this scale is divided into 4 sheets in the 1:5000, for which to the source emblem a small letter in the range of a-d is being written (fig. 3). For example: -25-8a.

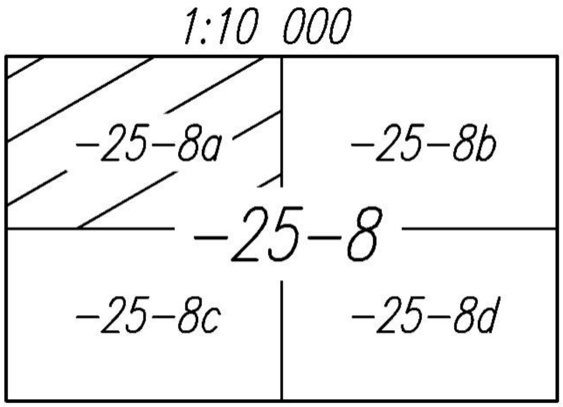

Fig. 3. The example of dividing a sheet in 1: 10000 scale into sections 1:5000 for the Sucha Góra system- e.g.-25-8a; source: own elaboration.

The second option is to divide the source sheet in a 1:10000 scale into 25 sections in the scale of 1:2000, which are being marked by writing to the starting emblem the number in a parenthesis, in the range of 1- 25, separated from the original emblem by a separator in the form of a dash (fig.4). For example: -25 -8 – (23).

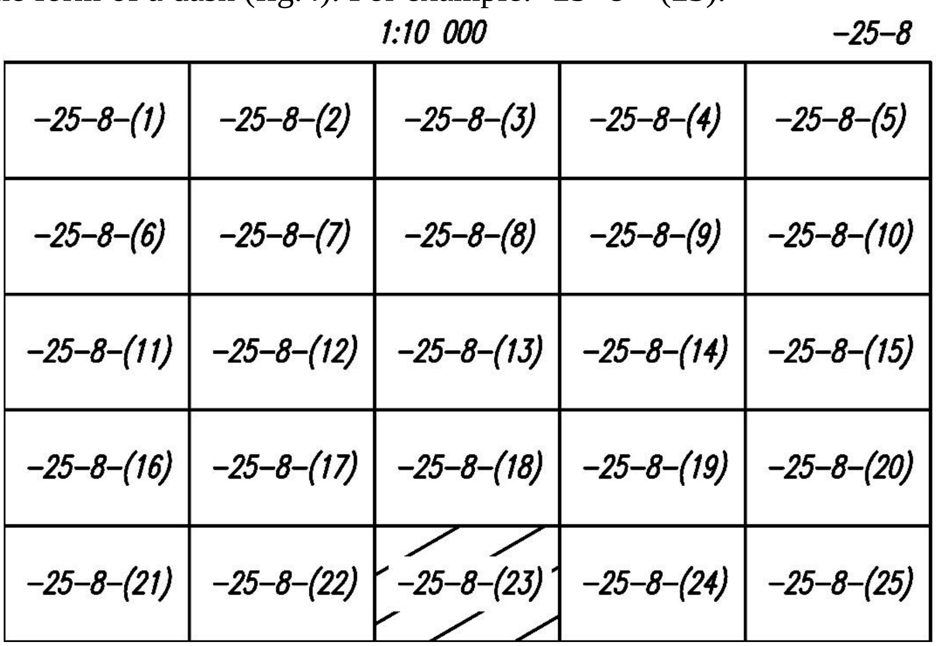

Fig. 4. The example of dividing a sheet in 1: 10000 scale into sections 1:2000 for the Sucha Góra system- e.g.: -25 -8 – (23); source: own elaboration.

The sheet in the scale 1:2000 is divided into 4 sheets in the scale 1:1000, for which the emblem consists of the emblem of the section in the scale 1:2000 with a small letter in the range of a-d being written to the number in a parenthesis, separated with a dash (fig. 5.). For example – 25 – 8 – (23 – a).

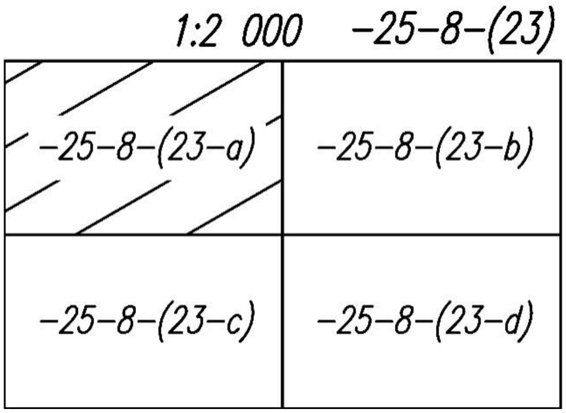

Fig. 5. The example of dividing a sheet in 1:2000 scale into sections 1:1000 for Sucha Góra system- e.g. – 25 – 8 – (23 – a); source: own elaboration.

The last division is the cut of the 1:1000 sheet into 4 sheets in the 1:500 scale. In this case, to the emblem a number in the range of 1-4 is being written again, it is placed directly after a small letter in a parenthesis (fig. 6). For example: - 25 – 8 – (23 – a4).

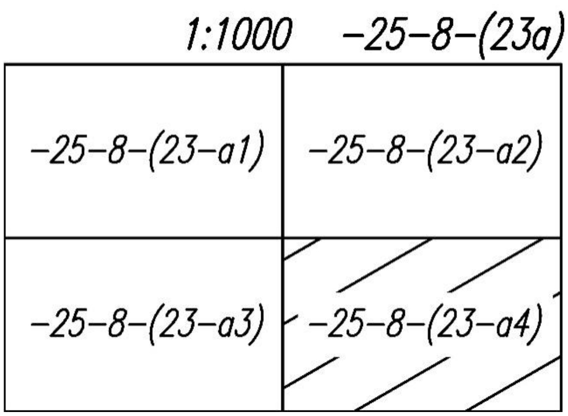

Fig. 6. The example of dividing a sheet in 1:1000 scale into sections 1:500 for Sucha Góra system- e.g. - 25 – 8 – (23 – a4); source: own elaboration.

However, it should be noted that in the case of mining companies, the sectional division for the Sucha Góra system was regulated by appropriate standards, which only showed that the cut of the section was to be rectangular, and their size adjusted to the needs of the mining companies [9]. As a result, the encountered mining maps in a sectional cut for the Sucha Góra system very often differ significantly among the companies, also on the issue of the adopted designations of the emblems.

1.3.2 The Borowa Góra system in mining

The system Borowa Góra was also used in the surveyor and cartographic works in the mining companies. The rules of its application as well as the issues of parameters, and the rules for determining the coordinates, in this case, were regulated by the mining standards. The oldest one, which the authors managed to reach, comes from 1961 [9]. It gives the following characteristic of a system:

- The reference surface is the Bessel ellipsoid with the following parameters: the length of a semi-major axis a=6377397,155 m, the length of a semi-minor axis b= 6356078,963 m, flattening f=0,003342773182, eccentricity I e^1= 0,006674372231, eccentricity II e^2 = 006719215795.
- The point of application is Borowa Góra with the following geographical coordinates: φ_0 = 52028'32,85'',λ_0= 21002'12.12''
- The scale distortion factor in the axial meridian is 1.
- For the calculation of the flat rectangular coordinates, the standard [9] cites the division of the Polish area into the three-stages bands for application, and the axle system for the Borowa Góra system in the civilian use. The images of meridians with an eastern geographical longitude of 15°, 18°, 21°, 24° are the axes of abscissas of the coordinate systems of particular bands. The initial value of the Y coordinate in particular zones is respectively: for the axial meridian 15°- 5 500 000m, 18°- 6 500 000 m, 21° - 7 500 000m, 24° - 8 500 000m.

Sectional division for the system Borowa Góra, used in mining, was described in a standard [9]:

- The sections take a shape of a rectangle.
- The sheet constituting the basis for the division is the 1:10000 scale section, which takes the designation from the name of the largest town, located in a given area, according to the 'Maps of the Use of the Earth's Surface;'.
- This section is divided into four sheets in a 1:5000 scale, marked with capital letters in the A-D range. For example: Katowice A (fig.7).

A	B
C	D

Katowice A

Fig.7. The example of dividing a sheet in 1:10000 scale into sections 1:5000 for Borowa Góra system-section *Katowice A*; source: own elaboration.

• The second option is the division of the source sheet into 25 sheets in 1:2000 scale, each of which is marked with a Roman number in the I – XXV range. For example: Katowice IX (fig.8).

I	II	III	IV	V
VI	VII	VIII	IX	X
XI	XII	XIII	XIV	XV
XVI	XVII	XVIII	XIX	XX
XXI	XXII	XXIII	XXIV	XXVI

Katowice IX

Fig.8. The example of dividing a sheet in 1:10000 scale into sections 1:2000 for Borowa Góra system- e.g. section *Katowice IX*; source: own elaboration.

• What is important, the sections in a 1:1000 scale are obtained directly from the division of the sheet in a scale of 1:10000. It is divided into 100 sections marked with Arabic numbers in the 1-100 range. For example: Katowice 12 (fig.9).

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	34	35	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70
71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	98	98	99	100

Katowice 12

Fig.9. The example of dividing a sheet in 1:10000 scale into sections 1:1000 for Borowa Góra system- e.g. section *Katowice 12*; source: own elaboration.

• The sheet in 1:1000 scale is divided into four sections in a scale of 1:500, each of them is marked with a small letter in the range of a – d. For example: Katowice 12a (fig.10).

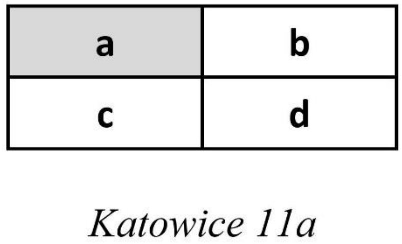

Fig.10. The example of dividing a sheet in 1:1000 scale into sections 1:500 for Borowa Góra system- e.g. section *Katowice 12a*; source: own elaboration.

1.4 Summary

The issue presented in the chapter is the result of research carried out in 2017 at the Silesian University of Technology [7], concerning accuracy assessment and determination of transformation parameters of the local flat rectangular coordinate systems to the state system PL – 2000. As a result of these studies realization, it was found that in the past, several coordinate systems of supra-local and local importance were used in Polish mining cartography. In the chapter, the most important ones are briefly characterized. In detail, there are presented the local flat rectangular coordinate systems, being currently most often used as the main ones, it is the Sucha Góra, Borowa Góra systems, including also information on the principles of creating a sectional division in particular systems. The described principles of division and marking of the sections, were developed on the basis of map analysis and cartographic elaborations, which are being used both in mining companies and in some Geodetic and Cartographic Documentation Centers.

The described issue should be considered as very important:

- due to the fact that the obligatory legal regulations impose an obligation on mining entrepreneurs of geodetic transformation of documents elaborated and carried out in the local coordinate systems to the geodetic reference system, in this case to the PL-2000 system.
- Due to the fact that almost in all analyzed mines, with the exception of one, the local coordinate systems are used, it is important to develop an appropriate transformation algorithm, allowing it to be carried out with the required accuracy.
- These data can support spatial databases, in particular those created within individual data issues included in the annexes to the INSPIRE Directive.

- In a situation in which currently mining enterprises are being closed, the appropriate scope and quality of data is important for the management of the postindustrial and degraded areas, including the use of these data in the GIS systems. Such systems should be supported with data already transformed or should be able to transform coordinates from the local systems to the state system. For this purpose, it is necessary to equip these systems with modules allowing introduction or development of the transformation factors at the required level of accuracy.

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