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Use of the Ott's system of coordinate for the protection of buildings and people in the Ostrava-Karvina Coal District

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ABSTRACT

The aim of this article is to determine the coordinates of the points of Ott's Coordinate System in contemporary obligatory reference coordinate systems, which means the coordinate system of Datum of Uniform Trigonometric Cadastral Network. Optimal transformation relations have been searched in such a way, so as not to disturb the accuracy of calculations and measurements acquired in Ott's triangulation. Ott's system of coordinates was and is hugely important particularly during the remediation works performed between 1996 and 1998, aimed at removing the consequences of coal mining in the Ostrava-Karviná Coal District.

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1. Introduction

The mine-district system of coordinates for mines located in the Ostrava Region was established in 1858 by Ing. František Ott, Surveyor of the Emperor Ferdinand Northern Railway (Severní dráha Ferdinandova), who carried out mine triangulation within the western part of the Ostrava-Karviná Coal District.

The coordinate axes of Ott's coordinate system were parallel to the axes of the Austrian St. Stephen Datum of Cadastre Coordinates valid for the territories of Lower Austria, Moravia, Silesia and Dalmatia. Due to a reliance on using compasses, the choice of coordinate axes adapted to mine mapping habits; thus the positive x-axis pointed to the north and the positive y-axis pointed to the east.

When calculating the surface area of mining fields displayed as units, corrections from cartographic distortion in lengths or angles were not applied due to the small areas being studied. The values which held a great level of interest for mine surveyors included the convergence of meridians, magnetic declination and the convergence of medians. A reference to Ott's study is used in a book written in Kurrent, a German neo-Gothic script, dating back to the period between 1870 and 1880, which contains calculations and coordinates of all mine shafts and mine outlets in Ott's system of coordinates.

In some mines in the Ostrava-Karviná Coal District, the Ott system of coordinates was still in use up until the 1970s; even today, its practical value lies in its ability to trace and liquidate old mine outlets or test and survey prospective shafts with the use of this system.

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2. Methods

2.1. Ott's triangulation

In order to achieve a reliable connection in mine surveying operations and due to the large area of mining fields per square mile, the method of triangulation was used for all surveys of the mining fields in the Ostrava Coal District in Ott's system. In light of the planned opening of mining fields, trigonometric networks were set up and their vertex points were located at elevated points where possible.

When using triangulation, it is first necessary to measure the exact length of at least one side of the trigonometric network triangle. The length of all sides of the trigonometric network triangle can then be derived from this length and the angles measured. If the trigonometric network covers a large area, it is necessary to select and measure the exact lengths of more than one side. Due to the long lengths of the trigonometric sides, this issue is usually solved by using a “geodetic base line” which is shorter and enables the calculation of the length of the first trigonometric side based on the measured angles and lengths.

The Emperor Ferdinand Northern Railway was selected to act as base line A in Ott's trigonometric network. The direction of the base line was set in parallel with this railway, 3.66 feet (1.156 m) from the main yard. The start point of base line A was set to the east of Ostrava's main railway station and it was stabilized using the aforementioned method of stabilization of trigonometric points. The direction of the base line was set by the Breithaupt theodolite. The intermediate points of the base line were set up within a distance of approximately 30 fathoms (56.89 m) by means of poles into which nails had been driven. The terminal point of the base line was situated at the Hrušov railway station.

The second base line (baseline B) was situated in Michálkovic, and it measured 103.251 fathoms (195.813 m). It was considered a control base line for the measurements carried out in the trigonometric network. Both base lines were measured repeatedly. The general principles of the creation and measurement of base lines are described in Ott (1859).

2.2. Ott's system of coordinates

The X-axis of Ott's system of coordinates was set in accordance with the third sheet line of the east column XIX to the west (dc) and the Y-axis in accordance with the fourth sheet line of the 9th layer to the south (hi) of the S-SK system (see Fig. 1). The intersection point of the said column and layer is the origin of the Ott system of coordinates and is marked on the map of the triangulation network as a red point. The origin was situated in the municipality of Záměst, 240 fathoms to the north of Josef-Schachte (Mine Joseph) and 50 fathoms to the east of Rothschild's Uhelná Street leading to Hrušov.

Ott's system of coordinates was connected to the St. Stephen Datum of Cadastre Coordinates by surveying the points from the second order cadastral triangulation in the territory of the “Ostrava Region”, where two geometers, Ploebst and Schmitt, worked between 1822 and 1824. These points were the churches (church towers) in the municipalities of

Vratimov (Ratimow), Hošťalkovice (Hostialkowitz) and Vrbcice (Wirbitz). At present, the coordinates of these points in fathoms can be found in the Central Archives of Surveying and Land Register (CASLR), namely in volume A2/b/S4 titled “Determination of triangulation results and topographical descriptions of trigonometric points” (1821–1829).

The church towers were surveyed from point F (see Fig. 2), which belonged to Ott's system of coordinates, and was situated on an old spoil tip in Muglinov. Its coordinates were determined by the resection method and served as the basis for deriving the azimuths of individual sides of triangles and for calculating the coordinates of individual points.

The X-axis of the Ott system of coordinates was parallel to the X-axis of the datum of the stable cadastre system passing through the main tower of St. Stephen's Cathedral in Vienna. The relationship between Ott's system of coordinates and the St. Stephen Datum of Cadastre Coordinates is determined by linear transformation:

$$y = y_0 + Y' \cos \psi + X' \sin \psi, \quad x = x_0 + X' \cos \psi - Y' \sin \psi, \quad (1)$$

where $y_0 = -138.443.332$ m, $x_0 = -183.579.651$ m are the coordinates of the origin of the Ott's system in S-SK, Y' , X' are the coordinates in the St. Stephen Datum and $\psi = 180^\circ$ is the angle between Ott's coordinate system meridian and the meridian of the St. Stephen Datum.

2.3. Significance of the Ott system of coordinates in the past and at present

Ott's triangulation was important for the accurate determination of the position of mining fields granted by the state as a lease. This was done by surveying the boundary markers of mining fields and calculating their coordinates, which were then used as the basis for the calculation of other corner markers of mining claims and surpluses based on the lengths and directions defined in the demarcation records. A mining claim (Section 42, 46 in (Emperor's Patent, 1854)) was an area in the shape of a rectangle with an area of 45.116 m² on the horizontal level of the gauge point. The gauge point (Section 45 in (Emperor's Patent, 1854)) was a point from which the mining claim was measured and it had to be situated in an opened part of the deposit inside the mining field that was to be granted as a lease (a mining lease was the right to extract reserved minerals). Within one year of the date of the lease, each leased mining field had to be surveyed and landmarked on the surface in accordance with the lease certificate and the map showing the mining claims. The land-marking conducted was recorded in the demarcation record in which each landmark position was described and plotted on the map of mining claims (Section 50 in (Emperor's Patent, 1854)). A surplus (Section 71 in (Emperor's Patent, 1854)) was an area locked by mining claims, in which it was no longer possible to place a whole mining claim. In the case of new leases, the corner markers of mining fields were determined in coordinates which helped eliminate the lengthy process of determining the leased mining fields pursuant to Sections 64–66 (Emperor's Patent, 1854). The demarcation lines, which defined the boundaries of coalfaces belonging to different

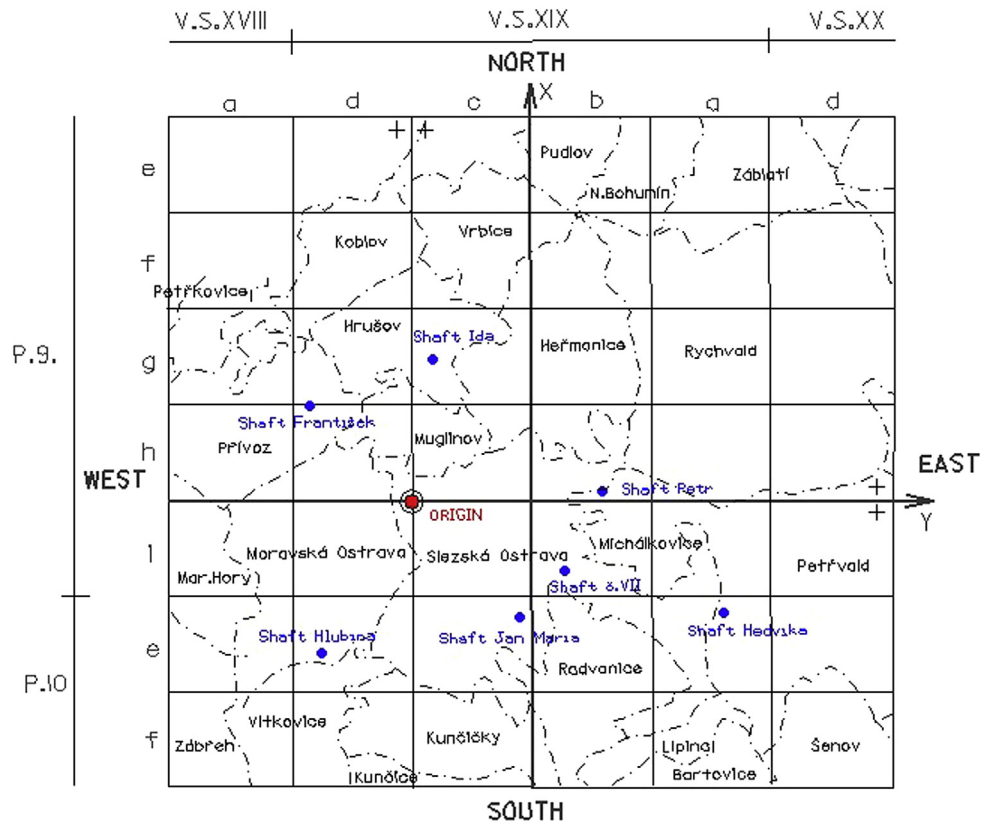


Fig. 1 – Ott's system of coordinates (Vykuřil, 1982).

mining companies, were determined by the triangulation method. This enabled the achievement of the required accuracy of demarcation of neighbouring mines' boundaries.

The geodetic bases formed by the points of Ott's triangulation were determined as entirely local systems. The connection of Ott's trigonometric network to the cadastral triangulation was performed in order to define mutual relationships between the St. Stephen Datum of Cadastre Coordinates and Ott's system of coordinates which was necessary in order to demarcate mining claims and surpluses.

The Ott system of coordinates is still in current use; this was particularly important during remediation works aimed at removing the consequences of coal mining in the Ostrava-Karviná Coal District between 1996 and 1998. The liquidation of mine outlets in the Ostrava part of the Ostrava-Karviná Coal District was carried out in compliance with the Czech Mining Authority Regulation No. 52/1997 Coll., as amended (Regulation, 1997). This regulation sets out the requirements for health and safety at work and for operational safety during the liquidation of mine outlets leading to the surface and mining works leading to these outlets during mining operations and during the extraction of non-reserved minerals underground. After the liquidation of these mining works, a final report is prepared, which must include, among other things, the identification and categorization (passportization) of mine outlets leading to the surface or approaching the surface. This process includes a record sheet of the relevant mine outlet which must contain, in addition to the name of

the shaft (adit), the x-axis and y-axis coordinates of the shaft in the valid system of coordinates in accordance with Regulation No. 435/1992 Coll., as amended (Regulation, 1992). For the purposes of passportization, it was necessary to highlight, in the terrain, the mouths of all active and old mine outlets dating back to the period of the oldest mining activities. The coordinates of the position of old mine outlets were determined by graphical transformation through identical points on the maps of the land cadastre and real estate cadastre, or by linear transformation to the S-SK system and subsequently using the Helmert transformation to the Datum of Uniform Trigonometric Cadastral Network ("SJTŠK") system. For safety reasons, after the determination and verification of the shaft mouth or adit position in the terrain (by geophysical measuring and drilling), an area was marked out on the surface in which the mine air could rise and endanger public health due to the passportized mine outlets in the Ostrava region of the Ostrava-Karviná Coal District ranking among gassy coal mines with the potential for the escape of methane gas to the surface.

The methods of surface, mine and elevation measurements are described in detail in *Ředitelská konference OKR (1928)*.

2.4. S-OTT, S-SK and S-JTŠK

To transform points from the Ott system of coordinates to the Datum of Uniform Trigonometric Cadastral Network system,

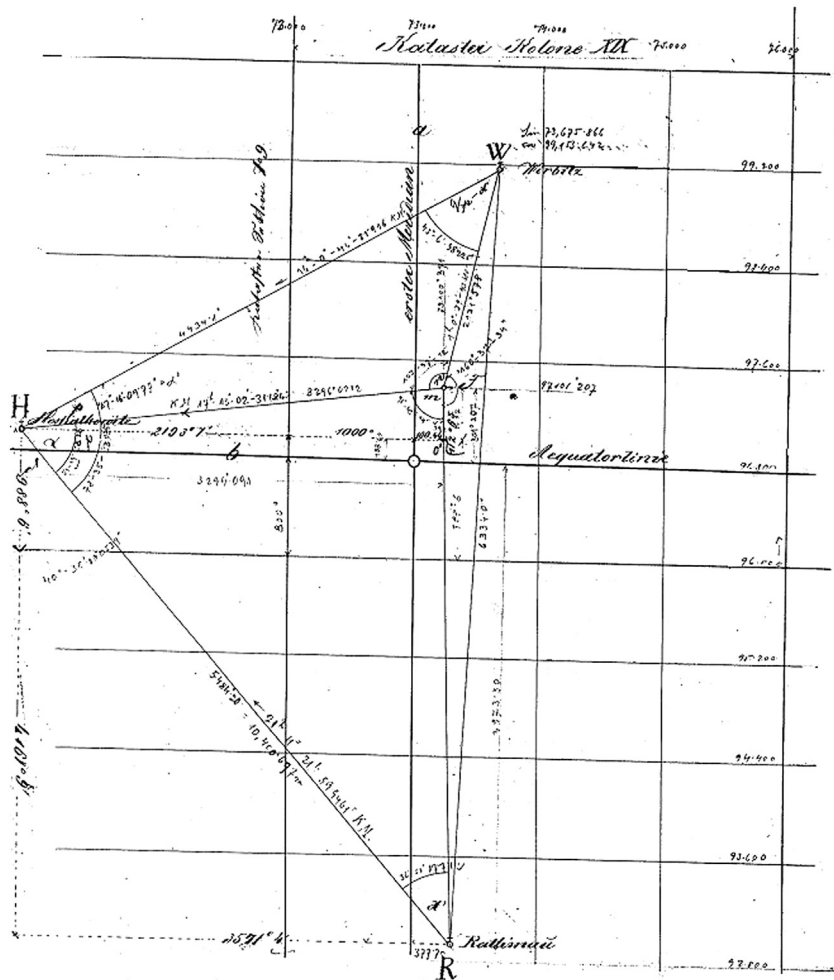


Fig. 2 – Connection of the Ott system of coordinates to the St. Stephen Datum of Cadastre Coordinates (Ott, 1859).

it is necessary to select identical points for transformation and to determine a transformation key in such a way that the accuracy of the measurements achieved by Ott's triangulation is adhered to.

The main problem in determining this transformation key is the area where the entire of Ott's system of coordinates is set. This area is distinct in that it has been undermined to every extent. This area includes, in particular, Slezská Ostrava and parts of Moravská Ostrava, Přívoz, Muglinov, Michálkovic and Heřmanice. Fig. 3 shows the names of the cadastral areas in red and their borders in green. The points of Ott's triangulation network are marked in black.

The first step was to transform all of the points from the Ott system of coordinates (124 points) into the St. Stephen Datum of Cadastre Coordinates using linear transformation.

2.5. Transformation between the St. Stephen datum of cadastre coordinates and the datum of uniform trigonometric cadastral network system in Moravská Ostrava and Přívoz

The Land Registry for the Moravskoslezský Region, based in Ostrava, provided the summary of a network of points (see Fig. 4) and a list of coordinates of the trigonometric points

which were used in the review and update of the land and real estate register and cadastral maps in the 1970s. These were identical points situated in two cadastral areas, i.e. the cadastral area of Moravská Ostrava and the cadastral area of Přívoz.

The transformation keys for the aforementioned cadastral areas were determined by means of a similarity transformation.

The transformation used is linear; in general cases, both systems are identified at a single point, i.e. in the center of gravity of identical points. With regards to all the other points used for determining the transformation key, it applies that the coordinates transformed from one system to another do not generally equal the coordinates given in the other system (they only meet the condition of the minimum sum of error squares).

The parameters of the transformation key include the angle expressing the mutual rotation of these coordinate systems ω , translation vector $\vec{t} = (t_x, t_y)$ and scale factor m , which is the ratio of any two corresponding lengths in both systems (see Fig. 5). Rotation angle ω is defined as the bearing of the positive x axis of the system (x, y) from which the points are transformed, with respect to the system, into which the points are transformed (X, Y) . In a similarity transformation, the scale factor is the same for all directions and $m \neq 1$.

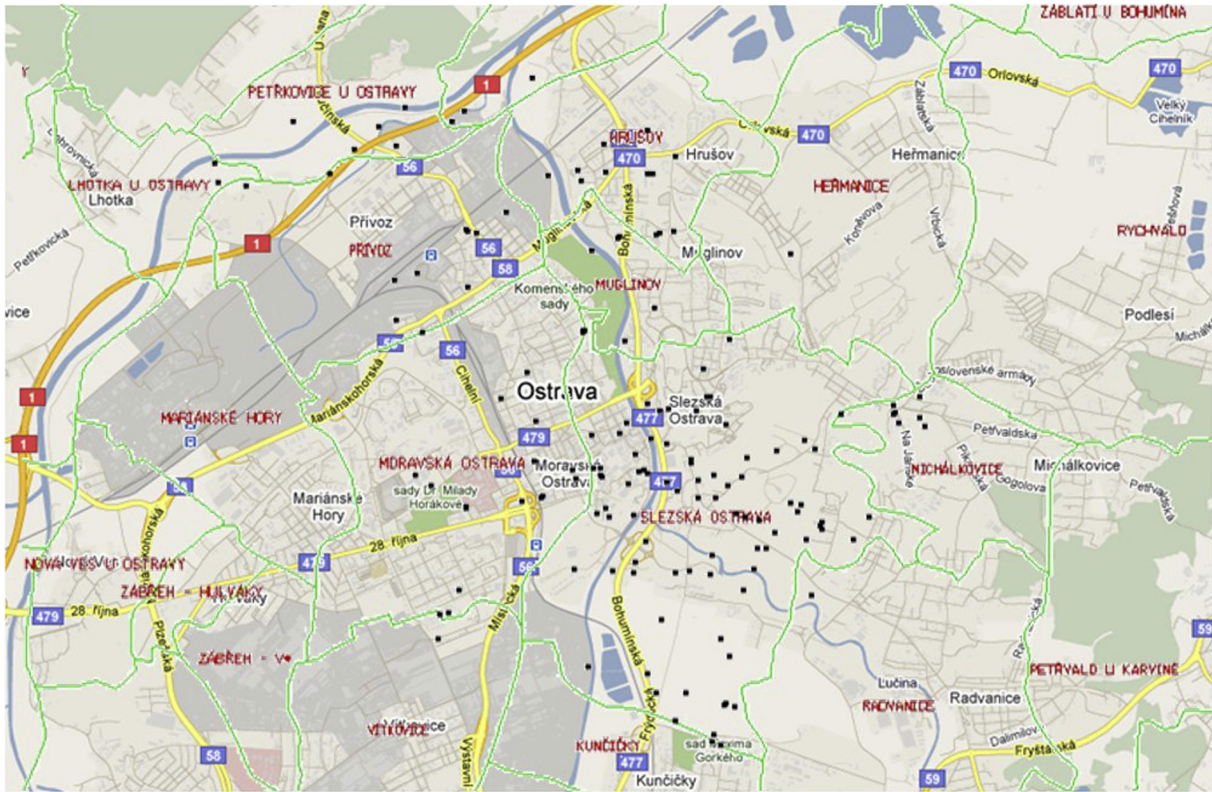


Fig. 3 – Points of the Ott system of coordinates in Ostrava.

To determine the transformation key $\vec{h} = (a, b, t_x, t_y)$, where $a = m \cos \omega$, $b = m \sin \omega$, it is necessary to know four coordinates, i.e. at least two identical points whose positions are known in both systems. The similarity transformation equation is expressed in the matrix notation:

$$\begin{pmatrix} X \\ Y \end{pmatrix} = \begin{pmatrix} t_x \\ t_y \end{pmatrix} + m \begin{pmatrix} \cos \omega & -\sin \omega \\ \sin \omega & \cos \omega \end{pmatrix} \cdot \begin{pmatrix} x \\ y \end{pmatrix} \quad (2)$$

$$\vec{X} = \vec{t} + m \cdot R \cdot \vec{x} \quad (3)$$

The calculation of transformation coefficients is made by adjusting the formula and substituting the identical points from the equation for the unknown vector of transformation coefficients.

$$\begin{pmatrix} X_A \\ Y_A \\ X_B \\ Y_B \end{pmatrix} = \begin{pmatrix} x_A & -y_A & 1 & 0 \\ y_A & x_A & 0 & 1 \\ x_B & -y_B & 1 & 0 \\ y_B & x_B & 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} a \\ b \\ t_x \\ t_y \end{pmatrix} \quad (4)$$

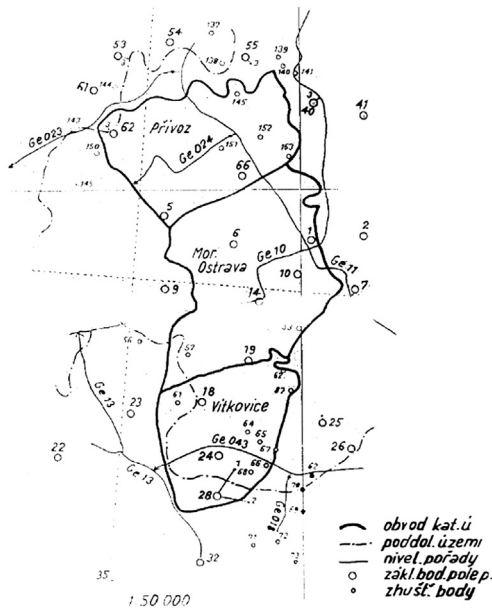


Fig. 4 – Overview of a network of points used in the review and update of the land and real estate register and cadastral maps in Ostrava.

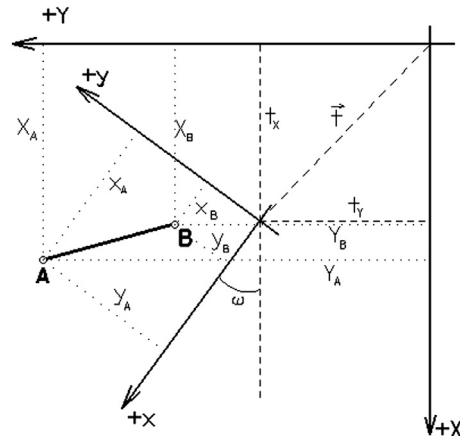


Fig. 5 – Similarity transformation.

$$\vec{X} = \mathbf{A} \cdot \vec{h}. \quad (5)$$

The vector of unknown transformation parameters is calculated by means of an inverse matrix:

$$\vec{h} = \mathbf{A}^{-1} \cdot \vec{X}. \quad (6)$$

The accuracy of the transformation for Moravská Ostrava and Přívoz are specified in Table 1. The values of accuracy are only expressed in millimetres because of the comparison that takes place between their small values. However, the original accuracy value remains the same as in the case of input coordinates.

Table 1 – Accuracy of the similarity transformation for Moravská Ostrava and Přívoz.

Cadastral area	No. of identical points	m_x [m]	m_y [m]	$m_{x,y}$ [m]
Přívoz	8	0.001	0.003	0.002
Moravská Ostrava	18	0.003	0.003	0.003

The method described above was used for the calculation of local transformation keys between the St. Stephen Datum of Cadastre Coordinates and the S-JTSK system for the cadastral areas specified above. However, as already mentioned, these areas lie in an undermined area. Moreover, the small values of accuracy are misleading and instead indicate a transformation carried out earlier. There is also no documentation confirming the accuracy and origin of the said points and it is necessary to take into account the historical development of the city and its extensive construction boom triggered by coal mining and the industrial processing of coal.

The area of the Ott system of coordinates is located to the southwest of these locations and, therefore, the area for the determination of the transformation key was extended to cover the territory of the former Těšín Region in the period of the formation of the Stable Cadastre. If we use the points of the first-, second- and third-order geodetic base of the Stable Cadastre in Moravia and Silesia, we can identify the origin and accuracy of their creation as data regarding the accuracy of measurements in the first-, second- and third-order trigonometric network of the Stable Cadastre is known.

3. Results and discussion

For the purpose of the transformation between the St. Stephen Datum of Cadastre Coordinates and the Datum of Uniform Trigonometric Cadastral Network, identical points from among the trigonometric points of the geodetic base of the first-, second- and third-order trigonometric network of the Stable Cadastre were selected.

The identical points were selected from points situated beyond the borderline of the area affected by coal mining. Their coordinates in the St. Stephen Datum of Cadastre Coordinates were found in the Fund of Geodetic Bases in the CASLR, in the volume numbered A2/b/S6 and titled “Sestavení triangulačních výsledků a topografické popisy trigonometrických bodů” (Triangulation results and topographical descriptions of

trigonometric points) (1821–1829). The respective sketch of the trigonometric network in the territory of Ostrava was found under number A2/b/S8, in a file titled “Illustration of trigonometric networks”, which includes a sketch of the trigonometric network of the Těšín Region (1829). A part thereof, surveyed by surveyor Ploebst, is illustrated in Fig. 6. The remaining part of Ostrava in the western direction was surveyed by surveyor Schmitt and its sketch titled “Overview of trigonometric cadastral surveying works relating to the large network in 1821 and 1822” is contained in the same volume (A2/b/S8).

The identical points for the transformation were selected on the basis of toponymic information, contained in the CASLR volume numbered A2/b/S31 and titled “Topographical description of the trigonometric points of the Těšín Region”. This volume included a sketch and coordinates of local military triangulation in the area of Fryštát – Č. Těšín from 1923 in the St. Stephen Datum of Cadastre Coordinates.

With each point it was verified that the coordinates are identical with those described in volume numbered A2/b/S6 and titled “Triangulation results and topographical descriptions of trigonometric points”.

The coordinates of the selected points in the S-JTSK system were obtained from the DATAZ database (databases of geodetic control) which is available at <http://bodovapole.cuzk.cz> via graphical search in the triangulation sheet section. Based on the said data and upon partial field research of the points, a total of 66 trigonometric points were selected and analysed by means of similarity transformation. For the purposes of this transformation, a transformation key between the St. Stephen Datum of Cadastre Coordinates and the S-JTSK system was created by the gradual elimination of outliers (major coordinate deviations). Only 13 points (see Fig. 7), which could be considered identical based on transformation accuracy, were subject to the transformation.

Fig. 7 illustrates the identical points for the transformation between the St. Stephen Datum of Cadastre Coordinates and the S-JTSK system (marked in green). The other selected trigonometric points which, however, were excluded from transformation as outliers are marked in red. The yellow line represents the approximate border of the area affected by coal mining and the blue line represents the borders of Ostrava “Table 2”.

Table 2 – Coordinate corrections of the identical points.

Point	Coordinate corrections			
	V_Y [m]	V_X [m]	Δ_p [m]	m_Δ [m]
403	−0.096	0.209	0.230	0.163
501	−0.096	0.079	0.124	0.088
504	0.039	−0.379	0.381	0.269
519	0.318	−0.208	0.380	0.269
525	−0.065	−0.130	0.145	0.103
537	0.080	0.085	0.117	0.083
543	0.178	0.090	0.199	0.141
544	−0.203	0.137	0.245	0.173
547	−0.030	0.063	0.070	0.049
549	−0.108	−0.122	0.163	0.115
550	0.159	−0.098	0.187	0.132
559	−0.132	0.215	0.252	0.178
560	−0.046	0.059	0.075	0.053



Fig. 6 – A part of the sketch of the trigonometric network in the territory of Ostrava (surveyor Ploebst).

4. Conclusions

The aim of this study was to find and evaluate as much unbiased information as possible regarding the Ott system of coordinates introduced by Ing. František Ott for the purposes of mine surveying operations in the western part of the Ostrava Coal District, and to subsequently assess its accuracy. This study also focused on optimum transformation relations between Ott's system of coordinates, the St. Stephen Datum of Cadastre Coordinates and the S-JTSK system from the perspective of an area affected by coal mining.

Initial information about the Ott system of coordinates was found in Ott's study titled "Aufnahme der Ostrauer-Grubenreviere, ausgeführt von Franz Ott, 1857–1859". This study served as the basis for the reconstruction of all calculations, including the connection of the Ott system of coordinates to the St. Stephen Datum of Cadastre Coordinates and the calculation of compass directions. By comparing the original and newly determined calculations their accuracy was set at the value of 0.110 m. Ott's system of coordinates also has great importance in modern times, particularly during the remediation works performed between 1996 and 1998,

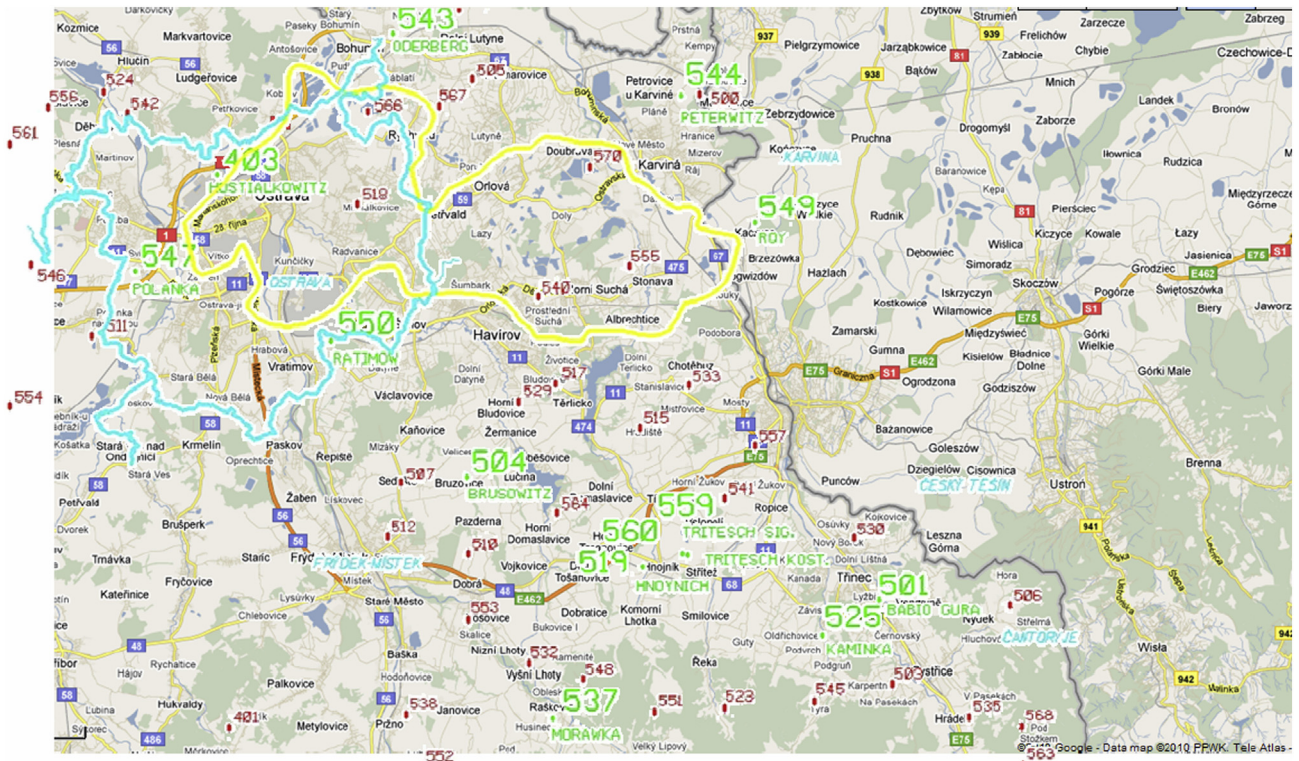


Fig. 7 – Identical points for the transformation between S-SK and S-JTSK in Moravia and Silesia.

aimed at removing the consequences of coal mining in the Ostrava-Karviná Coal District.

The main benefit is seen in obtaining original historical information about the Ott system of coordinates in the territory of Ostrava, which was subsequently processed in detail. Finding such historical information required significant effort and patience when searching for the required documents in the archives and file rooms of the Ostrava-Karviná Coal District. Based on a detailed analysis of Ott's study, i.e. by translating it into German Latin and then into Czech, by copying the illegible figures by means of a magnifying device, by reconstructing all of the specified calculations and their conversion, a number of findings were obtained regarding the development of Ott's system of coordinates and its accuracy and connection to the geodetic bases of the Stable Cadastre.

The optimum formulas for the conversion of the points of Ott's system of coordinates into the existing binding reference systems were determined in a way that the accuracy of the Ott system of coordinates achieved upon its formation and the accuracy of calculations was not decreased or diminished. During the entire process it was necessary to take into account that the relevant locality is part of an area affected by coal mining. It is very difficult to determine the borders of the area affected by coal mining, as such information was often intentionally concealed from the public or distorted. The results and the principal practical benefits of this study are the coordinates of the points of the Ott system of coordinates in the St. Stephen Datum of Cadastre Coordinates, in the S-JTSK system and in the ETRS89 system. The old mining works in the territory of Ostrava which are part of Ott's study can now be set out using GNSS technology. Their coordinates were

determined with a high degree of accuracy in case they would have to be used due to remediation works or sudden escape of hazardous gases, etc.

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