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TOPOGRAPHIC SURVEYING FOR GUIDING THE EXCAVATION OF AN INCLINED RAISE AT VULCAN MINING EXPLOITATIONTOPOGRAPHIC SURVEYING FOR GUIDING THE EXCAVATION OF AN INCLINED RAISE AT VULCAN MINING EXPLOITATION

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Abstract. *This paper presents the realization of topographic surveys for the underground driving of the inclined mining working no. 13VII, located between levels 255 and 316 in the Vulcan Mining Exploitation, Jiu Valley, Romania. The main objective was to establish and maintain a reliable geodetic support network capable of ensuring the correct spatial orientation, positioning and elevation control of the projected underground working. The current state of the art shows that, in deep mining operations, topographic support networks must be periodically verified and extended because mining activity, ground pressure and excavation works can affect the stability and accuracy of surface and underground reference points. The material and methods consisted of field measurements performed with a total station, angular and distance observations, trigonometric levelling, geometric levelling and analytical processing using the method of conditioned measurements and the least squares method. The surface triangulation network was verified planimetrically and altimetrically, after which a new geodetic point was integrated into the network. The reference system was then transferred underground through the Chorin shaft, using surface and underground junction operations, followed by polygonal traverses and levelling works on the mining levels. The novelty of the paper consists in the complete topographic approach applied to a real mining objective, combining network verification, network densification, reference-system transfer and practical guidance of an inclined working. The results demonstrate that the calculated corrections and coordinate values comply with the imposed accuracy requirements, confirming the stability of the support network and the correctness of the underground direction. The research is limited by the dependence on existing mining infrastructure, accessibility conditions and measurement errors specific to underground works. The paper has practical relevance for mining surveying, safe excavation works and the reliable development of underground mining operations.*

Keywords*: topographic surveys, mining surveying, geodetic network, underground reference system, inclined working, Vulcan Mining Exploitation.*

INTRODUCTION

Topographic surveys represent an essential technical support for the safe development, orientation and control of underground mining works. In deep mining areas, the continuous extension of excavation works requires a homogeneous and stable geodetic network, capable of providing accurate positional and elevation data for both surface and underground objectives. The Vulcan Mining Exploitation, located in the central sector of the Jiu Valley coal basin, carries out opening, preparation and exploitation works for hard coal deposits, requiring permanent correlation between surface geodetic control and underground mining activity.



Figure 1. Locating the perimeter

The present paper addresses the realization of topographic surveys for the driving of inclined working no. 13VII, between levels 255 and 316, in the Vulcan Mining Exploitation. Inclined workings, generally known as *suitoare*, connect mining galleries or levels situated at different elevations and play an important role in ventilation, coal transport, material supply and personnel circulation. Their execution requires precise planimetric and altimetric guidance, especially because deviations from the designed direction and gradient can affect safety, operational efficiency and the subsequent connection of underground workings.

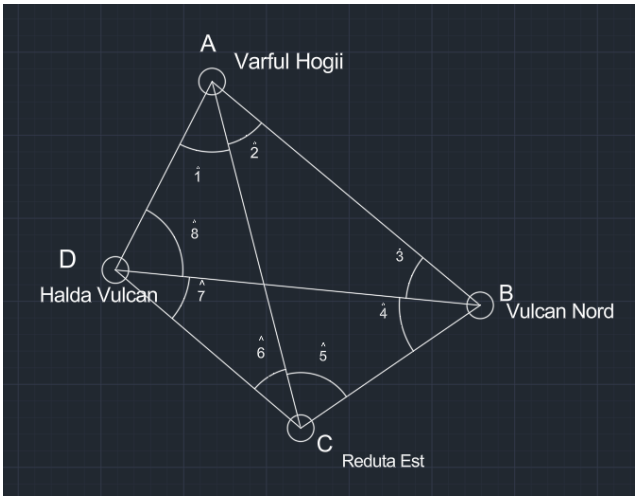


Figure 2. Processed in AutoCAD based on coordinates

The current state of the art in mining surveying is based on the integration of classical geodetic methods with modern electronic measurement equipment. Surface control networks are verified and densified using angular and distance observations, while underground reference systems are transferred through vertical shafts using junction operations, plumb wires and specialised levelling procedures. The processing of observations is commonly performed using rigorous adjustment methods, including the method of conditioned measurements and the least squares method, in order to obtain the most probable values of coordinates, orientations and elevations. The main objective of this paper is to develop and apply a complete topographic workflow for the correct driving of the projected inclined working. The specific objectives are: to verify the planimetric and altimetric stability of the surface support network; to densify the geodetic network by determining a new point; to transfer the reference system from the surface to the underground through the Chorin shaft; to establish underground polygonal traverses and levelling lines; and to provide the practical topographic guidance required for the execution of the inclined working.

The novelty of the paper consists in the integration of all major topographic operations required for an underground mining objective into a single practical case study: verification of the surface network, network densification, shaft connection, underground control network development and guidance of an inclined excavation. The results confirm that the applied methodology provides the accuracy required for safe and correct underground driving. The research is limited by the accessibility of underground workings, the influence of mining-induced deformations and the errors associated with field measurements. Nevertheless, the study has practical relevance for mining surveyors, mining engineers and organisations involved in the development of underground mining infrastructure.

MATERIAL AND METHODS

The research was carried out in the Vulcan Mining Exploitation, situated in the central part of the Jiu Valley coal basin, Hunedoara County, Romania. The study focused on the topographic support required for the driving of inclined working no. 13VII, between levels 255 and 316. The methodology combined the verification of the existing surface geodetic network, its densification, the transfer of the reference system to the underground, the development of underground control networks and the practical guidance of the projected excavation.

Surface geodetic network



Figure 3. Configuration of the surface geodetic support network.

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The surface control network consisted of four points forming a quadrilateral with both diagonals observed. Points C and D were redetermined using points A and B as the coordinate reference, and their computed positions were compared with the initial coordinates. Angular observations were processed by the method of condition equations, using three figure conditions and one side condition for the eight measured angles.

Observation corrections were obtained by forming the normal equations and solving them through Gaussian elimination under the least-squares criterion adopted in the thesis:

$$\sum_{i=1}^{8} v_i^2 = \min$$

Table 2

Initial and verified coordinates of the surface geodetic network

Control point	Identifier	X (m)	Y (m)
Vârful Hogii	A	5031452.185	4678544.528
Vulcan Nord	B	5030609.774	4679557.112
Reduta Est	C	5030147.498	4678879.356
Halda Vulcan	D	5030742.962	4678179.413

Adjusted angles were used to calculate side orientations and lengths, followed by the coordinates of the redetermined points. The positional differences were evaluated using:

ds=dx2+dy2.

The differences were compared with the planimetric tolerance of 0.150 m specified in the thesis.

Trigonometric height determination

The height component was determined by geodetic trigonometric levelling, starting from point A, whose elevation was 678.943 m relative to the Black Sea datum. Vertical angles were observed in both telescope faces, and the computation included horizontal distance, instrument height, target height and the combined curvature and refraction correction,

The height relation used in the thesis was: HB=HA+iA+DABtanαAB−IB+CT.

i_A denotes instrument height, D_{AB} horizontal distance, α_{AB} the vertical angle relative to the horizontal, I_B target height and C_T the combined correction.

Surface network densification

An additional point P was introduced near the Chorin shaft. Its provisional coordinates were determined by forward intersection, followed by indirect-observation adjustment based on coordinate variation using directions observed from A, B, C and D.

The model comprised 14 observation equations, coordinate corrections and separate station-orientation unknowns. Final coordinates were obtained using: XP=XP0+δXP,YP=YP0 +δYP. The elevation of P was determined by differential levelling with the instrument positioned between the staff locations, starting from a benchmark with an elevation of 620.480 m.

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Planimetric reference transfer

The reference system was transferred through the Chorin shaft using the known orientation of line AP and the coordinates of P. Two weighted plumb wires were suspended in the shaft, with connecting triangles at the surface and underground.

Surface connection angles were measured by the direction-set method, and each connecting distance was measured five times. The orientation of the line between the wires was derived from the connecting-triangle geometry rather than from coordinate differences, because their short separation increases sensitivity to positional errors. The underground connection established the orientation and coordinates required for the underground traverse.

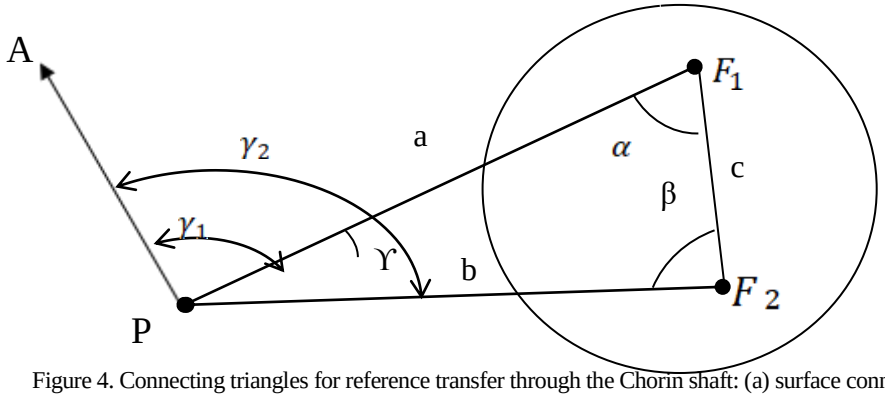


Figure 4. Connecting triangles for reference transfer through the Chorin shaft: (a) surface connection; (b) underground connection.

Height reference transfer

The height reference was transferred using the Haussman tape method. A long steel tape was suspended in the shaft, and levelling observations connected its readings to the surface benchmark and underground reference point. Corrections for tape calibration, temperature and extension under tension were included.

Underground control surveys

Underground control was developed through traverses starting from a known point and orientation. Horizontal angles were measured consistently on the same side of the traverse, together with the distances between successive stations. Coordinates were computed using: $X_{j+1}=X_j+S_j\cos\theta_j, Y_{j+1}=Y_j+S_j\sin\theta_j$

The precision assessment considered error propagation from the initial orientation, measured angles and side lengths. Heights were determined by differential levelling in forward and backward runs, with misclosures evaluated against the length-dependent tolerances adopted in the thesis.Licenta-Draghici-Petru-Vlad.docx

Setting-out and excavation guidance

The setting-out procedure used the coordinates of the attack point Q and breakthrough point R to define the axis orientation and setting-out angle relative to the underground reference direction. Planimetric guidance was specified using four direction wires aligned to appear superimposed in the telescope, while vertical guidance was specified using a gradient square. This describes the proposed guidance procedure and does not establish that a final breakthrough was independently verified.

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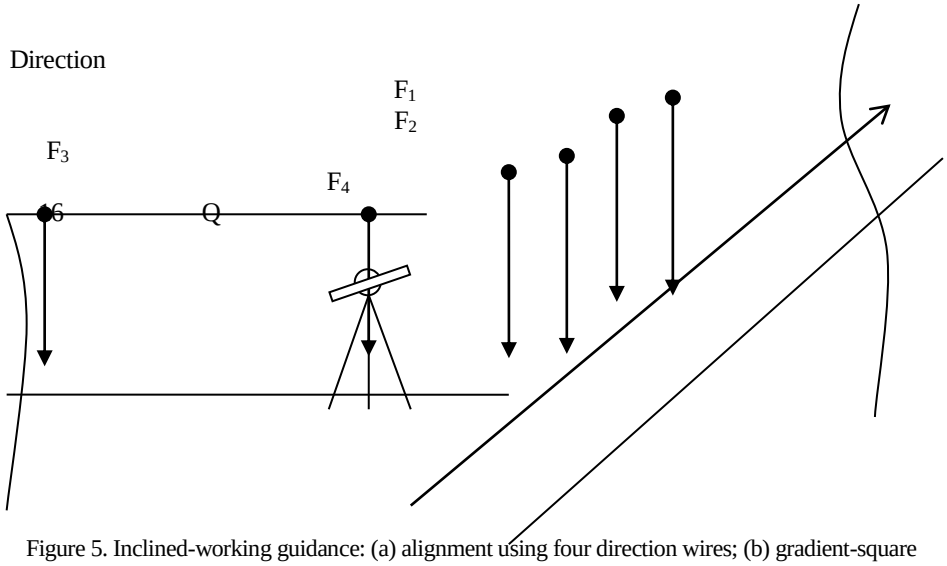


Figure 5. Inclined-working guidance: (a) alignment using four direction wires; (b) gradient-square arrangement

RESULTS AND DISCUSSIONS

Surface control verification

The coordinate comparison reported for the surface network indicated small positional differences at the redetermined points C and D. At C, the coordinate differences were +0.007 m in X and −0.005 m in Y, while at D they were +0.003 m and 0.000 m, respectively (Table 3). These differences were below the 0.150 m planimetric tolerance adopted in the thesis, supporting acceptance of the two redetermined points under that criterion.

Table 3

Reported coordinate verification of the redetermined surface points.

Point	Redetermined X (m)	Redetermined Y (m)	Difference in X (m)	Difference in Y (m)	Reported positional difference (m)
C	5030147.505	4678879.351	+0.007	−0.005	0.008
D	5030742.965	4678179.413	+0.003	0.000	0. 0

Points A and B retained their initial coordinates because they defined the reference for the redetermination. Their zero differences therefore do not constitute an independent stability check. The result should consequently be interpreted as agreement of C and D with the adopted reference and tolerance, rather than evidence of absolute stability of every surface point.

Densification and reference transfer

The final coordinate table for the additional surface point P gave X = 5030719.092 m and Y = 4678881.239 m. Its reported adjusted elevation was 620.510 m, also reproduced in the consolidated coordinate.These values document the intended surface control point near the Chorin shaft, although inconsistencies in the provisional coordinates and levelling entries require reconciliation before the adjustment can be considered independently verified.

The underground connection calculation provided coordinates for points 100 and 200 (Table 4), together with a reported baseline length of 148.452 m and orientation of 356.5673 gon.

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The height-transfer calculation reported an underground reference elevation of 363.929 m, subsequently used as the starting elevation.

Table 4

Reported coordinates of the surface densification point and underground connection points.

Point	Role	X (m)	Y (m)
P	Additional surface control	5030719.092	4678881.239
100	Underground connection	5030721.465	4678872.193
200	Underground connection	5030836.688	4678778.589

The reported outputs do not establish a fully consistent surface-to-underground reference chain. The surface connection uses coordinates for P that differ from the final densification table, and the height-transfer calculation starts from 620.500 m rather than 620.510 m. The underground traverse description also gives starting coordinates and an initial orientation that differ from the connection results. These discrepancies must be resolved before the transmitted reference can support a definitive accuracy statement.

Underground levelling results

The first underground levelling circuit started from an elevation of 363.929 m and returned an unadjusted value of 363.915 m; the second started from 316.065 m and returned 316.079 m. Using the thesis convention of reference elevation minus returned elevation, the corresponding misclosures were +0.014 m and −0.014 m. Their absolute values were below the respective tolerances reported in Table 5.

Table 5

Reported underground levelling misclosures and adopted tolerances.

Circuit	Starting elevation (m)	Returned elevation (m)	Misclosure (m)	Reported tolerance magnitude (m)	Closure criterion
Annex 9	363.929	363.915	+0.014	0.016	Satisfied
Annex 10	316.065	316.079	−0.014	0.017	Satisfied

The closure comparisons support acceptance of the two circuits under the thesis criteria, but the tabulated correction distribution requires further checking. In Annex 9, the final row changes from 363.915 m to 363.929 m while listing a correction of −0.021 m; Annex 10 contains similar differences between correction entries and changes in elevation. Consequently, the circuit closure test and the correctness of the adjusted point elevations must be assessed separately.

Setting-out data and limitations

The setting-out chapter identifies Q as the attack point and R as the intended breakthrough point, reporting project elevations of 251.200 m and 316.000 m, respectively. It also provides planimetric coordinates, an axis orientation, a setting-out angle and a gradient for the proposed inclined working. **L** These quantities should not be treated as a validated setting-out solution until the coordinate geometry and angular calculations have been reconciled.

The document contains different coordinate sets for R in the underground traverse and setting-out chapters, and reports R at 316.100 m in Annex 9 but uses 316.000 m in the project calculation. It describes excavation guidance using direction wires and a gradient square, rather than reporting an independently measured final breakthrough deviation. The defensible outcome is therefore a documented control-survey and setting-out study with reported surface-coordinate

agreement and acceptable circuit misclosures, but with unresolved consistency issues that prevent confirmation of the final breakthrough accuracy

CONCLUSIONS

The study demonstrates the application of surveying methods for guiding the excavation of the inclined raise between levels 255 and 316 at Vulcan Mining Exploitation. The work included the verification of the surface control network, the densification of the geodetic network, the transfer of the reference system underground, and the establishment of underground surveying traverses.

The surface network was checked by compensating the angular observations, while the new point P was determined and used as a reference for the underground measurements. The underground levelling traverses showed small misclosures, indicating that the measurements were generally suitable for the intended surveying operations.

The results confirm the usefulness of the applied methods for transferring planimetric and vertical control from the surface to the underground workings. However, some numerical inconsistencies remain in the calculations concerning the shaft transfer and the setting-out of the raise. These values should be recalculated and correlated with the original field measurements before the work is considered fully validated.

Overall, the study provides a sound methodological framework for mine surveying and raise excavation control, but the final geometric results should be regarded as provisional until the remaining calculations and the breakthrough verification are independently checked.

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