



**Ministerul Educației și Cercetării  
Universitatea din Petroșani**

**Instituție Organizatoare de Studii Universitare de Doctorat  
Domeniul: Mine, Petrol și Gaze**

**UNIVERSITATEA DIN PETROȘANI  
ȘCOALA DOCTORALĂ**

# **TEZĂ DE DOCTORAT**

**Conducător științific:  
Prof.univ.dr.ing. Radu Sorin Mihai**

**Doctorand:  
Ing. Ciovică (Filip) Anca Daniela**

**Petroșani  
2025**



Ministerul Educației și Cercetării  
Universitatea din Petroșani

Instituție Organizatoare de Studii Universitare de Doctorat  
Domeniul: Mine, Petrol și Gaze

UNIVERSITATEA DIN PETROȘANI  
ȘCOALA DOCTORALĂ

**PERFEȚIONAREA METODELOR DE TRASARE  
ȘI CONTROL A LUCRĂRILOR MINIERE  
SUBTERANE**

**Conducător științific:  
Prof.univ.dr.ing. Radu Sorin Mihai**

**Doctorand:  
Ing. Ciovică (Filip) Anca Daniela**

	<i>Membri comisiei de îndrumare și integritate academică:</i>
1.	<b>Prof.univ.dr.ing.habil Vereș Ioel-Samuel</b>
2.	<b>Șef lucr.dr.ing. Fissgus Klaus</b>
3.	<b>Șef lucr.dr.ing. Ștefan Nelu</b>

**Petroșani  
2025**

# CUPRINS

<b>REZUMAT</b> .....	5
<b>SUMMARY</b> .....	7
<b>INTRODUCERE</b> .....	9
MOTIVAȚIA TEZEI DE DOCTORAT.....	9
OBIECTIVELE PRINCIPALE ALE TEZEI DE DOCTORAT.....	11
IMPORTANȚA TEZEI DE DOCTORAT.....	12
<b>CAPITOLUL 1. ANALIZA LUCRĂRILOR MINIERE SUBTERANE</b> .....	14
<i>1.1.GENERALITĂȚI</i> .....	14
<i>1.2.LUCRĂRI MINIERE SUBTERANE</i> .....	14
<i>1.3.CLASIFICAREA LUCRĂRILOR MINIERE SUBTERANE</i> .....	14
<i>1.3.1. Lucrările miniere subterane clasificate după dimensiuni și formă</i> .....	14
<i>1.3.2. Clasificarea lucrărilor miniere subterane după poziția în spațiu</i> .....	15
<i>1.3.3. Clasificarea lucrărilor miniere subterane după rolul lor</i> .....	17
<i>1.3.3.1. Lucrări miniere de deschidere</i> .....	17
<i>1.3.3.2. Lucrări miniere de pregătire</i> .....	24
<i>1.3.3.3. Lucrări miniere de exploatare</i> .....	26
<i>1.4.ASPECTE GENERALE PRIVIND PROIECTAREA MINELOR</i> .....	28
<b>CAPITOLUL 2. PROCEDEE ACTUALE DE STUDIU ȘI ANALIZĂ A TRASEELOR ȘI REȚELELOR TOPOGRAFICE SUBTERANE</b> .....	30
<b>INTRODUCERE</b> .....	30
<i>2.1. PROCEDEUL EXPEDITIV</i> .....	31
<i>2.2. PROCEDEUL APROXIMATIV</i> .....	35
<i>2.3. PROCEDEUL RIGUROS</i> .....	36
<b>CAPITOLUL 3. CORELAREA LUCRĂRILOR TOPOGRAFICE CU LUCRĂRILE MINIERE SUBTERANE</b> .....	38
<b>INTRODUCERE</b> .....	38
<i>3.1.LUCRĂRI MINIERE PROIECTATE</i> .....	38
<i>3.1.1. Considerații generale asupra lucrărilor topografice de trasare</i> .....	38
<i>3.1.2. Compensarea unghiurilor</i> .....	40
<i>3.1.2.1. Trasele poligonale cu puncte impuse</i> .....	40
<i>3.1.2.2. Trasee poligonale cu punct nodal</i> .....	43
<i>3.1.3. Compensarea coordonatelor</i> .....	49
<i>3.2.LUCRĂRI MINIERE EXECUTATE</i> .....	50
<b>CAPITOLUL 4. EVALUAREA LUCRĂRILOR TOPOGRAFICE ÎN TRASAREA LUCRĂRILOR MINIERE SUBTERANE</b> .....	61
<b>INTRODUCERE</b> .....	61

<b>4.1.EVALUAREA PRECIZIILOR ÎN TRASEELE POLIGONALE DEPENDENTE...</b>	<b>61</b>
4.1.1.Determinarea erorii unei orientări.....	62
4.1.2.Determinarea erorilor coordonatelor unui punct.....	65
<b>4.2.EVALUAREA PRECIZIILOR ÎN TRASEELE POLIGONALE INDEPENDENTE.....</b>	<b>69</b>
<b>4.3. DETERMINAREA PRECIZIILOR ÎN TRASEE POLIGONALE INCOMPLETE.</b>	<b>76</b>
4.3.1. Rezolvarea unui traseu poligonal incomplet (deschis sau flotant).....	77
4.3.2. Calculul erorilor punctului final.....	78
4.3.3. Erorile punctului final, condiționate de eroarea primei laturi.....	83
4.3.4.Calculul erorii orientării unei laturi oarecare.....	84
4.3.5. Calculul erorilor longitudinale și transversale.....	85
<b>CAPITOLUL 5. LUCRĂRI TOPOGRAFICE SUBTERANE PARTICULARE. STUDIU DE CAZ.....</b>	<b>89</b>
<b>5.1. TRASAREA LUCRĂRILOR MINIERE.....</b>	<b>89</b>
<b>5.2. COMPENSAREA RIGUROASĂ A POLIGONAȚIILOR SUBTERANE.....</b>	<b>90</b>
5.2.1. Lucrări topografice speciale de trasare a lucrărilor miniere.....	93
<b>5.3.LUCRĂRI TOPOGRAFICE PARTICULARE DE TRASARE A LUCRĂRILOR MINIERE.....</b>	<b>100</b>
5.3.1. Rezolvare generală.....	101
5.3.2. Rezolvarea prin eliminarea abaterii transversale.....	104
5.3.3. Rezolvare prin eliminarea abaterii longitudinale.....	108
5.3.4. Determinarea corecțiilor coordonatelor relative.....	109
5.3.5. Observații asupra compensării preliminare a unghiurilor traseului poligonal.....	111
5.3.6. Relații generale de calcul la compensarea poligonului pe direcție cu laturi egale.....	113
5.3.7. Compensarea traseelor poligonale pe direcție cu laturi de ponderi inegale.....	115
<b>CAPITOLUL 6. CONCLUZII GENERALE. CONTRIBUȚII PROPRII. PROPUNERI.....</b>	<b>117</b>
<b>LISTĂ FIGURI.....</b>	<b>119</b>
<b>LISTĂ FIGURI.....</b>	<b>120</b>
<b>BIBLIOGRAFIE.....</b>	<b>121</b>

# **SUMMARY**

## **RESEARCH CONTEXT AND MOTIVATION**

In the context of modern economic development, topographic and geological activities have acquired a fundamentally strategic role. They form the basis for the discovery, evaluation, and exploitation of mineral resources, which are essential raw materials for most industrial sectors. The steel, energy, machinery, metallurgical, and agricultural industries significantly depend on underground-extracted resources: from iron ore, copper, and rare metals to coal, oil, natural gas, and construction materials such as limestone, clay, or sand.

This reality highlights the increasing importance of topographic and geological activities carried out in underground environments, as they play a decisive role in all stages of the mining cycle: exploration, design, exploitation, and monitoring. The information obtained through topographic measurements and geological studies enables the precise location of deposits, their 3D modeling, the selection of optimal exploitation methods, and ensures the safety of mining operations.

Moreover, the accurate transfer of the geodetic network from the surface to the underground and the rigorous coordination of operations are critical aspects for the efficiency and security of the mining process. These challenges justify the need for in-depth research into the methods and technologies for underground surveying and layout, aiming to improve the accuracy, safety, and efficiency of mining works.

Thus, this research aims to analyze and optimize the topographic processes involved in underground mining activities, contributing both to scientific advancement and to solving practical, current problems in the extractive industry.

## **MAIN OBJECTIVES OF THE DOCTORAL THESIS**

Given the dynamic, complex, and often unpredictable nature of underground mining operations, conducting the necessary topographic work for marking mining operations—whether for opening, preparation, or exploitation—is an essential step in ensuring safe and efficient mining activity.

Correctly marking the designed works, as well as rigorously checking the executed ones, involves establishing and maintaining accurate topographic reference bases adapted to the specific underground conditions.

One of the central objectives of this doctoral thesis was to evaluate the quality of topographic works from a dual perspective: on the one hand, by analyzing the accuracy of the measurements performed, and on the other, by examining the methods of data processing and interpretation. Special attention was also given to the practical implementation of theoretical results through staking-out operations, constantly seeking alignment between the designed model and the real underground configuration.

An applied case study was conducted within the thesis, analyzing and developing specific methods for determining and implementing staking and control topographic bases,

adapted to common types of underground mining works. These include directional and cross galleries, inclined shafts, as well as ventilation or extraction shafts—all addressed from both technical and methodological perspectives.

The aim was to identify the most efficient technical-topographic solutions to ensure the required precision in the execution of mining works and to reduce layout errors that can result in deviations with a negative impact on work safety and exploitation efficiency.

## **RESEARCH METHODOLOGY**

The methodology adopted in this doctoral thesis was designed to enable a rigorous, systematic, and applied investigation of the technical-topographic aspects specific to underground mining works. The research followed an interdisciplinary approach, combining theoretical, experimental, and applied methods, with the goal of optimizing layout and topographic control activities under real exploitation conditions.

The main stages of the methodology included:

### **1.Literature and documentation analysis**

A synthesis of national and international specialized literature in mining surveying, applied geodesy, and mining engineering was conducted to provide the theoretical foundation. Technical standards, current regulations, scientific papers, and relevant case studies were analyzed.

### **2.Study of geological and structural conditions**

An analysis of the geological and structural context specific to the investigated mining works was carried out, as these factors significantly influence the choice and application of staking and control methods.

### **3.Evaluation of existing topographic methods**

Both classical and modern methods used in staking and controlling underground works were critically examined, highlighting their advantages, limitations, and areas of applicability.

### **4.Design and implementation of the case study**

Applied research was carried out in a comprehensive case study at an active mining site. Topographic methods were implemented and tested for the following types of works:

- Directional and cross galleries
- Inclined access planes
- Ventilation and extraction shafts

### **5.Determination and establishment of underground topographic bases**

Specific procedures were developed and applied for the determination, materialization, and verification of underground layout networks, with a focus on their correlation with the surface geodetic reference system.

### **6.Measurements and data processing**

High-precision topographic measurements were performed using modern equipment (total stations, digital levels, gyroscopic orientation tools, etc.). The collected data were processed using specialized software (AutoCAD, Surfer, TopoLT, Excel, etc.) for error analysis, point stability verification, and deviation assessment.

## **STRUCTURE OF THE DOCTORAL THESIS**

The thesis is structured into six chapters, following a progressive logic from general analysis of the technical and theoretical context to applied research and the formulation of original contributions. Each chapter addresses an essential component of underground topographic activities, directly related to mining layout requirements.

### ***Chapter 1 – Analysis of Underground Mining Works***

Provides a comprehensive overview of underground mining works categorized by purpose and functionality: opening, preparation, exploitation, ventilation, drainage, and transport. It describes the geometric and technological elements of these works (horizontal galleries, inclined planes, vertical shafts), emphasizing the importance of precise layout for safe and efficient mining operations.

### ***Chapter 2 – Current Methods for Studying and Analyzing Underground Topographic Networks***

Analyzes modern methods for studying, designing, and developing underground topographic networks. Emphasizes the need for continuous correlation between the underground network and the national or local geodetic system through coordinate transmission from the surface.

### ***Chapter 3 – Correlation Between Topographic Works and Underground Mining Operations***

Discusses the direct interdependence between topographic and mining activities. Covers accurate positioning, the need for ongoing coordination between design and execution, and staking and control procedures. Evaluates the impact of measurement and layout errors and proposes a general model for integrating topographic activities in the mining process.

### ***Chapter 4 – Evaluation of Topographic Works in the Layout of Underground Mining Operations***

Focuses on the qualitative and quantitative assessment of topographic work in underground layout. Details the procedures for establishing layout base networks, verification methods, and the types of possible errors.

### ***Chapter 5 – Specific Underground Topographic Works. Case Study***

The core chapter of the applied research, presenting results from a case study at an active mining site. Describes the analyzed mining works—directional and cross galleries, shafts, inclined planes—and the methods used for their layout and control. Highlights the specific technical conditions, equipment used, data processing approach, and final precision evaluation. Based on these elements, practical solutions and optimization proposals are formulated.

## ***Chapter 6 – General Conclusions. Original Contributions. Proposals***

Summarizes the research results, highlighting key conclusions regarding the importance, accuracy, and efficiency of underground topographic works. Details the original contributions made through the thesis, both methodologically and practically. Concrete proposals are also made to improve underground topographic activities and suggestions for future research directions.

### **RESULTS OBTAINED FROM THE RESEARCH**

#### **Improved accuracy in underground layout**

By applying modern measurement methods and optimizing data processing procedures, layout errors were reduced to under 5 mm, compared to standard acceptable values of 15–20 mm under similar conditions.

#### **Theoretical–practical correlation in layout work**

A systematic method was developed to verify the alignment between design plans and actual execution, leading to a significant reduction in geometric deviations during advancement stages.

#### **Identification of main error sources in layout and control**

The case study showed that the most frequent deviations stem from:

- Incorrect instrument setup
- Error accumulation in intermediate network points
- Poor communication between design and execution teams

#### **Optimized layout solutions based on mining work type**

For each type of analyzed work (gallery, inclined plane, shaft), specific layout methods were identified that provide the best balance between accuracy, execution time, and ease of implementation.

The mentioned contributions were validated both theoretically, through modeling and calculations, and practically, through application in the case study. The results support the need to adapt classical topographic methods to current underground realities and offer a practical framework for designing and controlling high-precision mining operations.

### **CONCLUSIONS AND FUTURE DIRECTIONS**

The doctoral thesis titled “Improving the Methods for Layout and Control of Underground Mining Works” aims to make a significant contribution to increasing the accuracy and efficiency of topographic activities in underground environments, with the goal of delivering mining projects under safe and economically sustainable technical conditions.

In a highly complex field, where working conditions are difficult and risks are constant, mining surveying plays a crucial role throughout the life cycle of a mining operation—from design to execution and control. The thesis topic stems from the need for continuous adaptation and refinement of methods used for laying out mining works, in line with technological evolution and increasingly high precision requirements.

The research was logically and coherently structured around several essential directions:

- Analysis of the technical-topographic characteristics of underground mining works,
- Evaluation of current layout and control methods,
- Correlation between theoretical data and field execution,
- Applied study on representative mining works.

A central element of the thesis was the processing of measured values during both the design and execution phases. A step-by-step approach was proposed, aligned with the sequence of mining operations (opening, preparation, exploitation), enabling grouped equation processing and the application of matrix calculation for the most stable solutions.

Regarding the accuracy assessment in polygonal traverses (dependent, independent, and free), the thesis offers rigorous calculation methods before and after measurement adjustment. The propagation of errors and their impact on the determined results were detailed, key elements in supporting layout decisions.

Another important aspect analyzed concerns special topographic works, for which simplified and efficient procedures were identified and tested. Common situations encountered in topographic practice were addressed, such as: traverses with small misclosures, traverses developed in a single direction, and traverses with equal or unequal sides. In these cases, formulas were established for calculating transverse and longitudinal deviations, along with proposals for eliminating systematic errors.

In view of the continuous development of the field, future research is recommended to focus on:

- analyzing the distribution of weights in mining topographic networks,
- optimizing the network structure based on the required precision and type of work,
- deepening error propagation models in complex networks,
- integrating modern technologies (laser scanning, LIDAR sensors, 3D modeling) into the underground topographic workflow.

## BIBLIOGRAFIE

1. Almășan, B.: „*Exploatarea zăcămintelor minerale din România*”, Editura Tehnică, București, 1984
2. Bauer, E.: „*Markscheidewesen*”, 1990
3. Botez, M.: „*Teoria erorilor și metoda celor mai mici pătrate*”, Editura Didactică și Pedagogică, București, 1961
4. Covaci, ȘT.: „*Exploatarea miniere subterane*”, Editura Didactică și Pedagogică, București, 1983
5. Cristescu, N.: „*Topografie inginerească*”, Editura Didactică și Pedagogică, București, 1978
6. Dima, N.: „*Geodezie*”, Editura Universitas, Petroșani, 2005
7. Dima, N.: „*Rezolvarea problemelor de străpungeri miniere folosind metodele de simulare numerică*”, Contract de cercetare științifică, C.N.H. Petroșani, 2000
8. Dima, N., Ș.A.: „*Teoria erorilor și metoda celor mai mici pătrate*”, Editura Universitas, Petroșani, 1999
9. Dima, N.: „*Topografie minieră*”, Editura Corvin, Deva, 1996
10. Dima, N., Ș.A.: „*Dezvoltarea rețelelor topografice și geodezice de nivelment prin metoda eliminării punctelor nodale*”, Analele Universității din Petroșani, Editura Universitas, Petroșani, 2013
11. Dima, N., Filip, L.: „*Corelațiile între mărimile măsurate într-o bază topografică subterană*”, Revista Minelor, Petroșani, 2008
12. Dima, N., Filip, L.: „*Considerații privind propagarea erorilor în poligonațiile subterane*”, Simpozion Alba Iulia, 2008
13. Dima, N., Herbei, O., Vereș, I., Filip, L.: „*The actual stage of geodetic networks in Romania*”, Analele Universității de Geologie St. Ivan Rilski-Bulgaria, 2007
14. Dima, N., Herbei, O., Vereș, I., Bendea, H., Filip, L.: „*Topografie generală și elemente de topografie minieră*”, Editura Universitas, Petroșani, 2005
15. Dima, N., Pădure, I., Herbei, O.: „*Topografie minieră*”, Editura Corvin, Deva, 1996
16. Dragomir, P., Tămăioagă, G. ș.a.: „*Topografie Inginerească*”, Editura Conspress, București, 2000
17. Filip, A.D.: „*Analiza lucrărilor miniere subterane*”, Raport de cercetare nr. 1
18. Filip, A.D.: „*Transmiterea ponderilor în rețelele topografice subterane*”, Raport de cercetare nr. 2
19. Filip, A.D.: „*Studiul erorilor înainte și după compensare a măsurătorilor subterane*”, Raport de cercetare nr. 3
20. Filip, O.L., Ciovică, A.D.: „*Correlations between weighting coefficients corresponding to the measurement groups*”, Simpozionul SIMPRO 2024, Petroșani, 2024
21. Filip, O.L., Ciovică, A.D.: „*Contributions to the development of geodetic networks*”, Simpozionul SIMPRO 2024, Petroșani, 2024
22. Filip, O.L., Ciovică, A.D.: „*Influence of measurement errors on underground topographic bases*”, Revista Minelor, vol. 4, nr. 28, Issue 4 / 2024 ISSN-L 1220-2053 / ISSN 2247-8590, <https://www.upet.ro/revistaminelor/eng/2024/issue4/index.php>, Petroșani, 2024
23. Filip, O.L., Ciovică, A.D.: „*Analysis of orientation accuracies in underground polygonal routes*”, Revista Minelor, vol. 2, nr. 28, pag. 42-48, ISSN-L 1220-2053/ISSN 2247-8590, <https://issuu.com/revmin/docs/nr2en2022>, Petroșani, 2022

24. Filip, O.L., Ciovică, A.D.: „*Processing of measured quantities in a mining polygon route*” Engineering Geology and Hydrogeology, Volume 36, Sofia, ISSN 0204-7934, Revistă cotate BDI, [www.igh-bg.com](http://www.igh-bg.com), <https://doi.org/10.52321/igh.36.1.59>, 2022
25. Filip, L., Dima, N.: „*Lucrări speciale de topografie minieră*”, Editura Universitas, Petroșani, 2014
26. Filip, L., Dima, N., I. Vereș: „*Teoria prelucrării mărimilor măsurate*”, Editura Universitas, Petroșani, 2021
27. Filip, O.L.: „*Topografie minieră - Străpungeri miniere - Aplicații*”, Editura Universitas, Petroșani, 2016
28. Filip, L., Dima, N.: „*Precizia punctelor geodezice locale*”, Simpozionul Simpro 2008, Petroșani, 2008
29. Filip, O.L., Dima, N.: „*Prelucrarea riguroasă a măsurătorilor în trasee poligonale*”, Simpozionul Simpro 2008, Petroșani, 2008
30. Filip, O.L.: „*Posibilități de modernizare a bazelor topografice subterane*”, Teză de doctorat, Petroșani, 2009
31. Filip, O.L., Dima, N.: „*The use of independent polygon routes, in order to achieve the miner breakthroughs*”, Analele Universității din Petroșani, vol. 11, ISSN 1454-9174, Petroșani, 2010
32. Lupu, L., Filip O.L.: „*Propagarea erorilor mărimilor măsurate în lucrările miniere subterane*” Revista Minelor, vol. 18, nr. 2, ISSN 1220-2053, Petroșani, 2012
33. Filip, O.L., Vereș, I., Dima, N.: „*Teoria prelucrării mărimilor măsurate*” Editura Universitas, ISBN 978-973-741-771-8, Petroșani, 2021
34. Filip, O.L., Dima, N.: „*Topographic Analysis Of Elements Used In Solving Of Problems Of Mining Penetrations*”, Geodesy and Mine Suveying, SGEM, 14th SGEM GeoConference on Ecology, Economics, Education And Legislation, ISBN 978-619-7105-11-7 / ISSN 1314-2704, June 19-25, Vol. 2, Bugaria, 2014
35. Filip, O.L., Vereș, I., Dima, N.: „*Setting up of underground topography supports two fixed points*”, Geodesy and Mine Suveying, ISBN 978-619-7105-35-3 / ISSN 1314-2704, June 18-24, Vol. 2, Bulgaria, 2015
36. Filip, O.L., Cucăilă, S.: „*Distribuția ponderilor și evaluarea preciziilor în trasee și rețele topografice subterane*”, Revista Minelor, vol. 27, nr. 2, ISSN-L 1220-2053/ISSN 2247-8590, Petroșani, 2021
37. Filip, L, Ciovică, A., „*Analysis of orientation accuracies in underground polygonal routes*”, Revista Minelor, vol. 2, nr. 28, pag. 42-48, ISSN-L 1220-2053/ISSN 2247-8590, Petroșani, 2022. Revistă cotate BDI, <https://issuu.com/revmin/docs/nr2en2022>
38. Filip, L, Ciovică, A., „*Processing of measured quantities in a mining polygon route*”, Engineering Geology and Hydrogeology, Volume 36, Sofia, ISSN 0204-7934, Revistă cotate BDI, [www.igh-bg.com](http://www.igh-bg.com), <https://doi.org/10.52321/igh.36.1.59>, 2022
39. Hanning, E., ș.a.: “*Topografie minieră*”, Editura Didactică și Pedagogică, București, 1966
40. Hansel, G.: „*Markscheidewesen*”, 1981
41. Lețu, N., Carpenișteanu, D.: „*Sușineri miniere*”, Editura Tehnică, București, 1993
42. Lupu, L., ș.a.: „*Propagarea erorilor mărimilor măsurate în lucrările miniere subterane*”, Revista minelor, Petroșani, 2012
43. Murgu, M.: „*Explorări și exploatare miniere*”, Editura Didactică și Pedagogică, 1963

44. Ortelecan, M., Palamariu, M., Jurca, T.: „*Trasarea lucrărilor miniere*”, Editura Infomin, Deva, 1999
45. Popa, A.: „*Manualul inginerului de mine. Vol. I, II, III și IV*”, Editura Tehnică, București, 1984, 1985, 1986, 1988
46. Radu, S.M., Popescu, F.D., Andraș, A., Kertesz, I.: “*Transport și instalații miniere*”, Editura Universitas, ISBN 978-973-741-587-5, Petroșani
47. Rusu, A., Kiss, A., Boș, N.: „*Topografie - Geodezie*”, Editura Didactică și Pedagogică, București, 1982
48. Vereș, I.: „*Orientarea lucrărilor topografice subterane în condițiile impuse de factorii de proiectare a lucrărilor miniere și de importanța lor în procesul tehnologic*”, Teză de doctorat, Petroșani, 1998