UNIVERSITATEA DIN PETROŞANI

ŞCOALA DOCTORALĂ

DOMENIUL DE DOCTORAT: MINE, PETROL ŞI GAZE

TEZĂ DE DOCTORAT

Conducător ştiinţific:

PROF. UNIV. DR. ING. RADU MIHAI SORIN

Doctorand:

CHEZAN MIHAELA CECILIA

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TITLUL TEZEI:

PERFECŢIONAREA TEHNICILOR ŞI METODELOR DE TRASARE ŞI CONTROL A INSTALAŢIILOR DE TRANSPORT MINIER

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SUMMARY

The main objectives of the doctoral thesis can be summarized in:

1. Analysis of mining transport conveying appliance (installations) used in underground operations and open pit mining

There were presented horizontal, vertical and inclined transport conveying appliance (installations), with emphasis on their geometric elements and the stability conditions imposed for a good operation.

2. Aspects regarding the current state of geodesy and topography in the mining domain (field).

There were presented point positioning elements that form the support base: surfaces and national and local reference systems and their correlation.

3. Topographic support networks used to monitor the stability of mining transport conveying appliance (installations) and the contributions made in their study regarding: internal error of the end point in the suspended polygon, the geodetic network in open pit mining operations and mining triangulation.

The doctoral thesis includes four major chapters that deal with theoretical and practical ideas about: "Improving the techniques and methods of setting out and control of mining transport conveying appliances (installations)".

Chapter one of the doctoral thesis is entitled: "General notions of mining transport". It refers to the analysis of mining transport conveying appliances (installations) used in underground operation and open pit mining.

In this first chapter, the horizontal, vertical and inclined transport conveying appliances (installations) are treated. The emphasis is on the geometric elements of these transport conveying appliances (installations) and on the stability conditions required for their proper functioning.

So, there are specified theoretical ideas regarding: “belt (type) wiper conveyors”, "belt (type) carrier conveyors", and "rail transport”, (with emphasis on their general presentation and underground railway).

Vertical transport is also classified. Were mentioned the main types of extraction machines, (more precisely: "drum extraction machines" and "motor wheel extraction machines"), and then are presented cages and chips.

For the correct operation of mining conveying appliances (installations), it is necessary a periodically check of their positioning in space, using topographical methods and techniques that provide superior accuracy.

In the second chapter entitled: "Aspects on the current state of geodesy and topography in mining" were presented five subchapters entitled: generalities, the evolution of land measurements in the previous century and in the current century, modern topographic equipment used in underground mining, elements of positioning and geodetic networks.

In the subchapter of “generalities”, were presented some aspects regarding of: the definition of geodesy (given by Helmert or given by the International Federation of Geodesy), the basic activities of geodesy and the fields with which this science is in connections.

The definition of geodesy was given by Helmert in 1880, in his book "Mathematical and Physical Theory of Geodesy." "Geodesy is the science of measuring and representing the shape of the Earth". Geodesy underwent a great evolution in the last half of the twentieth century.

Geodesy provides the results of measurements and calculations, the geometric reference for the other sciences that study the dynamics of the planet and the factors that influence it. We cannot talk about geodesy without relying on some auxiliary sciences, such as cartography and photogrammetry.

One of the basic activities of geodesy is to establish the position of points or 3D points located on the Earth's surface, on water or in space, but also underground. The positioning of the points is given by a series of coordinates that are part of a certain system, which varies over time, currently materialized by a geodetic system. In this geodetic system the position is offered with the help of geodetic latitude and geodetic longitude, plus the ellipsoidal altitude.

A review of the evolution of land measurements from the previous century to the current century was also made in the thesis.

After the period of progress of the sciences of terrestrial measurements, in the Middle Ages there was a period of significant stagnation and regression. Issues were discussed regarding the shape (sphericity of the Earth) and the Radius of the Earth. In the 11th century, Al-Biruni (973-1048) measured the Radius of the Earth by a new procedure and then repeated the measurement in the West. According to him, the results obtained were similar to those obtained by the teams of wise people from Baghdad. The Radius of the Earth given by Al-Biruni was 12,851,369 elbows (one elbow represents the measure of length equal to 0.42 meters). The discoveries of the Middle Ages culminated with the discovery of America. St. Thomas Aquinas (1227-1274) stated that the Earth must be spherical. Saint Isidore of Seville designed one of the first maps of the Middle Ages. This map is the first known printed map. In this map, known as "T in O", are represented the three continents that were known at that time, surrounded by the primitive ocean. The letter "T" was seen by medieval authors as a representation of the Cross of Christ, further strengthening the idea of the dependence of the material world on the Divine Order. Thus, this map contains a representation of both the material and the celestial world. In the 16th century, the concept of the size of the Earth was revised. At that time, the Flemish cartographer Gerhard Kremer made successive reductions in the size of the Mediterranean Sea and the whole of Europe, which had the effect of increasing the size of the earth. The importance of geodetic operations performed by the Arabs is obvious. It took several centuries for these operations to be repeated in Europe, and especially in France, the cradle of modern geodesy. In clear opposition to Christian thought, Muslim culture privileged the geographical sciences. The holy book called the Qur'an advised the need to observe the Earth and the Heavens in order to find in them the evidence of the Muslim faith. Therefore, it is understandable that the new Muslim thinking was in favour of scientific knowledge. In turn, knowledge of geography would allow Muslims to learn exactly the route needed to reach the Holy City: Mecca. Greek geodetic work, with measurements of the Earth's circumference, was continued by the Arabic wise-people of Baghdad (ninth century), who, assuming the sphericity of the Earth, came to introduce new methodologies in their observations. Several measurements of the 1^{o} meridian were made between the Tigris and Euphrates rivers to compare the calculations made by the Greeks. The value assigned to the arc measurement is accepted as having the value of: 56 2/3 miles. The integration of the West into Earth sizing operations was undoubtedly favoured by the continuous translation of Arabic texts, which in this way recalled the theories of the Greek classics. Another essential factor for the development of geographical knowledge was the invention of printing, even though printing was invented in China in 593. The Dutchman Laurens Coster, later considered the inventor of printing, in the fourteenth century was the first person using a wooden pattern.

In the 19th century, the progress of practical geodesy is registered. The word geoid first appears to denote the physical figure of the earth. Geodesy becomes an essential support for the cartographic representations of each country. Although the methods of the 18th century remain in general terms: triangulation, spherical astronomy, gravimetry and time measurement, the observations are made with much more precise instruments and with an extreme rigor in the methodology used. Geodetic networks have begun to be configured according to the criteria of the main chains along the meridians and parallels.

The end of the century was marked by the great work of measuring the meridian arcs carried out by geodesists together with astronomers, to determine the parameters of that ellipsoid that has the best approximation with the physical earth. The most important ellipsoids were Struve's ellipsoid, Bessel's ellipsoid and Clarke's ellipsoid. Gauss (1803-1807) was one of the greatest mathematicians of all time and in 1808 devised the method of equal heights to determine longitude and latitude simultaneously. Gauss recognized in 1828 that the ellipsoidal model is not valid if it is desired to obtain greater accuracy, stating that the deviation from the physical vertical, materialized by the instrument and the vertical defined by the ellipsoidal system could no longer be ignored. This leads to the need to consider another surface that best fits the actual shape of the Earth. Despite this, the first works and geodesic networks compensated with the least square’s method (Legendre 1806, Gauss) treated the deviations from the vertical as random errors and not as systematic errors. The determination of the geoid would have been the general concern of specialists until the middle of the twentieth century and the main objective of geodesy. Geoid determination remains a key issue of geodesy and even today, its importance has been increased again due to the emergence and development of GPS techniques and the use of three-dimensional global reference systems. In the twentieth century, the concept of classical geodesy disappeared and the notion of spatial geodesy appeared, which made extensive use of the mathematical foundations that had already been established for traditional geodesy. With new technologies, new measurement possibilities appear and due to space techniques we can determine the shape of the Earth or we can determine the coordinates of the points on the Earth's surface. Spatial geodesy is based on observations of points outside the Earth's surface, which must not be visible. The launch of the Sputnik-1 satellite in 1957 ushered in an era of artificial satellites, opening a new frontier of exploration. This was followed by the use of satellites in various applications for the interest of the world community. Technology has advanced dramatically and one of the areas in which this progress has manifested itself in particular is that of applications concerning the Earth sciences, especially the study of the shape and dimensions of the Earth. The launch of the first artificial satellites was another important step in geodesy. Within the groups of space geodesy systems stand out: Constellation NAVSTAR and Constellation GLONASS (Global Satellite Navigation System) Both constellations were created by the US and Russian defence departments, respectively. This positioning takes place on a Cartesian inertial reference system, which in the case of using the American constellation NAVSTAR corresponds to the WGS-84 system and in the case of using the Russian constellation Glonass corresponds to the PZ-90 system. The applications of these satellite positioning systems are very varied. Altimetry measurements obtained from satellites, added to the gravimetric data obtained at the surface are the most innovative observations globally. One of the main applications of gravimetry in the field of geodesy is the determination of geopotential altitudes for the representation of the real shape of the Earth and the definition of the real shape of level surfaces, especially the geoid and the definition of the curvature of the gravitational field.

21st Century Geodesy takes a step forward with the ambitious Galileo project, which was launched in 2006. Galileo is a European initiative to develop a civilian-owned global satellite navigation system that gives Europe independence from current systems: GPS (USA). and GLONASS (Russian Federation). There are four characteristic parameters that are used to evaluate the performance of all global "GNSS" satellite navigation systems: signal availability (which means that there must always be at least four satellites in the receiver's visibility), continuity (signal transmission must not be interrupted), accuracy (degree of uncertainty of the position provided by the system) and integrity (veracity of the information provided by the system, including the alarm when the system does not work properly).

There was presented a modern topographic equipment used in mining with an emphasis on underground mining. Currently, the following equipment and technologies are available: laser scanners, GPS technology but also other sophisticated software systems and tools. These devices complement the traditional or classical measuring instruments very useful in mining: goniometers, theodolites, tachymetric theodolites, levels, etc. The current generation of modern topographic systems provides the mining surveyor with the means to produce high-precision plans and efficient manipulation of measurement data, in order to provide 3D representations of the terrain to be measured. In addition, the use of "laser-tunnel" tunnel equipment began in underground mines, while laser levelling systems added a new level of precision to surface excavation. In the current century, digital mapping of mines and the widespread use of UAV equipment (drones) have taken place. As part of the Swedish group Hexagon, "Leica Geosystems" offers the mining sector both topography equipment and its Jigsaw management system. "Leica Geosystems" has launched its own "JPS Jigsaw" positioning system, developed in collaboration with "Locata". Instruments available for underground measurements also include the Leica robotic monitoring system, which can provide topographic data of the environment. Operated remotely from a secure location, data is collected and transmitted wirelessly. For data processing, Leica FieldPro provides an interface to combine AutoCAD software with that of Leica total stations. The company "British Columbia" in Canada specializes in settlement monitoring using the Lidar ALS-70 scanner, with a vertical accuracy of 100 mm and is one of the few aerial laser scanners with power and multi-pulse capability required for mining applications. The Australian company Locata Corp has invented a new technology that creates local ground positioning networks. It offers high-precision GPS-style positioning, navigation and synchronization capability called PNT, a technology that is completely independent of satellite signals. Surface mining was one of the first to enthusiastically adopt "Locata". "Leica Geosystems" has developed the first "GPS + Locata" receiver for use in the surface mine. This ensures the positioning of machines with centimetre accuracy, even when RTK GPS (real-time kinematic method) fails completely. In mining topography, the emphasis is on the real need for traditional topography equipment, which can be used both on the surface and underground. Most surveying equipment manufacturers around the world include these types of tools in their product portfolio. For example, Topcon positioning systems offer a series of compact total stations with "self-tracking", designed to operate tasks in mining topography such as: tracing the volume of excavations, with the help of a single person. The Austrian surveillance equipment manufacturer "Riegl" has made the VZ-6000 laser scanner available to surveyors. The scanning system from the UK supplier, "3D Laser Mapping", uses laser scanners: Riegl VZ-4000 and VZ-1000 for data acquisition. The data is processed in the "SiteMonitor" software to perform topographic measurements to determine the stability of the mine. 3D Laser Mapping recently acquired the rights to market a mobile Lidar scanner, developed by an Australian research organization CSIRO. The scanner called ZEB1 uses robotic technology called "simultaneous location and mapping" (SLAM). Topography of gaps, such as open banks, abandoned mines, etc. it is probably the most dangerous work on the surveyor's agenda by me. Measurement Devices Ltd (MDL), part of the UK-based Renishaw Group, offers a solution with its C-ALS system” (“Cavity laser self-scanning system”). The "MS3" automated well measurement and monitoring system, developed by the Canadian company "Sight Power Inc.", offers a new way to measure and study wells. Trimble also focuses on expanding the value and use of topographic technology in mining applications. Trimble describes its "Ux5" aerial imaging solution as a complete unmanned imaging system designed specifically for surveyors and geospatial professionals. According to the Australian company Sandpit Innovation, the mining sector currently uses a combination of ground topography and aerial flight, with the ongoing use of UAV technology, to determine monthly or overall material volumes. "Sandpit" has partnered with "Lockheed Martin" to develop an advanced conciliation service called "mineRECON", which uses satellite imagery to measure materials and provide quick reports on the volume of materials.

There were presented the main positioning elements, from the reference surfaces and coordinate systems, to the reference and coordinate systems, (with emphasis on the national reference system and the 1970 stereographic projection), to aspects regarding the geodetic networks and their functions and classification. In our country, the conventional National reference system is based on: the 1940 Krasovski ellipsoid, the Stereographic projection 1970 for the positioning of geodetic networks in the plane and the geoid or quasi-geoid for altitudes or elevations. Recently, the European EUREF system has been introduced and progressively expanded, in certain stages, in the form of points, points that have been brought together in a higher order geodetic network, respectively positioned with high precision satellite.

Chapter 3 was entitled: “Topographic support networks. Internal error of the endpoint in the suspended polygon. Up-to-date mining network. Mining triangulation” and refers to the following topics: “Considerations on topographic support networks for mining activities”, “Average error and limit error of directly measured topographic quantities”, “Internal error of endpoint in suspended polygon”, “Proximity network up to date” and “Mining Triangulation”.

For the design and execution of open pit mining and underground operation constructions, topographic measurements have been necessary since ancient times. But due to the changes, on the one hand the area of the elevations increased, and on the other hand the demands for their accuracy increased. Topographic surveys serve chronological phases of work: delimitation of the exploitation perimeter, determination of the geometric shape of the deposit presentation, design and execution of mining works of constructions and conveying appliances (installations) from the surface and underground, exploitation of the useful mineral substance.

The chronology and the specificity of the development phases of a deposit differentiate the character of the surveys and the topographic documentation, so there are:

-topographic works necessary for the prospecting and exploration of the deposit, for the design of the mining unit at an overall level;

-topographic works necessary for the execution of constructions; setting out of open pit mines and underground operations, periodic control of the execution and stability of mining transport conveying appliances (installations);

-constructions geodetic survey, the executed excavations.

This correlation is ensured by framing and re-evaluating all the successive data and surveys in a single reference system, namely created which from the point of view of precision must satisfy the requirements of the most demanding phase: the execution of the opening and preparation mining works. This unique reference system adopted is realized and materialized in the field through a network of support points.

The accuracy of the points determines the cost, the duration of the realization but also the area of use. The accuracy of the network can be characterized by Ferroro error, by offset angle error, coordinate error, point position error, indirectly determined side error.

The subchapter entitled: "Considerations on topographic support networks for mining activities" includes: "The role of support networks in mining topographic activity", "Projection system", "Coordinate system" and "Point accuracy". "Point accuracy" refers to: "Boundary error of underground mining works", "Rational support network" and "Section and network accuracy".

The subchapter entitled: “Average error and limit error of topographic quantities measured directly” deals with issues related to: “Accuracy assessment” (more precisely: “Reliable range of normal distribution”, “Influence of the actual number of additional measurements on the confidence interval” “Confrontation confidence intervals in case of a small number of measurements with practical experience ”but also“ Average error of average error, measurement of accuracy ”) but also considerations regarding:“ Average error and limit error ”.

The subchapter entitled: "Internal error of the endpoint in the suspended polygon" includes: "Product of the composition of normal distributions", "One-dimensional derived variables", "Defining the range of internal mean errors using coordinate ellipses", "Influence of angular and orientation errors", "Influence of side errors" and "Influence of polygon geometry on error accumulation".

The subchapter entitled "Geodetic approach network" includes notions of: "Influence of relief and coverage", "Combined linear and angular intersection" and "Parallactic polygonal lines".

The last subchapter entitled: "Mining triangulation" is a complex subchapter that deals with theoretical and applied notions regarding: "Optimal accuracy and maximum rational accuracy of the mining topographic support network at the level of triangulation points", "Reference area and plan mining projection", "Verification of geodetic triangulation. Improving accuracy", "Boundary precision of third and fourth order networks" and "Transcalculation of geodetic coordinates on the equipotential surface element".

"Optimal accuracy and maximum rational accuracy of the mining topographic support network at the level of triangulation points" includes: "Triangulation accuracy", "Evaluation of the accumulation of errors in the reference polygon", (more precisely: angular and orientation errors "), but also:" Assessment of the accumulation of errors in the geodetic network of the reference range", (more precisely:" Geodetic network supported on IV order points", "Proximity network supported on V order points" and " Required accuracy of the triangulation network: optimal accuracy. Comparing the actual accuracy with the optimal one").

"Reference area and mining projection plan" includes: "A generalization of the limit accuracy for the last step. Limit of systematic deformations", "Deformation caused by vertical convergence", "Successive reduction of level surfaces, place of measurements, at the reference ellipsoid and Gaussian sphere" (dealing with the topic of: "Ellipsoid reduction of measured quantities" and "Reduction of on the ellipsoid on the Gaussian sphere"), but also: "The mining projection plan".

On the subject: "Verification of geodetic triangulation. Improvement of accuracy ", notions related to:" Verification of the V-order network "," Verification of the IV-order network "," Verification of the III-order network "," Local improvement of the geodetic triangulation accuracy "and" Evaluation of increased accuracy".

The analysis of "Limit accuracy of third and fourth order networks" includes: "The general expression of the decrease in accuracy in the thickening operation" and "Decreasing the accuracy when thickening by varying the coordinates".

And last but not least, "Transcalculation of geodetic coordinates on the equipotential surface element" refers to: "Transcalculation of Gaussian - Krüger coordinates" and "Transcalculation of stereographic coordinates".

Chapter 4 is the case study, being given by: "Analysis of measurements in the indirect determination of errors". The practical application includes the following subchapters: "The role of polygonation methods in raising the topographic support networks for mining activity", "Variants of indirect measurement of distances in polygonations", "Correlation between distance and accuracy of indirect measurement with horizontal stage" and "Correlation between distance and precision for indirect measurement with horizontal stage".

In the mining regions, the polygonation method has a special role in raising the support network due to the impossibility or uneconomical application of methods such as: micro triangulation, intersections. The extension of the reference system, materialized in the area of the mining field through the points of the state or basin triangulation, located in the dominant peaks of the relief, up to the mouths of galleries, wells or inclined planes has its own peculiarities. In general, it can be done in two phases: the determination of close points by the method of intersections and the execution of polygons between these points, whose routes include the enclosures and the access gates to the underground.

There are frequent cases when it is not possible to create close points, polygonation remaining the only method of thickening. But, measuring the length of the sides, in the conditions of a very rugged and covered ground, respecting the precision requirements, is a particularly difficult operation.

The direct method is generally excluded due to the large number of gates required to create straight portions, directly measurable, due to the accumulation of errors in the actual measurement of lengths, inclinations and especially due to low efficiency.

Indirect determination can be performed either by geometric relationships between a directly measured quantity and the desired distance, or physically, using optical or electromagnetic waves. The first process uses optical-mechanical devices (wire, steel roulette, horizontal or vertical stage, theodolite, tachymeter, etc.), the second electronic rangefinders, representing a new auxiliary means of geodesy.

The group of electronic devices gives measurement errors of the order of: $\pm$ 5 cm + (2. 10^{-6} d) $\div$ $\pm$ 1 cm + (2. 10^{-6} d) for extremely low time consumption. In this way the rangefinders give, at a high economy, a sufficient measurement accuracy for almost all geodetic operations. We will only remember the measurement variants that ensure an accuracy of at least 1: 10000. This precision limit cannot be used to measure the sides of polygons intended to create support networks.

The doctoral thesis also includes conclusions, bibliography, list of figures and list of tables.