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Theoretical Substantiation and Technology of Geodetic Support of Chromite Deposits on the Case of Kazakhstan: Literature Review

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Abstract

The study aims to examine modern technologies and develop theoretical foundations for geodetic support for the extraction of chromite ores at the Khromtau deposit. The Khromtau deposit is situated in northwest Kazakhstan's Aktobe region, about 90 km east of the regional capital, Aktobe city. This area is a component of the dry steppe terrain that makes up a large portion of northern Kazakhstan. Research methods such as analysis, comparison, systematisation, and synthesis were used while writing the study. The analysis has identified the most important technologies necessary for successfully searching and providing chromite deposits. Geodetic work is an important part of this process, including triangulation, polygonometry, and levelling techniques. These methods allow for a more accurate determination of the examined area's geometric characteristics, which contributes to a more accurate identification of potential chromite deposits. Surveying includes planning and controlling geometric parameters in the field itself. These parameters are of great importance when developing plans for the placement of future mining operations, considering the deposit's complex mining and geological features. Filming is an integral part of the exploration of chromite deposits. It includes the creation of three-dimensional models of deposits and the surrounding area, which provides a more complete and visual representation of the geometry of the deposit.

Keywords

Ore, mine surveying, levelling, polygonometry, triangulation.

Introduction

Chrome ores are an important strategic resource due to chrome's critical uses in metallurgy, chemical industries, and advanced manufacturing. When added to steel and other alloys, chrome is a crucial alloying element that provides superior hardness and corrosion resistance (Xu et al., 2021; Gu et al., 2022). These alloys are essential for sectors such as aerospace, automotive, energy production, and military applications, which accounts for their strategic significance. The development and extraction of chromite ores is a complex and dangerous task that requires the use of modern technologies because the ores often occur in complex geological formations that make mining challenging. The extraction process calls for meticulous planning, advanced mining engineering, and comprehensive geodetic mapping to guarantee that the mines are developed safely and cost-effectively. Furthermore, there may be asbestos and other potentially harmful substances in chrome ores, calling for strict environmental controls during mining and processing. Geodetic support is an integral part of the extraction of chromite ores, as it ensures the accuracy and safety of work. Chromite deposits are an important mineral resource base for the metallurgical industry. This research focuses on analysing the geodetic support for chromite ore extraction in the Aktobe region of Kazakhstan, specifically at the Donskoy Ore Mining and Processing Plant (DGOK) and the "10th Anniversary of Independence of Kazakhstan" mine. The problem of the study is the need to develop and optimise methods of geodetic support for the extraction of chromite ores. Other researchers have previously engaged in similar research topics.

A study conducted by Beckbergenov et al. (2019) examines issues related to chromite mining development by creating a combined development system and provides methodological recommendations for its implementation in production conditions. This proposed technology method will substantially increase the efficiency of underground mining at DGOK mines. The study also presents a technological scheme for combined geotechnology of underground mining at great depths in DGOK mines, especially in conditions of severe fracturing and instability of ore deposits. Amiralinova (2021) explores issues related to the provision of surveying operations during ore extraction at one of the largest chromite deposits in the world, located in the Republic of Kazakhstan, Aktobe region, in the city of Khromtau. The Diamond-Pearl deposit of the "10th Anniversary of Independence of Kazakhstan" mine has been discovered and is being developed using one main shaft and two ventilation shafts. The deposit is developed using the floor method, considering data from the state geodetic network (SGN). Theodolite passages are based on the points of the reference network, while angular passages are oriented to the points of theodolite and polygonometric passages. Beckbergenov et al. (2021) conducted a study on developing a combined extraction method designed for sustainable chromite extraction at the mines of the Don mining and processing plant. This method involves dividing the extracted deposits into sections and consistently advancing the development front in a staggered manner within each section having the shape of a trapezoid with an angle of inclination of the side walls within 70-80℃ from the top layer of backfill.

Safirova (2021) researched Kazakhstan's mineral industry in 2017-2018. It was determined that interest in the mining industry of Kazakhstan will continue to grow, and the number of projects for the extraction of substantial mineral resources in the country will also increase. The increase in the number of exploration projects being implemented in Kazakhstan indicates the potential for further growth in mining in the country. However, it has been examined that the future development of this industry will depend on many factors, including mineral prices and the development of government policies and programmes aimed at stimulating the growth of mineral production. Kim et al. (2019) engaged in developing and implementing a new technology for producing chromite agglomerates. Their work included theoretical studies and experiments on the agglomeration of chromite ores in the DGOK. Theoretical analysis has shown the need to introduce a low-melting material, fayalite, with a lower melting point of 1208℃, into the composition of the agglomerate or pellets. This was achieved by adding fine-grained "acidic" fluxes such as quartzite and dust obtained during the gas purification of ferroalloy furnaces to the sintering mixture (Borisov et al., 1987; Bieliatynskyi et al., 2016). This technology has been successfully implemented at the Aksu ferroalloy plant.

The presented examinations play an important role in this field of research; however, a full-fledged investigation of geodetic support technologies for ore deposits has not been conducted. Based on the above, this study aims to develop a comprehensive methodology and technology for geodetic support of chromite deposits, considering the specific features of deposits in the Aktobe region, namely the "10th Anniversary of Independence of Kazakhstan" mine. The results of this study will be of practical importance for the activities of mining enterprises operating in chromite deposits and contribute to more effective management of these resources.

Materials and Methods

In this study, various research methods were applied, which helped to gain a deeper and more complete understanding of the subject. The main methods used in the study were analysis, comparison, systematisation, and synthesis. A detailed analysis of existing geodetic methods and technologies used to extract chromite ores was conducted. Scientific publications, papers, and regulatory documents related to this topic were examined. Data analysis identified the strengths and weaknesses of existing methods and areas requiring additional research. The analysis was used to examine the theoretical foundations of geodetic support for chromite deposits and analyse existing methods and technologies of geodetic support. By comparing different deposits and their geological characteristics, it was possible to identify common features and differences. This comparison allowed for the identification of factors that may be key in searching for new deposits. Systematisation was an important stage of the study, especially in the context of surveying and filming. It allowed obtaining primary data and information about specific deposits, including their physical condition, structure, and natural features.

Based on the synthesis, a comprehensive methodology and technology for geodetic support of chromite deposits were developed, considering the specific features of these deposits. This methodology combines best practices from various sources to create a modern and effective approach to geodetic support for the extraction of chromite ores. The synthesis of methods and knowledge was an important stage in developing a comprehensive methodology and technology for the geodetic support of chromite deposits. This process allowed combining the best practices from various sources and the creation of a modern and effective approach to geodetic support for extracting chromite ores, considering the specific features of deposits in the Aktobe region.

An important part of the process was the review of modern scientific research and development in geodesy and mining ore deposits. This allowed us to consider the latest achievements in this field and integrate them into the methodology. All these research methods were used together to create a comprehensive study capable of providing the most efficient and accurate geodetic support for the extraction of chromite ores. In this study, such stages of work were conducted as the analysis of scientific literature, the analysis of methods of geodetic support surveying, the analysis of survey work, and 3D filming. The systematisation and analysis of the existing scientific and technical literature related to the geodetic support of chromite deposits were conducted. In the course of the study, a deeper systematisation and analysis of scientific and technical literature related to the geodetic support of chromite deposits was conducted. This important stage of the study allowed researchers to gain a more complete and detailed understanding of the current state of knowledge and technology in this field. In addition to identifying gaps and prospects for future research, a more detailed assessment of existing geodetic support methods, including triangulation, polygonometry, and levelling, was also conducted.

The analysis of surveying and the filming work were also important stages of the study since these aspects are directly related to the practical implementation of geodetic support. In analysing the surveying work, the researchers examined in detail the processes, techniques, and tools used by the surveyors when working at chromite deposits. Similarly, during the analysis of the survey work, the methods and techniques used to collect data and create geodetic models of deposits were examined. All these aspects of the study jointly contribute to a deeper understanding and improvement of geodetic support for chromite deposits and help develop recommendations and regulations to optimise this process in the future.

Results

Theoretical Justification. The chromite mines of the Don complex are located near the city of Khromtau in northwestern Kazakhstan, at a distance of 90 km east of Aktobe, the regional city centre. This enterprise currently combines two underground mines, an actively functioning quarry, two enrichment plants, two concentrate factories, and a fine tailings processing plant (Serikova, 2022). Here are some of the key objects:

1. "10th Anniversary of Independence of Kazakhstan" mine.
2. Molodezhnaya mine.
3. Yuzhny quarry opened for the 20th anniversary of the Kazakh SSR.
4. Factory No. 1 (DOF-1) and Factory No. 2 (FOOR) – crushing and beneficiation plants, the products of which are coarse-grained, high-grade lump ore.
5. OMK-1 and OMK-2 are concentrate production plants that further refine the chromite concentrates.
6. Pellet processing factories No. 1 (UPO-1) and No. 2 (UPO-2) – produce chromite pellets as a value-added product.
7. Tailing dump No. 1.

Chromite deposits were discovered in the 1930s, and mining at the Don quarry began in 1938. In 1959, annual production exceeded 1 million metric tonnes; in 1973, it reached 3 million metric tonnes. In 1982, mining began at the Molodezhnaya underground mine, and the mine was put into operation in 1982 (Figure 1). Since the first mining in 1938, 24 quarries have been opened. The Yuzhny quarry is still active, but it is planned to close by 2022. In 1995, the DGOK merged with the Aktobe and Aksu ferroalloy plants and became part of Kazchrome (Melcher et al., 1999). The Don complex is served by roads and railways, connecting it to the west from Aktobe and east to Astana and the Aksu ferroalloy plant (Prentkovskis et al., 2009; Prentkovskis et al., 2010). Electricity is supplied by Kazakhstan's energy system. The topography of Kazakhstan's central and northern parts is essentially a flat, treeless steppe.

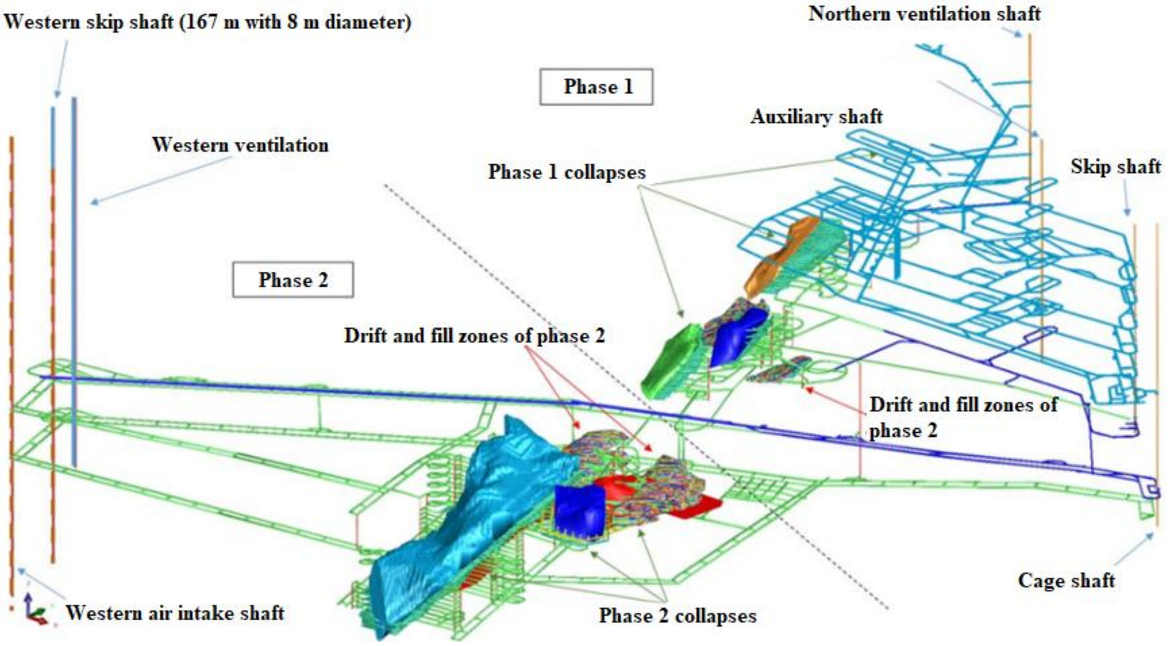

Fig. 1. A long section of the "10th Anniversary of Independence of Kazakhstan" mine (Oldcorn, 2018)

The Don chromite mining complex near Khromtau City in northwestern Kazakhstan is a major producer, with underground mines, open pit quarries, processing plants, and tailings facilities. Considering current ore reserves and projected production volume, the Don complex is expected to be operational until 2051. The products of the Don deposit include concentrates of various grades and sizes, pellets, briquettes, and rich ore. High-quality ore is only subjected to grinding and calibration without further processing. Understanding this sprawling complex's geological setting and layout is critical for planning efficient and safe geodetic support operations.

Geodetic Measurements. Triangulation is a geodetic method that creates a network of adjacent triangles on the ground, each of which measures all internal angles (Villar-Cano et al., 2020). This method involves placing triangles on the Earth's surface in a certain order so that their shape approximates an equilateral one. All angles inside each triangle are measured, which ensures reliable control of angular measurements on the ground. It is enough to measure one of them to determine the lengths of the sides of a triangle, which makes the process more efficient. The state triangulation network is classified into four levels: 1st class (20 from 25 km), 2nd class (15 from 20 km), 3rd class (10 from 15 km), 4th class (5 from 10 km). The upgrade is due to an increase in the accuracy of measuring instruments. Before creating a triangulation network, reconnaissance is conducted, during which certain points are selected for the placement of triangles and the heights of geodetic markers are specified (Shevchenko et al., 2020).

Polygonometry is a method of geodetic measurements on the ground, during which all lengths of sides and angles in triangles are measured. In polygonometry, theodolites are used to measure angles. Various tools are used to measure the lengths of the sides in polygonometric passages, such as light and radio distance metres, optical-mechanical rangefinders, and tapes (Zhugurova et al., 2020). The lengths of the sides can also be determined by measuring from a known basis through auxiliary geometric shapes with measured angles. When designing a polygonometric network, an optimal plan for the placement of moves is developed, anchor points are selected, and observations and analysis of the results are conducted.

The map primarily displays the existing points of triangulation and polygonometry in the work area. Then, the moves are planned, starting with higher grades (Figure 2). The following conditions are considered: the lines of moves are placed along streets, roads, glades, and other convenient places for measurements; anchor points are selected close to the objects to be photographed and built to ensure convenience and safety of work; polygonometric moves are tried to be elongated and equilateral, avoiding the proximity of short sides to long ones; the linear discrepancy is estimated, and if it exceeds the set value, the project is adjusted (Stepanchuk et al., 2016; Urakov et al., 2021).

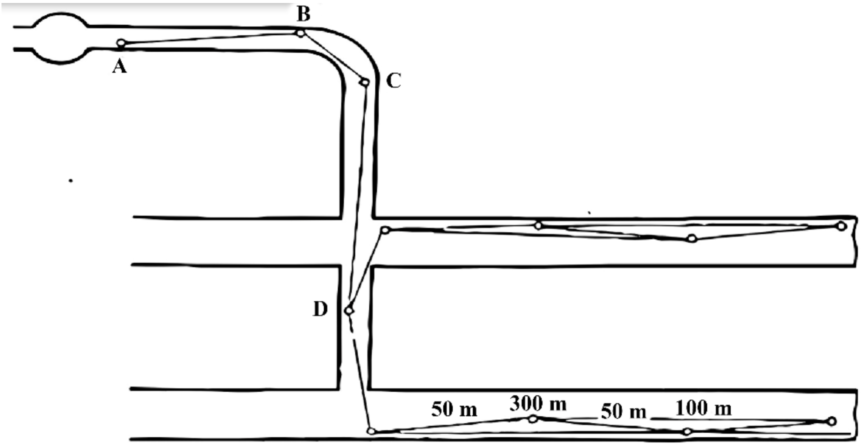

Fig. 2. Polygonometric stroke (Narymbaeva, 2020)

The heights of geodetic points are determined by the levelling method, one of the geodetic measurement methods. The height difference between the points and their height relative to the selected horizontal surface is measured in the levelling process. The results of these measurements are used to create relief images on plans and maps and build profiles of the Earth's surface (Grigoriadis et al., 2023). There are several types of levelling, including geometric and trigonometric levelling. Geometric levelling is performed using special geodetic tools, such as levellers. It is classified according to technology and accuracy of work into four classes: I, II, III, and IV. Trigonometric levelling, in which the height differences of terrain points (exceedances) are measured, and their heights are determined using an angle-measuring geodetic device such as a theodolite (Figure 3).

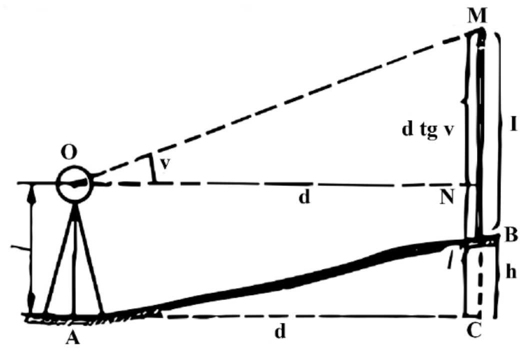

Fig. 3. Trigonometric levelling scheme (Narymbaeva, 2020)

Various types of measuring rails are used for levelling:

1. Three-metre double-sided with divisions marked with checkers on each side, with one side painted red and the other – black.
2. Three-metre double-sided slats with black divisions on one side and red divisions equal to 11/10 cm on the other side.
3. Three-metre single-sided or double-sided slats with dashed divisions have half-centimetre intervals.
4. When using the first type of rails, the divisions are digitised in decimetres, and on the black side, zero coincides with the heel, and on the red side, the countdown starts from the heel and goes up to 40 dm. Random division errors should not exceed 0.5 mm.

The foundation of geodetic measurements for chromite deposits is composed of triangulation, polygonometry, and levelling. In triangulation networks, horizontal control is established by measuring angles. To survey corridors, polygonometry combines measurements of angles and distances. Relief mapping is guided by levelling, which measures elevation variations using specialised tools like levellers and rods. Efficient planning, reconnaissance, and network architecture based on hierarchies enable precise geometrisation of the deposit.

Surveying Work. Surveying work is conducted at all stages of the development of a mineral deposit, starting with exploration and ending with the liquidation of mining enterprises. In the exploration stage, the surveyors, based on the topographic survey data and the approved exploration project, determine the location of exploration works such as wells, pits, and ditches. After that, they take pictures and create a plan for the location of these workings (Dolgikh et al., 2020). Together with geologists, the surveyors document information about the workings conducted, including the sampling location, geological characteristics of rocks, and other mineral properties. This allows for characterising the shape of the deposit, the surrounding rocks, and the geometry of the distribution of the mineral's properties. The collected data is used to calculate the volume of mineral reserves.

When designing mining enterprises, surveyors provide graphic and digital materials to account for the geometry of design structures and workings. During the construction process, their tasks include transferring the geometric elements of projected structures and workings to the terrain, monitoring compliance with the geometric parameters of the project, and surveying the position of new structures and mine workings. When developing mineral deposits, surveyors obtain information about the position and condition of underground mining, the geological features of the deposit, and the systematic accounting of mining operations. They also ensure the protection of structures from the effects of mining operations, monitor the movement of mineral reserves, and participate in planning the development of mining operations (Dolgikh & Kremer, 2023).

During the liquidation of mining enterprises, surveyors film underground workings, update surveying plans, process coordinates, levelling and orientation data and transfer important surveying documents for storage. The survey data is used to create current, extremely accurate 3D models of the infrastructure, such as shafts, ramps, and subterranean chambers, as well as the mined-out sections, depleted ore reserves, and any residual pillars and sill resources. The structural study of the residual ground conditions, the estimation of future subsidence hazards, the design of appropriate sealing and flooding procedures, and closure planning all greatly benefit from these final 3D models.

Filming and 3D. Underground filming can be classified into three main types: joint horizontal filming, electronic roulette filming, and measurements of mine workings. Joint horizontal filming of workings is used in most cases when performing surveying work related to determining the position of workings, while simultaneous transmission of coordinates from one station to another point of the filming survey network is necessary. The electronic roulette filming of the cleaning mine faces includes measurements using an electronic tape measure from the points of the filming survey network. The survey results are used to supplement graphic documentation and solve various mining problems. Measurements of mine workings consist of linking the faces of the workings to the nearest points of the filming survey network, which is the simplest measurement method. The measurement results determine the volume of mining operations performed and add information to graphical documentation (Ospanova et al., 2020).

Modern underground filming can be divided into two main categories: filming to replenish mining plans and profiles of the main pumping, air supply, and other workings and filming to create a three-dimensional model of the completed workings using the Surpac software. In both cases, a common filming method is used. Even in underground environments where surface methods are traditionally used, this method is becoming more common due to its simplicity, convenience, and the ability to conduct a large number of measurements from a single station. The use of electronic total stations in underground conditions makes this method the most effective in terms of measurement time and shooting accuracy. The objects of the survey can be all types of mining, including preparatory and treatment works, exploration, hydrogeological, technical wells, chambers for various purposes, and transport routes (Clarke et al., 2023).

This Surpac software solution is used to develop plans for further development of mining operations, the design of blast wells, and other related works (Monyakeng, 2022). 3D models provide information about the spatial location of workings, including coordinates, heights, cross-sectional areas of workings, and volumes of extracted rock mass from various processes. The objects being filmed in 3D are mine workings, connecting elements between them, niches for various purposes (including electrical and overload niches), and geological disturbances, regardless of their location inside the workings. Transverse profiles along rectilinear mine workings are usually performed at intervals of 2 m, except in areas with special features such as landslides and niches for various purposes (Stupnik et al., 2023). If necessary, the filming can be conducted with an interval of 1 m along the rectilinear parts of the mine workings. 3D mining modelling is performed in accordance with the 3D modelling instructions and other recommendations provided for working with the Surpac software. The models can be used to create longitudinal profiles of capital, pumping, and other types of workings. In addition to these capabilities, 3D models allow the creation of cross-sections of workings, which allows for estimating the monthly volume of extracted rock mass from various workings and controlling the quality of completed mining operations with respect to deviations from design parameters in terms of the area of completed workings (Rodriguez et al., 2020).

The files created during the 3D modelling process are divided into sub-stages. If a work intersects several sub-stages, then these sub-stages can be combined if this does not interfere with further modelling. If combining sub-floors entails conflicts, then the same output can be divided between two sub-floors in accordance with any profile. Therewith, it is not allowed to cut off parts of existing workings or the workings of higher horizons. At the output, certified 3D models are created that carry complete information. The study substantiates the basic principles of geodetic support for chromite deposits, including creating a geodetic reference network, surveying, creating digital terrain models, and 3D models of mine workings. The following is recommended to improve the efficiency of geodetic support for chromite deposits in Kazakhstan:

1. Develop unified regulatory documents regulating the geodetic support of chromite deposits.
2. Introduce modern technologies of geodesy, surveying, filming, and 3D modelling.
3. Provide training and advanced training for surveyors working at chromite deposits.

Underground filming models and visualises extraction voids by integrating survey network measurements. Joining vertical and horizontal traverses at mineralised faces is a common approach. Stope volumes and geometries can be completely captured by 3D laser scanning. Complex orebodies can be digitally scanned in three dimensions for production planning and reconciliation using specialised mining software such as Surpac. Regular filming monitors development in comparison to plans.

The study also highlights the importance of geodetic support for the successful exploration, construction, and operation of chromite deposits. The results obtained can be used in the mining industry's practice to optimise operations and ensure safety in the fields.

Discussion

The study's findings demonstrate the necessity of thorough investigative work in order to precisely locate and assess the areas and topography that may contain chromite deposits. No single method can produce signs and outcomes that are sufficiently trustworthy on their own. Rather, an integrated multidisciplinary strategy integrating several approaches is required to achieve a more accurate identification of chromite deposits. It is a good idea to consider and evaluate additional information and technologies that have been looked at by other researchers who have focused on different facets of ore prospecting, in addition to the geodetic surveying, geological mapping, and geophysical exploration activities detailed in this study. Some researchers have turned their attention to various aspects of this issue in the course of their papers, which are discussed below.

Eskandari et al. (2023) investigated the possibilities of using satellite remote sensing, unmanned aerial vehicle (UAV) geological mapping, and machine learning methods for the exploration of deposits of podiform chromites. As a result of the study, it was determined that special attention should be paid to serpentinites with a probable dunite protolith covered with an iron and nickel laterite crust. These geological formations proved to be the most promising for detecting chromite deposits, especially in the presence of contact with the main dikes. This means that when searching for chromites, attention should be focused on such sites, which can substantially increase the efficiency of exploration work. The researchers also identified the potential of multi-scale remote sensing, including satellites and UAVs, to identify traces of chromite mineral deposits. These technologies can be successfully applied to identify areas where the formation of podiform chromites is possible and clarify their size and shape. This opens up new prospects for the mining industry, optimising the processes of prospecting and exploration for deposits of chromite minerals. The study highlights the importance of sharing modern technologies and methods to improve the efficiency of geological exploration and the discovery of valuable natural resources, such as chromites. These results can contribute to a more sustainable and efficient use of the Earth's natural resources. This technology can be useful for exploring regions with chromite deposits. However, this method can be quite expensive and not practical since the scale of observation is not large. In addition, a method such as 3D scanning may be more productive in obtaining the necessary data on chromite deposits.

A study by Baklavaridis et al. (2021) aimed at the mineralogical examination and evaluation of chromite ores in the Grevena and Kozani massifs in Vourina, Greece. Various analytical methods were used for this purpose, including X-ray diffraction (XRD) to determine the mineral phase, scanning electron microscopy (SEM) in combination with energy dispersion spectroscopy (EDS) analysis to examine the elemental composition of the samples in detail, and thermogravimetry and differential thermogravimetry (TG/DTG) to examine their thermal properties. In this study, an original characterisation of the Vourine chromite complex in the region of Western Macedonia, Greece, was conducted. Special attention was paid to chromite deposits in the Etorash mine area. The results of X-ray diffraction showed that magnesium and aluminium chromite phases, also known as "aluminopicrochromite," predominate in all samples, and traces of forsterite (magnesium olivine), serpentine and chlorite were also identified (Borisov et al., 1998). Based on the data obtained by scanning electron microscopy and analysis of energy dispersive spectroscopy, the average chemical formula of chromites was calculated, which indicates a specific type of chromite: $(Fe_{0.4}, Mg_{0.6}) (Cr_{1.6}, Al_{0.4})O_4$. Additionally, the study identified weight loss during heat treatment in the range of 4.4% to 14.36% at temperatures from 600°C to 750°C. These results indicate the presence of hydroxyl silicate minerals, serpentinite, and chlorite in the samples, which is consistent with the results of ignition loss (LOI) (Kunitskiy et al., 1988; Prokopov et al., 1989). The mineral phases identified in this study are also present in the main rocks of dunite, diorite, harzburgite, and peridotite of the ophiolite complex, which contain chromite ore. The methods used in this work are quite effective for detecting chromite deposits and examining their chemical structure. The research results can be useful for analysing the chemical composition and characteristics of ore deposits. Notably, these methods can be implemented to examine Khromtau, but expensive equipment and trained specialists are necessary for this. Currently, using these methods will not be possible since there is no way to purchase equipment and train technology specialists.

Junge et al. (2021) conducted a study to examine the mineralogical features of deposits of podiform chromites in the ophiolite of Myrdite, located in Albania. Chromite is a critical mineral for chromium production, which in turn is important in steel production, especially in the ferroalloy sector. In world practice, chromite mining is mainly associated with stratiform deposits associated with ultramafic-mafic layers and podiform deposits of chromites in ophiolites. The study showed that chromite deposits in the Bulkiz area, inside the ophiolite of the Eastern Mirdite in Albania, are characterised by the presence of chromite with a high Cr_3 content in the main chromite ores. This indicates the origin of these deposits in the conditions of the suprasubduction zone. Chromite microtextures in Myrdite ophiolites have a variety of shapes, ranging from interspersed and nodular to semi-massive and massive ores. These differences are explained by different melting processes occurring during chromite crystallisation. At the initial stage of the formation of chromite deposits, the interaction of a melt rich in SiO_2 with peridotite leads to the formation of a hybrid melt. From this melt, chromite crystallises around olivine grains, creating interspersed chromitites. For the formation of nodular chromitites, further penetration of larger melt masses is required, penetrating through channels inside the peridotite. As a result of the mixing of these melts, the crystallisation of larger chromite grains occurs. Semi-massive and massive chromitites form due to the compaction of nodules under the influence of dynamic processes. This study identifies the complex processes of the formation of chromite deposits in Myrdite ophiolite and provides valuable information for understanding these deposits' geological and geochemical aspects. The study is quite useful for examining the composition of chromite deposits. It can be applied as an addition to the investigation of the conducted research to examine the structure of chromites, which will be useful for further use of the ore.

Rezayee et al. (2023) conducted a study, the purpose of which was the structural analysis and inversion of susceptibility data obtained from ground-based magnetic measurements to create a map of chromite mineral resources. Various derived maps were used to determine the boundaries of structural faults and anomalous areas, including the total horizontal derivative, analytical signal, and theta map, which indicate a direction from northwest to southeast. In the inversion process, a variety of regularisation norms, including smooth, intermediate, and compact models, were used to determine susceptibility values at various points in the model. In particular, sparse and block norms for inversion were proposed based on field data synthesised to determine the corresponding norm. The results of the three-dimensional inversion of ground-based magnetic data showed that the region with high magnetic activity, presumably corresponding to the host rocks, is located in the area where chromite is assumed to be present. The study also used derivative methods such as common horizontal derivative analysis, analytical signal, and theta map to understand better the overall structure driven by geological processes. A three-dimensional model was developed that combined magnetometry data to understand better the composition and structure of the Koh Safi chromite ore deposit and determine the distribution of chromite mineral resources. As a result of the study, it was determined that there are zones with the presence of serpentinite changes in the examined territory since chromite mineralisation is not abundant. A certain amount of magnetite is formed during serpentinisation, and magnetometry can effectively detect its presence. It is important to note that this method is not suitable for complex analysis of chromite deposits, as additional geodetic works will need to be implemented and conducted. Compared with the conducted research, this study will not be able to offer the same results as after conducting geodetic surveying and filming work.

Conclusions

In the study, the following results and conclusions were obtained, representing important steps in understanding and developing the subject. Theoretical foundations for geodetic methods such as triangulation, polygonometry, and levelling were developed to ascertain chromite orebodies' geometry accurately. Using these surveying foundations, the complicated three-dimensional forms of the Khromtau chromite deposits may be accurately mapped and monitored in space. It was explained how important surveying is to a chromite mining operation's whole lifecycle, from initial exploration to continuous extraction to eventual closure. Its crucial significance is shown by pointing out how surveying inputs make important tasks possible, including measuring reserves, making sure design specifications are met, monitoring development progress, and recording final excavation conditions. Current cinematography, 3D digital modelling, and subterranean scanning technologies were investigated as potent visualisation tools. Comprehensive geographical databasing of extraction voids and remaining reserves is made possible by combining traditional surveying with laser scanning and technologies such as Surpac. At the Khromtau mines, this digital capability is essential for maximising production scheduling, mine planning, and reconciliation.

In the future, it is necessary to investigate the impact of geodetic support on the safety and efficiency of the operation of the "10th Anniversary of Independence of Kazakhstan" mine. This research should be aimed at identifying factors affecting the safety and efficiency of operation and the development of methods to improve these indicators, namely, the development of methods to improve the accuracy of geodetic support for ore deposits; the examination of the impact of geodetic support on the safety and efficiency of operation of the "10th Anniversary of Independence of Kazakhstan" mine; a more accurate analysis of ore deposits with the determination of the chemical characteristics of fossils; and the development of regulatory documents for the systematic conduct of geodetic, surveying, and filming work according to established rules and specific technology.

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