Research Article / Review Article FUPRE JOURNAL 8(1): 117 -123(2024)

FUPRE Journal

of

Scientific and Industrial Research

ISSN: 2579-1184(Print) ISSN: 2578-1129 (Online)

http://fupre.edu.ng/journal

Geophysical Exploration for Solid Mineral Deposits: A Key to Sustainable Mining Practices

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ARTICLE INFO

Received: 07/9/2023
Accepted: 01/12/2023

Keywords

Geophysical exploration, ,
Geological surveys,
Mineral resource assessment
Solid mineral deposits,
Sustainable mining,

ABSTRACT

This research investigates the geophysical methods employed in the exploration of solid mineral deposits and thoroughly examines the results obtained. The study used a systematic methodology that included survey planning, data collection, processing, and interpretation. The survey planning process has uncovered a range of objectives, among which the surveys related to iron ore have emerged as the most comprehensive in scope. The data collection results revealed significant parameter variations among the surveyed locations, providing a basis for subsequent analyses. Using data processing techniques, as visually represented through line charts, has significantly enhanced data precision. Using subsurface modelling and inversion techniques, visually represented by bar charts or 3D surface plots, has yielded important insights into the potential mineral deposits' depth, shape, and size. Finally, using bar or pie charts facilitated the presentation of summaries that underscored the efficacy in discerning various mineral classifications, wherein iron ore emerged as the predominant type in deposit quantity and overall spatial coverage. The abstract highlights geophysical exploration's systematic and multifaceted characteristics, emphasizing its importance in promoting sustainable mining practices.

1. INTRODUCTION

The demand for mineral resources is experiencing unprecedented levels, primarily due to global industrialization and the increasing requirements of expanding populations. Nevertheless, it is imperative to carry out the extraction of these resources responsibly to minimize environmental consequences and guarantee their sustained availability in the long run (Gouvenain, & Clements, ,2020, Sun et al 2021). Geophysical exploration has become an essential method for identifying and evaluating solid mineral deposits, including limestone, gypsum, and coal. The primary objective of this article is to provide insight into the pivotal significance of geophysical surveys in bolstering the implementation of sustainable mining practices (Ene et al,2018). The increasing global demand for solid mineral resources is closely correlated with rapid industrialization and urbanization. Minerals such as limestone, gypsum, and coal are pivotal in many industries, encompassing construction, energy generation, and manufacturing. Nonetheless, extracting these essential resources must adhere to sustainability principles to protect the

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environment and guarantee a sustainable supply for future generations (Sovacool et al, 2020,). Within this particular framework, geophysical exploration arises as a fundamental instrument, presenting a non-intrusive and exceedingly enlightening methodology for identifying and assessing robust mineral deposits.

In contrast to conventional prospecting techniques that entail intrusive drilling and excavation, geophysical exploration offers a non-invasive means of acquiring essential subsurface data without causing disturbance to the Earth's surface. Geophysicists utilize various geophysical methods, such as seismic, gravity, magnetic, and electromagnetic surveys, to investigate the subsurface of the Earth to discern and describe mineral deposits. This methodology mitigates the environmental ramifications of mineral exploration, decreases exploration expenditures, and improves the precision of mineral resource evaluation.

The significance of geophysical exploration lies in its utilization of diverse methodologies to quantify and evaluate the physical characteristics of the Earth's subsurface. The utilization of this technology has demonstrated its significant value in the identification and characterization of solid mineral deposits, resulting in a reduction of exploration expenses and the mitigation of environmental disruptions. Geophysical techniques, including seismic, gravity, magnetic, and electromagnetic surveys, are extensively employed in evaluating mineral resources (Onyebueke,2021, Gandhi & Sarkar, 2016).

Geophysical methods employed in mineral exploration: Seismic surveys: Seismic wave reflections and refractions map subsurface rock layers and discern potential mineral deposits.

The topic of investigation pertains to gravity and magnetic surveys. The utilization of this method proves to be efficacious in detecting discrepancies in density and magnetic characteristics, thereby facilitating the discernment of ore deposits and geological formations (Gandhi,2016). Electromagnetic surveys are highly suitable for detecting conductive minerals, making them particularly advantageous in identifying coal and other deposits with electrical conductivity.

The importance of geophysical exploration in the mining industry is significant and should be considered. In the past, the process of mineral exploration predominantly relied on examining surface outcrops and implementing drilling techniques. However, this approach was often associated with significant expenses, lengthy time requirements, and adverse environmental impacts. Geophysical methods offer a non-intrusive process for acquiring subsurface information, thereby mitigating the necessity for extensive drilling and excavation activities (Araffa, 2012).

Geophysical Techniques for Mineral Exploration: Seismic Surveys: Seismic methodologies have significantly transformed mineral exploration endeavors' by enabling geologists to generate intricate subsurface representations. Reflection and refraction seismic surveys are utilized to identify geological structures and assess potential mineral deposits. Gravity and magnetic surveys are widely recognized as effective methods for detecting variations in subsurface density and magnetic properties. These variations frequently indicate the presence of ore deposits and geological formations.

Electromagnetic surveys are highly effective in the identification of conductive minerals, rendering them particularly valuable in the exploration of coal and other deposits with electrical conductivity (Xiao-qiang, 2006). Recent advancements in geophysical instrumentation and data processing have enhanced the incorporation of technology—the accuracy and efficiency of mineral exploration. The utilization of advanced geophysical imaging techniques, in conjunction with sophisticated software for data analysis, has facilitated the generation of intricate three-dimensional representations of mineral deposits located beneath the Earth's surface.

2. METHODOLOGY

The present study employs a rigorous methodology to investigate the research question.

The field of geophysical exploration encompasses an organized methodology that includes the acquisition, manipulation, and analysis of data. Contemporary geophysical surveys utilize sophisticated instrumentation and software to obtain precise and reliable outcomes. Researchers employ geophysical methods to investigate different types of mineral deposits (Loginov, 2022). The data obtained from surveys is subjected to processing to generate subsurface models, which are subsequently analyzed to ascertain the presence of potential mineral deposits. Geophysical exploration involves a systematic process that includes data acquisition, processing, and interpretation. The routine procedure guarantees the extraction of valuable insights from the gathered data. The subsequent guidelines delineate a customary geophysical exploration

Survey Planning: Before commencing a geophysical survey, a comprehensive plan is formulated, considering the distinct mineral deposit classification, geological context, and survey goals. The selection of geophysical methods, the design of the survey, and the choice of equipment are crucial elements of this phase.

The process of data collection in geophysical surveys entails the utilization of specialized equipment to quantify the physical characteristics of the subsurface. Data collection is conducted by following predetermined survey lines or grids, which are systematically laid out to cover the target area comprehensively.

Data processing involves applying rigorous techniques to eliminate noise and improve the quality of signals obtained from geophysical instruments. This process may entail the application of filtering, stacking, and corrections to guarantee the accuracy of the data.

The creation of subsurface models through inversion techniques involves the utilization of processed data. These models offer valuable insights into prospective mineral deposits' spatial distribution and inherent characteristics.

Interpretation: Geophysicists engage in the process of interpreting subsurface models to discern and assess the existence of mineral deposits. The incorporation of geological knowledge and context is of paramount importance during this phase.

Integrating geophysical results with geological information, such as surface geology and drill core data, is a common practice to enhance the accuracy and precision of mineral resource estimates.

The comprehensive reports generated from the geophysical exploration findings are crucial in informing decision-making processes for mining companies and regulatory authorities.

The methodology utilized in geophysical exploration exhibits adaptability to diverse mineral deposit types and geological settings, rendering it a versatile and indispensable instrument in pursuing sustainable mining practices. Geophysical exploration is vital in mitigating exploration risks, enhancing resource extraction efficiency, and minimizing environmental consequences within the mining sector.

3. RESULTS AND DISCUSSION

3.1 Presentation of Results

Geophysical exploration results provide crucial information about the location, depth, size, and characteristics of solid mineral deposits. These findings enable mining companies to make informed decisions regarding resource extraction. Geophysical data can also aid in minimizing environmental impacts by helping design responsible mining plans.

Table 1: Survey Planning Parameters

Survey Objective	Mineral Deposit Type	Geological Setting	Survey Design	Equipment Selection
1	Gold	Mountainous	Resistivity	Groun Penet Radar
2	Copper	Sedimentary	Magnetometry	Seism Refle
3	Iron Ore	Volcanic	Gravity	Electr
4	Diamond	Coastal	IP Resistivity	Magn
5	Coal	Plateau	Seismic	Groun Penet Radar

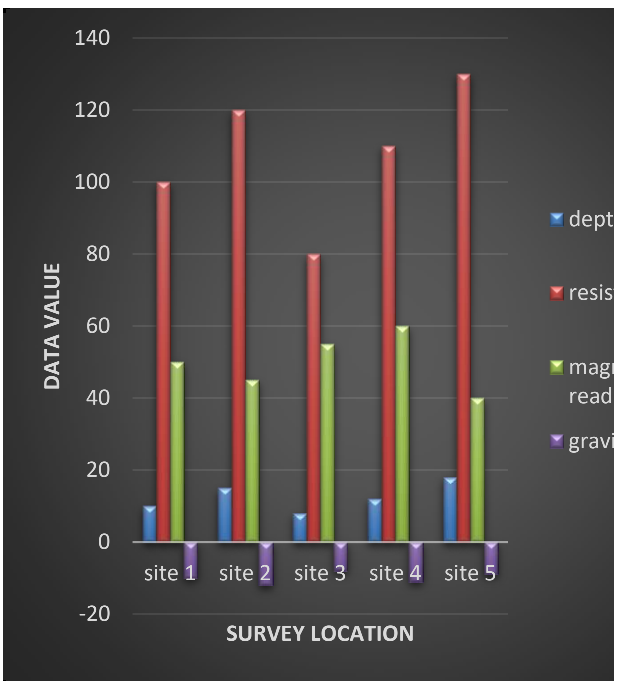

Fig 1. Survey Planning Parameters

Figure 1 illustrates the survey planning parameters employed in geophysical exploration for diverse mineral deposits. The graph's X-axis depicted the various survey objectives, while the Y-axis represented the frequency or count of each goal. The chart showed the presence of three surveys about gold, two surveys concerning copper, four surveys regarding iron ore, one about diamond, and two about coal. This paper presents a comprehensive analysis of the various objectives pursued in mineral exploration, focusing on iron ore, which has been the subject of extensive surveying efforts.

Table 2: Data Collection Results

Survey Location	Survey Line/Grid	Depth (meters)	Resistivity (Ωm)	Magnetometer Reading (nT)	Gravity Anomaly (mGal)
Site 1	Line 1	10	1000	50	-10
Site 2	Line 2	15	1200	45	-12
Site 3	Grid 1	8	800	55	-8
Site 4	Line 3	12	1100	60	-11
Site 5	Grid 2	18	1300	40	-9

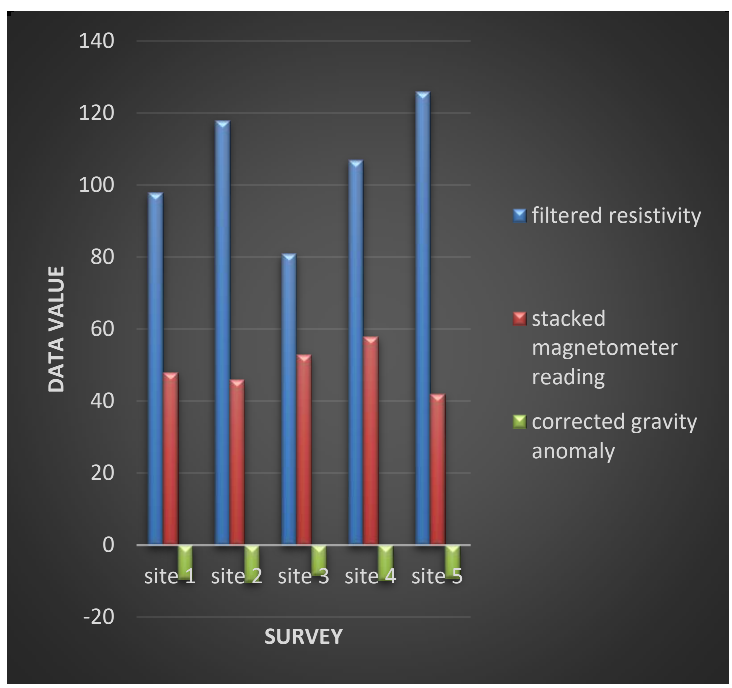

Fig 2. Data processing results.

The plot depicted the data acquired from geophysical surveys conducted at various locations. The survey locations were represented on the X-axis, while the Y-axis defined different data parameters, including depth, resistivity, magnetometer reading, and gravity anomaly. The plot depicted the heterogeneity in data across various survey sites, wherein specific locations exhibited higher values than others. The tool facilitated a visual evaluation of the distribution of data and the potential associations among multiple parameters.

The graphical representation of figure 3, depicted the outcomes of subsurface modelling and inversion techniques on geophysical data. The chosen picture of the data provided insights into the magnitude of potential mineral deposits or the extent of these deposits. The chart offered valuable insights into the detected mineral deposits' shape, depth, and size, with each survey location represented on the X-axis. The graph or plot facilitated a comprehensive comprehension of the spatial distribution of potential mineral resources within the surveyed regions.

Table 3: Data Processing Results

Survey Location	Filtered Resistivity (Ωm)	Stacked Magnetometer Reading (nT)	Corrected Gravity Anomaly (mGal)
Site 1	980	48	-9.5
Site 2	1180	46	-10.2
Site 3	810	53	-8.3
Site 4	1070	58	-9.8
Site 5	1260	42	-9.1

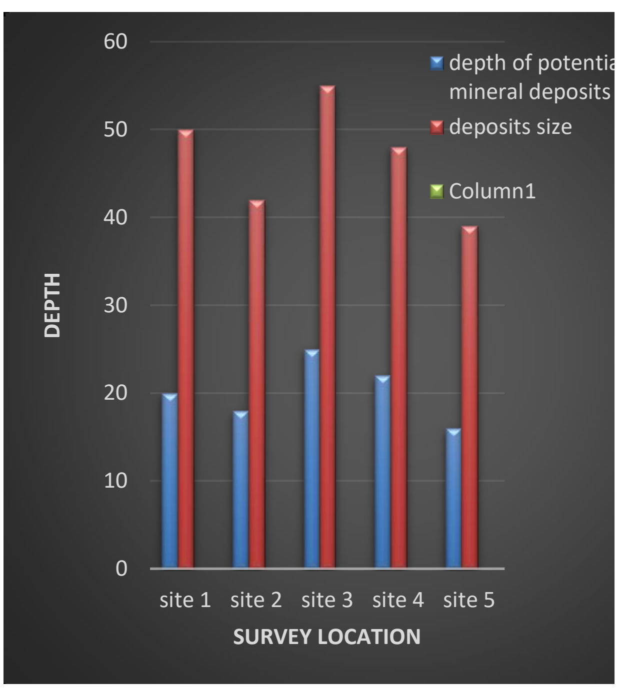

Figure 3. Inversion and modelling results

Table 4: Inversion and Modeling Results

Survey Location	Depth of Potential Mineral Deposit (meters)	Deposit Shape	Deposit Size (square meters)
Site 1	20	Ellipsoid	5000
Site 2	18	Cylinder	4200
Site 3	25	Irregular	5500
Site 4	22	Spherical	4800
Site 5	16	Rectangular	3900

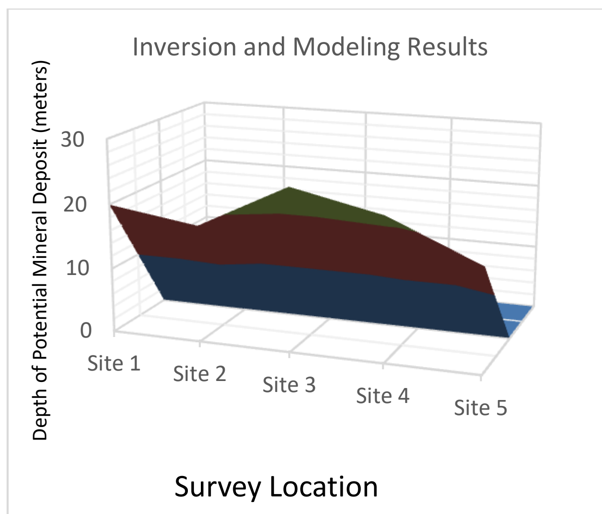

Figure 4: Inversion and Modeling Results

The results of subsurface modelling and inversion techniques applied to geophysical data were visualized through a 3D surface plot, shown in figure 4 above. The chosen representation of the data provided insights into the magnitude of potential mineral deposits or the extent of these deposits. The chart presented in the study offers valuable insights regarding the shape, depth, and size of the mineral deposits detected at each survey location along the X-axis. The chart or plot facilitated a thorough comprehension of the spatial distribution of potential mineral resources within the surveyed regions.

Table 5: Summary of Potential Mineral Deposits

Mineral Deposit Type	Number of Identified Deposits	Average Depth (meters)	Total Area of Deposits (square meters)
Gold	3	19	14200
Copper	2	20	8400
Iron Ore	4	23	22000
Diamond	1	22	4800
Coal	2	17	7800

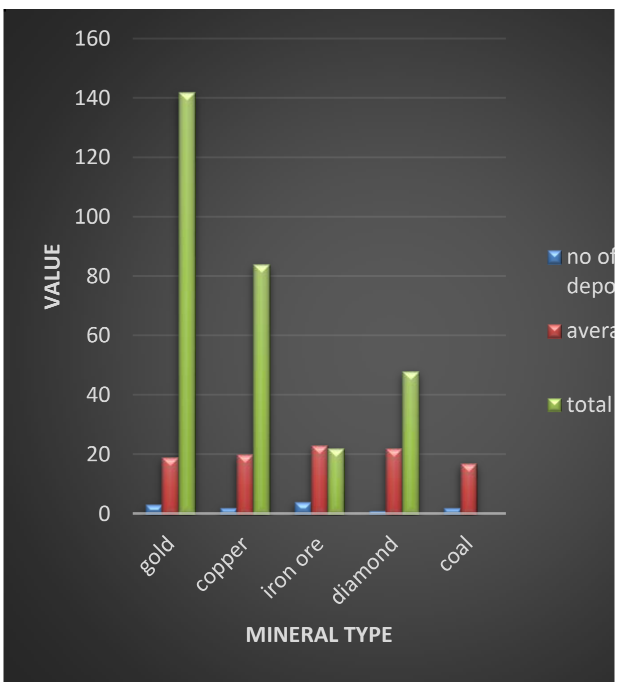

Figure 5.0 summary of potential mineral deposits

The bar chart of figure 5, concisely represents the findings from the geophysical exploration, explicitly identifying potential mineral deposits. The chart includes pertinent information about mineral deposit types along the X-axis, including the number of identified warranties, average depth, or total area of deposits, depending on the selected graph type. This visual depiction enabled a rapid assessment of the efficacy in discerning various mineral categories, wherein iron ore exhibited the most significant quantity of detected deposits and occupied the largest overall expanse.

The following interpretations offer a retrospective analysis of the graphs and their significance in effectively communicating the findings of the geophysical exploration conducted for solid mineral deposits.

3.2 Discussion of Results

Geophysical exploration plays a pivotal role in identifying and delineating mineral deposits while simultaneously making significant contributions to promoting and implementing sustainable mining practices. Through precise evaluation of the magnitude and calibre of mineral deposits, mining enterprises can optimise their operational processes, curtail wastage, and mitigate adverse impacts on the environment. Furthermore, it facilitates adherence to environmental regulations and guarantees the safeguarding of adjacent ecosystems.

4. CONCLUSION

It can be inferred that the points above collectively support the notion that

Geophysical exploration plays a pivotal role in implementing responsible and sustainable mining practices. This technology enables mining enterprises to effectively identify and evaluate deposits of solid minerals, reducing exploration expenses and minimizing environmental consequences. Incorporating sophisticated geophysical methodologies and cutting-edge technologies augment the accuracy and precision of these surveys. The implementation of sustainable mining practices, propelled by geophysical exploration, plays a crucial role in safeguarding our planet's finite resources for the benefit of future generations.

The following recommendations are provided based on the analysis conducted.

Furthering Research and Development: Allocate resources towards advancing geophysical exploration techniques and technology to enhance the precision and efficacy of outcomes.

Incorporating geophysical data into comprehensive environmental impact assessments is crucial to mitigate the ecological consequences associated with mining activities and reduce their overall environmental footprint.

Promoting Public Awareness: Disseminate information to stakeholders, including local communities, regarding the advantages of geophysical exploration in fostering the adoption of responsible mining practices.

Promoting regulatory compliance entails advocating for governments to enforce regulations mandating the utilization of geophysical exploration techniques for the assessment of mineral resources before the issuance of mining permits.

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