Comprehensive geophysical exploration of the Shanshulin lead-zinc mine in Laoyingshan town, Guizhou Province, China

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SUMMARY

The rising demand for base metals due to sustainable development and renewable energy has outpaced the discovery of new deposits, necessitating better exploration methods. This study focuses on lead and zinc exploration in the Shanshulin area, employing the SSIP and AMT techniques. The SSIP survey on profile L-23 identified three low-resistance anomalies associated with potential mineralization. The AMT survey on profile L-24 revealed a complex underground structure, distinct resistivity variations, and accurately delineated faults and potential mineralized zones. Integration of geophysical data with geological models validated the results, providing valuable insights for focused exploration. The findings include anomalies indicating disseminated or vein-type mineralization along L-23 and potential mineralized zones in the Huanglong formation along L-24. These results contribute to improved understanding and targeted resource extraction.

Keywords: Shanshulin mine; Spread spectrum induced polarization; Audio magnetotelluric; Minerals exploration; Lead-zinc

INTRODUCTION

The focus of the study is on the Shanshulin lead-zinc deposit. The researchers want to investigate the geophysical signatures of geological structures and hosted mineralization, focusing on resistivity and polarization. The study begins by providing a review and summary of the geological background in the study area, as well as explaining the fundamental principles and applications of the AMT and SSIP geophysical methods. The research follows a systematic flow, starting with data collection using SSIP for the L-23 profile and AMT for the L-24 profile. We choose these geophysical methods to explore subsurface structures in the mining area. We then subject the collected data to a two-dimensional inversion process to ascertain the deposit's depth of burial and the ore bodies' distribution.

The study aims to learn more about the connection between geological structures, mineralization, and the geophysical signatures seen in the Shanshulin Pb-Zn deposit by carefully looking at the geophysical responses that were collected. The research employs geological and geophysical analysis techniques to verify anomalies and identify sub-surface structures within the study area.

Methodology

The research includes the utilization of two geophysical methods: spread spectrum induced polarization (SSIP) and audio-magnetotelluric (AMT). SSIP is an advanced geophysical technique that operates in the frequency domain. It offers several distinctive features, including deep penetration into the subsurface, high measurement precision, resistance to interference, cost-effectiveness, and efficiency. These qualities have led to its widespread adoption and significant economic advantages (XI, X., YANG, H., ZHAO, X., et al. (2014). SSIP uses m-sequence pseudo-random spread spectrum signals as its primary source current (GOLOMB, S. W. (1994).. The survey configuration for SSIP involved a pole-dipole array centered on top of the ore bodies. We positioned the survey line approximately perpendicular to the fault system hosting the ore bodies. We placed potential electrodes at 40-meter intervals, covering a profile length of 1480 meters.

We performed data acquisition using eight units of GS2IP-FW10 equipment, injecting four separate alternating currents of different frequencies. We selected F2 as the optimal frequency for this research. AMT, on the other hand, is an electromagnetic surveying technology that relies on naturally occurring ionospheric currents and lightning storms as passive energy sources for geospatial mapping to depths of 500 meters or more (MCKAY, A. J. 2004). The earth and seas generate currents due to time-varying electric and magnetic fields, resulting in magnetotelluric (MT) signals. We use AMT devices to monitor these signals (MOGENSEN, G. T. 2014) & and (ZONGE, K. L., & HUGHES, L. J. 1991). The interaction of the atmosphere, magnetosphere, and Earth's currents produces low frequency magnetotelluric electromagnetic signals, typically below 1 Hz. The research covered a survey profile line of 1040 meters, with a line spacing of 40 meters between successive station points. The AMT data collection devices recorded data at frequencies ranging from 10,400 kHz to 1 Hz. By utilizing both SSIP and AMT methods, the research aims to achieve a comprehensive understanding of the geological structures, mineralization, and subsurface conditions in the study area. These geophysical techniques offer valuable insights into the characteristics and distribution of lead-zinc deposits, helping to inform exploration and resource assessment efforts

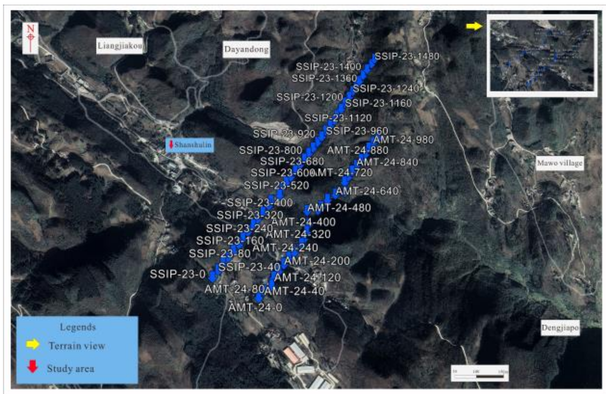

Figure 1: Aerial and terrain view of survey profiles in the study area mention with red arrow

Results and discussion

Profile L23

The inversion results of exploration profile L-23 indicate similar geological structures across different frequencies, with the F2 frequency yielding the best results. The resistivity model reveals structures ranging from high to low resistance along the profile. In the SW section, two high-resistive bodies (R1 and R2) are observed, likely associated with specific limestone formations (Figure 2). The central section exhibits a low resistive zone (C1), while the NE section displays a high resistive zone (R3) and a conductive zone (C2). The polarizability model displays two induced polarization anomalies, named IP-1 and IP-2. These point to possible mineralization in the Huanglong formation (C2h) and the Emeishan basalt ($P_3\beta$).

Geophysical models for L23 survey line in the Figure 3 (c) have been developed using the SSIP resistivity inversion data. This model provides insights into the spatial arrangement of geological units and their corresponding resistivity properties. Mineralized target zones (JP23-1 & 2) are commonly defined as regions characterized by high conductivity, accompanied by an abundance of electrically resistant and moderately conductive components. The region mostly has lithologies characterized by high resistivity, such as limestone, dolomitic limestone and bioclastic limestone.

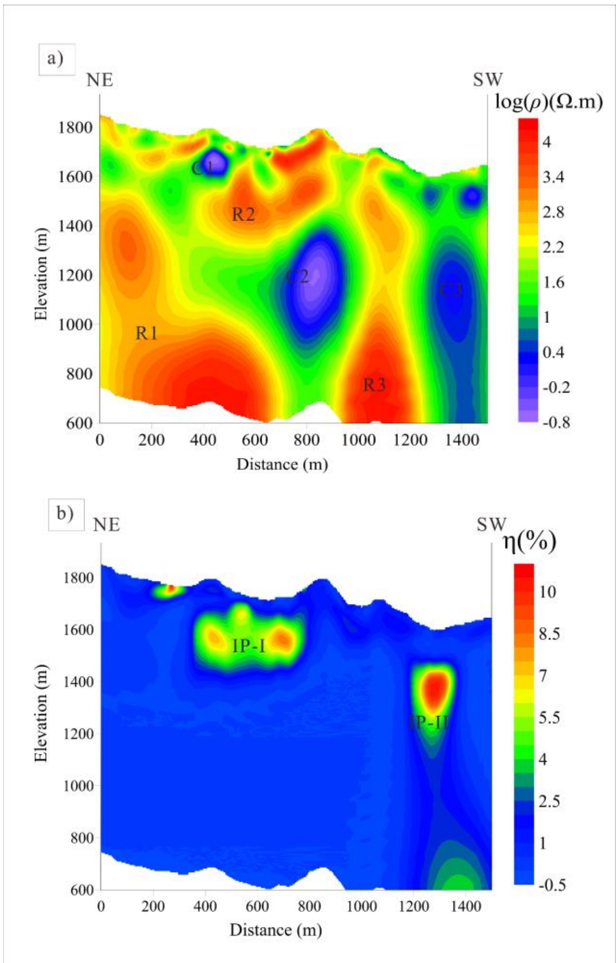

Figure 2: Two-dimensional models obtained by SSIP survey across Shanshulin deposit. (a) Resistivity model, (b) Polarizability model. Both models are derived at a frequency of 0.203125 Hz

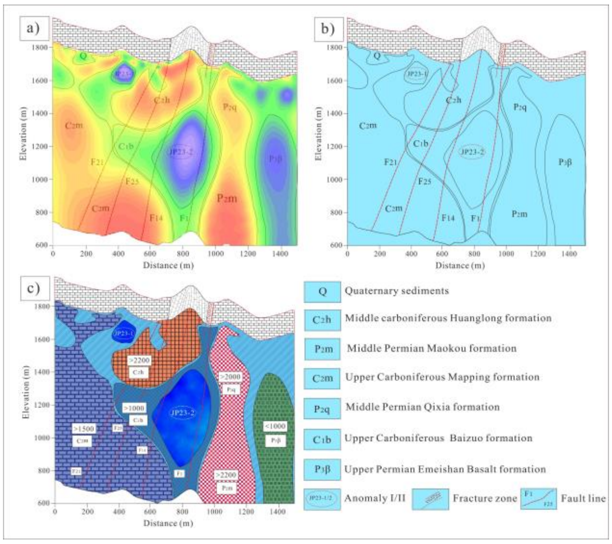

Figure 3: Shanshulin geological overlap with (a) SSIP resistivity model and c) geophysical model based on SSIP resistivity model showing lithological units and resistivity values

Profile L24

We got a resistivity model from the AMT data in TM mode for Profile L-24 over the Shanshulin lead-zinc deposit. Along the profile, there are clear signs of high, low, and moderate electrical resistivity. High-resistive structures R1 and R2 are likely limestone formations, while moderate structures M1 and M2 correspond to the Huanglong formation. A conductive zone C1 is linked to Yelang and Longtan formations (Figure 4). The M1 structure, supported by geology, literature, and electrical parameters, suggests potential ore-bearing strata. The D-mode 2D resistivity model confirms these subsurface structures observed in the TM resistivity model, including fault lines F1 and FW1 that affect resistive zone R3 (Figure 5).

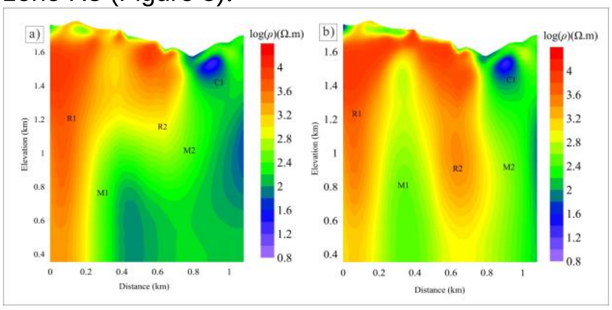

Figure 4: Two-dimensional resistivity model for Shanshulin deposit exploration profile L-24 resolved by a) TM mode and b) D mode showing the resistive, moderated and conductive zones

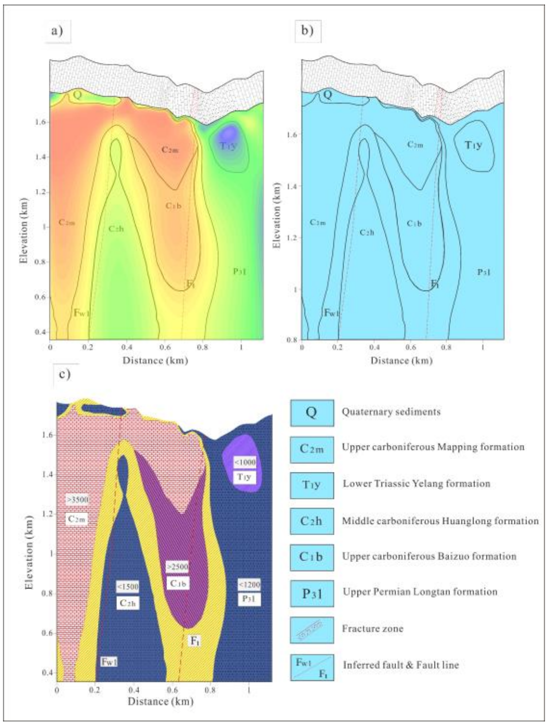

Figure 5: AMT inversion model of the D-mode a) geological model overlaps with D mode b) showing geological units, faults and resistivity variation c) geophysical model based on D mode

Conclusions

The geophysical investigation at the Shanshulin lead-zinc mine utilized Spread Spectrum-Induced Polarization (SSIP) and Audio Magnetotelluric (AMT) methods. SSIP measured resistivity and polarizability, while AMT examined resistivity variations. Both methods successfully identified potential mineralized zones, particularly SSIP, with resistivity and polarizability insights. The resistivity model revealed diverse structures. These included high-resistance bodies R1 and R2 (limestone formations), low-resistance zones C1 and C2 (baizuo formations), and high-resistance zone R3 (Maokou and Qixia formations). Mineralization potential correlates with IP anomalies. The AMT data in the TM and D modes confirmed that the underground structures are very intricate. They showed faults (F1 and inferred FW1), limestone formations, and possible mineralization in the Huanglong formation (M1 structure). The D mode enhanced fault identification and provided valuable geological insights for mineral exploration.

References

XI X, YANG H, ZHAO X, et al. Large-scale distributed 2D/3D FDIP system based on ZigBee network and GPS. In: Proceedings of the Symposium on the Application of Geophysics to Engineering and Environmental Problems 2014, F, 2014 [C]. Society of

Exploration Geophysicists and Environment and Engineering.

GOLOMB S W. Shift-register sequences and spread-spectrum communications. In: Proceedings of the IEEE 3rd International Symposium on Spread Spectrum Techniques and Applications (ISSSTA'94), F, 1994 [C]. IEEE.

MOGENSEN, G. T. Instrumentation for Impedance Measurements in the ELF/VLF Band for Geophysical Investigations. Journal of Geophysics, 2014.

ZONGE, K. L., HUGHES, L. J. Controlled source audio-frequency magnetotellurics. Journal of Geophysics, 1991.

MCKAY, A. J. Geoelectric fields and geomagnetically induced currents in the United Kingdom. Journal of Geophysics, 2004.Fraser DC, Hodges G (2007) Induction-response functions for frequency-domain electromagnetic mapping system for airborne and ground configurations. Geophysics 72: F35–F44