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IP/Resistivity methods for Pb-Zn deposit exploration: A case study in Sudöşeği, (Simav-Kütahya, Türkiye)

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Abstract

Studying Pb-Zn deposits is highly significant in meeting the global demand for lead and zinc, which are essential elements used in various industries such as battery production and construction. The Sudöşeği region in Simav-Kütahya holds significant potential for the occurrence of lead-zinc (Pb-Zn) mineral deposits. This study employs induced polarization (IP) and resistivity techniques to examine subsurface geological formations and evaluate the probability of a Pb-Zn deposit. Geophysical methods offer valuable insights into variations in electrical conductivity and chargeability, assisting in the identification of minerals. The study identified strong correlations between IP and resistivity patterns and well-established geological features, confirming the efficacy of this integrated approach in mineral exploration. The L 100, L 300, and L 500 profiles exhibited rechargeability values, which suggest the possibility of mineralization. The L 100 profile and L 500 profile exhibited significant potential owing to their exceptional rechargeability values. This case study highlights the significance of IP (Induced Polarization) and resistivity methods in the identification of Pb-Zn (lead-zinc) deposits and the improvement of resource evaluation and extraction strategies.

1. Introduction

The geological community is exploring innovative methods for identifying and evaluating mineral deposits, such as Pb-Zn ore systems, due to their economic value and wide geographic distribution. Geophysical methods, such as induced polarization and resistivity techniques, are crucial for enhancing resource efficiency and meeting global demand.

Induced polarization (IP) and electrical resistivity tomography (ERT) are geophysical techniques used to examine subsurface structures and geological formations [1-2]. ERT detects small conductive rocks, while IP detects conductive rocks. Combining these techniques can reveal electrical conductivity and polarizability characteristics, potentially revealing sulfide mineralization, specifically lead-zinc deposits [3].

High chargeability is a key characteristic of geological formations containing sulfide minerals, which often exhibit low resistivity [4-5]. This study's geophysical signatures may suggest sulfide mineralization, particularly in lead-zinc (Pb-Zn) deposits. Resistivity and induced polarization techniques have been successfully used in mineral exploration [6-7].

This study investigates the geophysical characteristics of lead-zinc (Pb-Zn) deposits in Türkiye, a region that has a notable historical heritage dating back to the Roman era [8]. Geological surveys conducted in the Sudöşeği region of Simav-Kütahya have uncovered promising conditions for the presence of lead-zinc minerals. These conditions include the existence of lead-containing rocks such as the Eğrigöz Plutonic Complex, the presence of hydrothermal fluids that transport lead and zinc ions, and the presence of structural traps that enhance the confinement of these fluids [9].

These geophysical signatures may indicate the presence of sulfide mineralization, specifically in lead-zinc deposits, according to the study. The resistivity and induced polarization techniques have proven effective in mineral exploration studies. The study additionally highlights that conducive factors for lead-zinc mineralization encompass the existence of rocks containing lead and zinc, hydrothermal fluids with the ability to transport these ions, and structural traps such as faults and fractures that can augment the containment of hydrothermal fluids [9].

The study conducted by Yalçın et al. [10] in the Kavşut region of Göksun-Kahramanmaraş employs induced polarization (IP) and resistivity methods to identify polymetallic deposits. The results have consequences for enhancing mineral exploration methodologies and advocating for sustainable resource utilization. The independent study conducted by Yalçın and Canlı [11] in Kayseri, Turkey, seeks to enhance comprehension of Pb-Zn mineralization through the utilization of IP/Resistivity. Additional exploration is required to verify the existence and economic viability of substantial lead and zinc mineral deposits in the Sudöşeği region. The study employs IP and resistivity techniques to augment our comprehension and demarcate prospective ore deposits.

2. Material and Method

The IP/Resistivity method employs induced polarization to precisely delineate the distribution of subsurface resistivity and chargeability. The true chargeability (M) is determined by the ratio of the stopped voltage to the measured voltage.

The resistivity method entails the use of a stainless-steel electrode that is inserted into the ground to enable the injection of an electric current. Afterward, two electrodes are strategically placed at various locations to measure the voltage difference in the soil. The measured voltage is commonly recorded in volts, frequently in millivolts. Similarly, the magnitude of the electric current that is applied is typically quantified in units of amperes, commonly expressed in milliamperes. The mentioned numerical values, along with the geometric factor K of the electrode array, are used to compute the apparent resistivity (measured in ohm-meters) at the precise measurement location. The designated value is situated below the center of the electrode array system.

A resistivity and IP measurement device, specifically an AGI brand, 8-channel system with 84 electrodes, was utilized in the research field. Using the Pole-Dipole Gradient method, 6 profiles were generated by employing electrode spacing ranging from 25 meters. The line was produced using a Magellan handheld GPS device, which has a positioning accuracy of 3 meters. The collected data underwent analysis using the EarthImager 2D evaluation software. This study provides data from two profiles.

The RES2DINV and RES3DNV software developed by Geotomo were employed to conduct inverse modeling on the resistivity and chargeability data, to attain a more precise and realistic geological depiction. GPS elevation data obtained from the profiles were used to correct the effects of topography during the reverse resolution process. The report appendix includes graphs that depict the charging and self-resistance profiles for the reverse solutions. The charts utilized warm red-purple tones to illustrate higher charging and self-resistance values, while cooler colors such as green and blue were used to represent lower values. This study specifically examines regions characterized by elevated chargeability, as these areas are deemed significant for the process of metallic purification.

Line preparation studies were conducted using the Magellan handheld GPS, which has a positioning accuracy of ± 3 meters.

The IP/Resistivity measurements were conducted using the Elrec Pro 10-channel receiver, produced by Iris, a collaborative Japanese-French company, and the VIP-5000 (5000 W) transmitter, also manufactured by Iris. A specialized three-phase, automatic voltage-regulated generator with a power output of 13 kilowatts at 230 Volts and a frequency of 60 Hz was utilized to supply electrical energy to the transmitter device.

The VIP-5000, with an output power of 5000 Watts, is capable of producing a current of up to 3000 Volts or 10 Amps (10000 mA).

The Elrec Pro receiver unit provides precise and accurate measurements of chargeability, natural potential, and resistivity in the time domain. It features 20 chargeability windows and a graphic LCD.

Each current point was equipped with four steel electrodes serving as current electrodes. The electrodes were positioned orthogonally to the profile and spaced 1 meter apart. To reduce the contact resistance of the current electrodes, the electrodes of each size were disassembled after being driven halfway. Then, a solution of soapy and salty water was poured into the resulting holes before driving the electrodes again. The presence of salt in the water enhances its conductivity, while the soap acts as a retardant, prolonging the wetness of the current-applied area on the ground.

Receiving electrodes made of copper and copper sulfate pots with permeable properties were utilized.

Throughout the measurement, efforts were made to minimize the resistances of the current electrodes to achieve a current exceeding 3000mA. Typically, it was feasible to achieve high current values, ranging from 2000 to 3000 mA, in all locations.

IP/resistivity measurements were conducted in the time domain using an 8-second square wave cycle. This cycle consisted of 2 seconds of positive charge, followed by 2 seconds of holding, then 2 seconds of negative charge, and finally 2 seconds of holding.

The receiver recorded chargeability measurements at 20 consecutive time intervals. The chargeability results were documented within 20 consecutive time intervals of 30 milliseconds each, following a delay of 450 milliseconds, to comply with the "Newmont" standard range of 0.45 to 1.1 seconds. During the recording process, at least two measurements were taken at each point to ensure that the damping curves have an optimal appearance, the RMS values are minimal, and the Mx values are repetitive. If the damping curves do not match the ideal damping curve due to geological factors, the recording is terminated and efforts are made to eliminate the disturbance effect before repeating the recording.

2.1. Geological Framework and Mineralization

The study area is located in the Tavşanlı zone of the Kütahya-Bolkardağ Belt, approximately 50 km north of Simav district, near Sudöşeği village. The mentioned area is a component of the northern Menderes core complex located within the Anatolian tectonic belt. The region comprises Precambrian mylonitic biotite gneisses, Paleozoic metamorphic rocks, Jurassic limestone, and Cretaceous Dağardı ophiolite mélange, which were penetrated by Miocene Eğrigöz granitoids [12].

Sudöşeği, a vein system located within the Eğrigöz Plutonic Complex, contains high-quality ore characterized by a coliform-cruciform texture [9]. Although there is no documented evidence of mining activity, small excavations and discarded flotation devices were discovered [9]. The ore deposit contains galena, sphalerite, and chalcopyrite minerals in coliform-cruciform and stockwork zones. Pyrite, quartz, and carbonate gangue are also present in significant amounts in the stockworks and brecciated zones [9].

3. IP-Resistivity Applications

To achieve a more precise geological depiction, the resistivity and chargeability data acquired from the profiles were consolidated and subjected to inversion. The GPS elevation data of the profiles were used to account for topographic effects in the inverse analysis.

The profiles' inverse solutions yielded graphs displaying chargeability and resistivity. The graphs were color-coded to visually represent the data. The utilization of warm red-purple hues was employed to signify elevated chargeability and resistivity values, whereas cool colors such as green and blue were employed to depict lower values. The study focused on identifying and prioritizing areas with high resistivity, which are indicative of the presence of karstic sinkholes.

The majority of the profiles measured in the field displayed typical chargeability values. Nevertheless, specific regions yielded elevated chargeability values, suggesting the potential existence of sulfide ores. The high chargeability values indicate the possibility of substantial mineral deposits in those regions.

The L 100 profile was initially conducted under strict conditions, during which the occurrence of corrosion phenomena was observed (Figure 1). After examining the charging interval resulting from the conversion of land data into geophysical sections, it is clear that two closure forms span from scale 125 to scale 175 of the profile. This extension is observed at the depth where the initial closure occurs, specifically between 1060 and 1015. A unit with high electrical permeability and low self-resistance was observed in a strategically advantageous location with low resistance.

The L 200 profile, depicted in Figure 2, provides a thorough investigation of the area where the fault is located, conducted in a perpendicular direction. After analyzing the charging interval resulting from the transformation of land data into geophysical sections, it is clear that there is a charging anomaly. This anomaly exhibits fluctuating values observed within the measurement points ranging from 150 to 200. A deviation has been identified within the measurement range of 150-200 points, specifically indicating a diminished charging value ranging from 1050 to 1000 cylinders. Moreover, there has been a detection of a transmissible unit of resistance.

Profile L 300 (Figure 3) was oriented at a right angle to the fault, and the rechargeability values obtained showed significant variation near the surface. Irregularities were detected at measurement points 325 and 350 in this profile. An observation was made that the anomaly commenced at an altitude of 1060 and persisted with a sharp descent until reaching an altitude of 1010. Upon analysis of resistivity, it is observed that the unit exhibits a low resistivity.

No chargeability value was detected in the L 400 profile (Figure 4), which runs perpendicular to the fault at an angle. However, a partially low resistivity unit was observed at the fault location.

Upon analyzing the rechargeability cross-section of the L 500 profile, it is evident that the profile exhibits a rechargeability value from measure number 200 to measure number 250, gradually increasing in depth from an elevation of 1060. Regarding resistivity, it is noted that there is a unit with low resistivity and high electrical permeability present at the fault location. Additionally, there is a unit with high resistivity starting from point 250 to point 375 at the 1025 levels (Figure 5).

Upon analyzing the chargeability section of the L 600 profile, it was noted that no chargeability was detected. Additionally, low resistivity inclusions with a resistivity of 10 ohms were observed (Figure 6).

The study demonstrates the existence of minerals in the region, implying the necessity of additional investigation to evaluate the economic viability of extracting the ore.

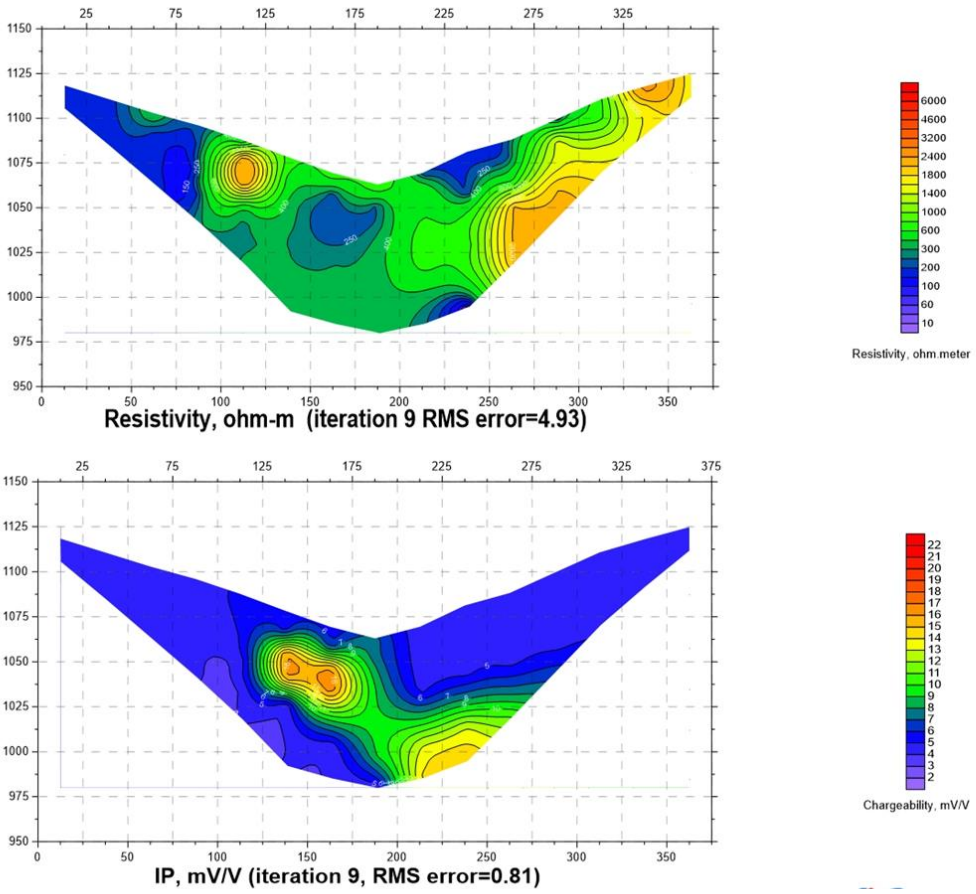

Figure 1. The inverted resistivity and IP sections with the topography of the L100 profile.

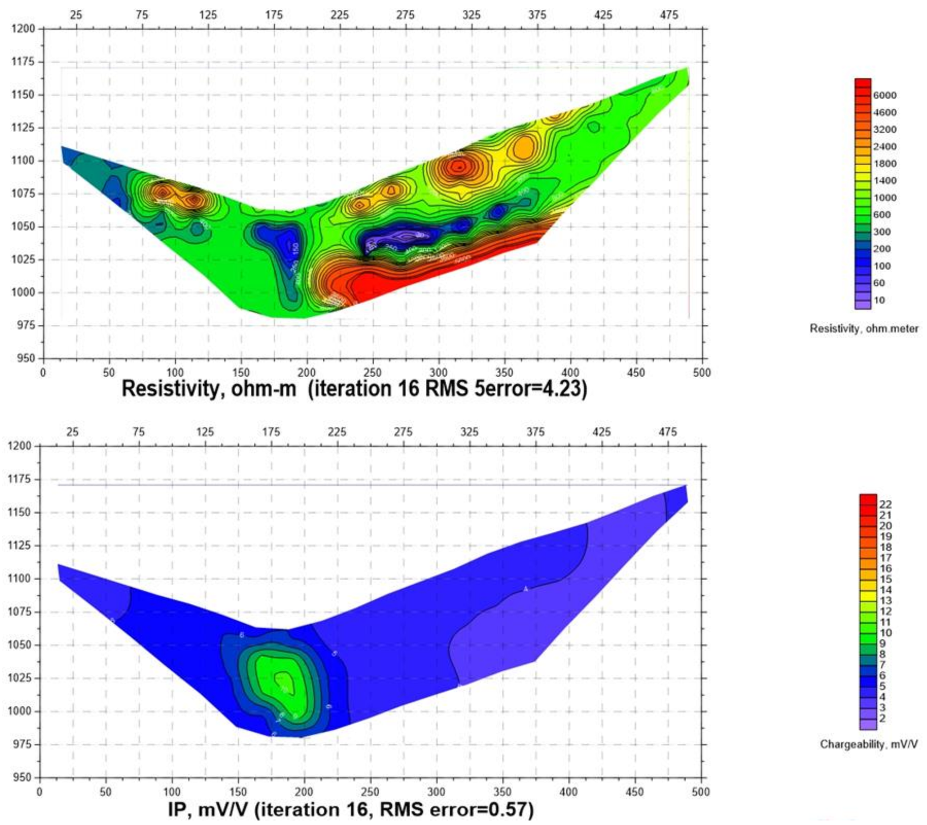

Figure 2. The inverted resistivity and IP sections with the topography of the L200 profile.

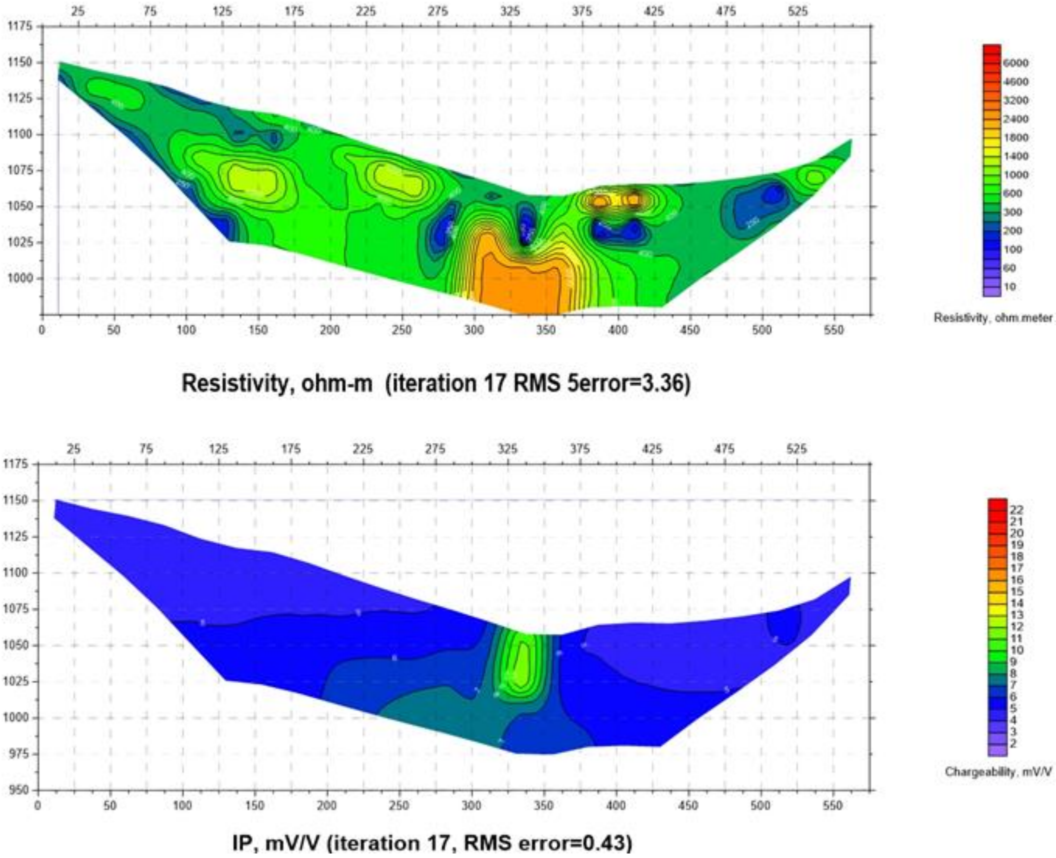

Figure 3. The inverted resistivity and IP sections with the topography of the L300 profile.

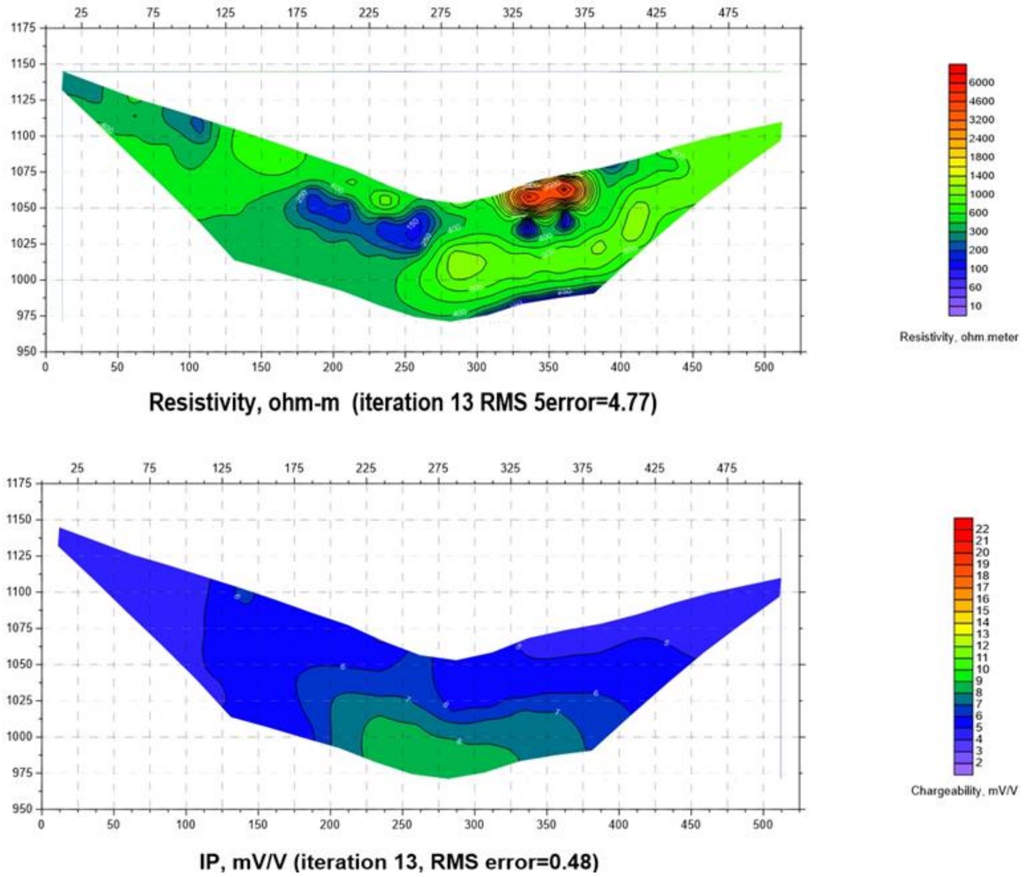

Figure 4. The inverted resistivity and IP sections with the topography of the L400 profile.

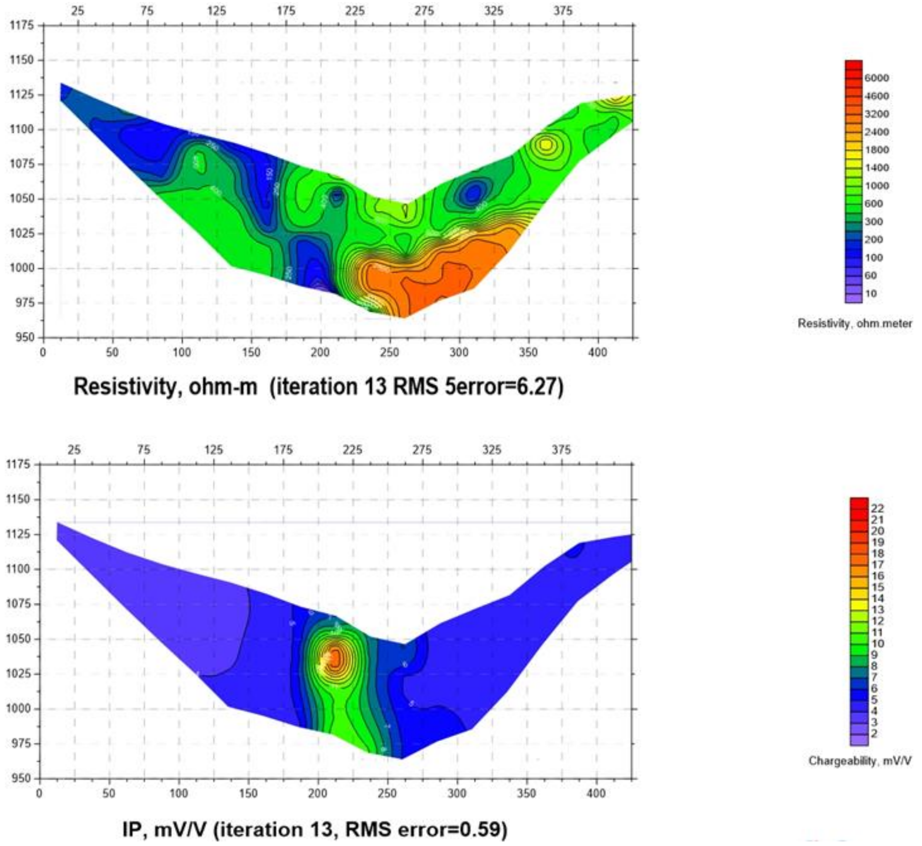

Figure 5. The inverted resistivity and IP sections with the topography of the L500 profile.

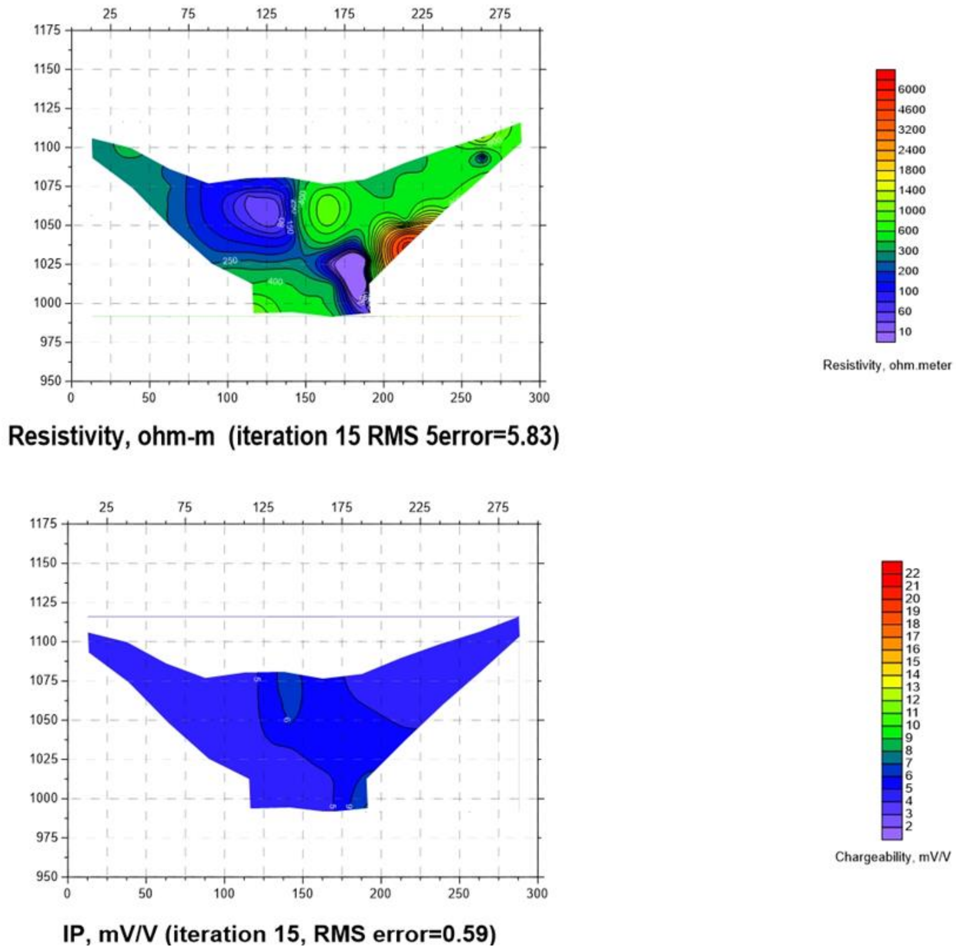

Figure 6. The inverted resistivity and IP sections with the topography of the L600 profile.

The profile's low chargeability indicates the possibility of a transitional area for mineralization, while high resistivity values indicate the presence of resistant rocks that influence mineralization. Additional inquiries, such as conducting surveys and engaging in drilling activities, are necessary to comprehend the intricate geological formations and assess the potential for mineral deposits in the region. The integration of geophysical data with other geological information will augment the assessment of mineral potential.

4. Discussion

The induced polarization method is utilized to identify mineralized zones in lead-zinc deposits through the analysis of induced polarization reductions. The resistivity method offers valuable data on the electrical resistivity of the subsurface, which can be used to map geological structures and detect potential ore deposits.

The study revealed a notable absence of vertical alignment in the NW-SE direction, specifically in the L 100 profile, indicating the possibility of a reversal.

The research conducted by Yalçın et al. [10] in Göksun-Kahramanmaraş employs IP and resistivity techniques for the identification of polymetallic deposits, thereby improving mineral exploration methodologies and encouraging the sustainable utilization of resources. The study conducted by Yalçın and Canlı [11] in Kayseri, Türkiye, employs geophysical techniques, specifically IP/Resistivity, to gain insights into Pb-Zn mineralization. The main objectives of the study are to enhance resource evaluation and promote environmentally sustainable mining practices.

The advancement of geophysical survey technology is resulting in the production of increasingly accurate and detailed maps of the underlying geological features. This enhances comprehension of the dispersion of mineral deposits, facilitating more prosperous exploration and mining endeavors. Utilizing compatible IP and resistivity values is a valuable technique in mineral exploration, and it is anticipated to persist as a prominent method in the field.

5. Conclusion

The study emphasizes the utilization of IP and resistivity techniques for the investigation of Pb-Zn deposits in the Sudöşeği region of Simav-Kütahya. The correlation between atypical geophysical indicators and geological characteristics is substantial, suggesting the efficacy of this integrated methodology. The study identifies prospective mineralized regions, offering valuable data for the assessment of resources and the development of extraction strategies. The IP/Resistivity method is utilized to measure and assess the chargeability and resistivity of underlying layers, enabling the identification of areas that may contain valuable mineral deposits. This approach is essential for the sustainable and ethical extraction of mineral resources.

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Author contributions

Cihan Yalçın: Writing-Reviewing and Editing, Geology, Methodology, **Hurşit Canlı:** Editing, IP/Resistivity and GPR**.**

Conflicts of interest

The authors declare no conflicts of interest.

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