Journal of Geography and Cartography 2024, 7(2), 10193.
https://doi.org/10.24294/jgc10193

Article

Application of geophysical methods in subsurface mapping and mineral exploration: Adiyaman-Besni region, Türkiye

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CITATION

Yalçın C, Karan A. Application of geophysical methods in subsurface mapping and mineral exploration: Adiyaman-Besni region, Türkiye. Journal of Geography and Cartography. 2024; 7(2): 10193. https://doi.org/10.24294/jgc10193

ARTICLE INFO

Received: 8 November 2024
Accepted: 4 December 2024
Available online: 13 December 2024

Abstract: The present study aimed to delineate subsurface features and identify prospective metallic mineral deposits in the Adıyaman-Besni area, situated within the Southeastern Anatolian Thrust Belt of Turkey. This region, characterized by ophiolitic mélanges and volcanic massive sulfide (VMS) deposits in its geological framework, possesses significant mineralization potential, encompassing copper, lead, and various other sulfide minerals. Utilizing the combined methodologies of Induced Polarization (IP) and Electrical Resistivity Tomography (ERT), a comprehensive electrical mapping of the subsurface structures was conducted, revealing that mineralized zones had low resistivity and high chargeability. The findings indicate that the combined use of IP and ERT techniques yields excellent precision in accurately delineating the features of sulfide mineralization and the peripheries of mineral deposits. This study offers fundamental data for the economic assessment of prospective mineral deposits in the Adıyaman-Besni region and underscores the benefits of IP and ERT techniques in subsurface mapping and mineralization delineation investigations. The mineralized zone has low resistivity (< 50 ohm-m) and strong chargeability (> 30 ms), according to geophysical tests. It also offers a methodological framework for subsequent mineral exploration research in analogous geological formations.

Keywords: subsurface mapping; induced polarization; electrical resistivity tomography; metallic mineralization; Adıyaman-Besni

1. Introduction

The Adıyaman-Besni region, situated in southeastern Turkey, possesses significant potential for metallic mineral resources. The geological framework, particularly the ophiolitic mélanges in the area, provides a conducive environment to produce metallic mineral deposits, including copper, lead, and zinc [1,2]. The investigation and mapping of metallic mineral resources have become increasingly precise and effective due to advancements in contemporary geophysical techniques. Geophysical techniques, including Induced Polarization (IP) and Electrical Resistivity Tomography (ERT), have proven useful for subterranean imaging of metallic minerals [3,4].

Subsurface mapping is crucial, particularly for the search for metallic minerals. IP and ERT techniques yield a comprehensive representation by utilizing the electrical characteristics of subterranean formations and mineral deposits. The IP approach demonstrates excellent efficiency, particularly in regions with sulfide mineralization, and produces anomalies based on the polarization characteristics of metallic minerals [5,6]. The ERT method is essential for ascertaining the depth, width, and extent of mineral deposits by delineating the electrical resistivity distribution of subterranean formations. The integration of these methodologies facilitates a more accurate definition of metallic ore deposit limits [7,8].

Currently, the application of integrated geophysical techniques in subsurface mapping and mineral prospecting is well acknowledged in scholarly literature. Yalçın and Canlı [5] performed comprehensive research employing IP and ERT techniques to identify Pb-Zn deposits in the Sudöşeği region of Turkey. The research indicated that low resistivity and elevated chargeability values are crucial for Pb-Zn mineralization, and the combined application of both methods ensures excellent precision [5]. In a study by Andi et al. [6] in Sumatra, IP and ERT techniques were effectively utilized to ascertain the distribution of gold mineralization in the subsurface [6].

Cyprus-type volcanogenic massive sulphide (VMS) deposits and ophiolitic complexes in Turkey facilitate the production of metallic mineral deposits, particularly in areas like Adıyaman-Besni. The Adıyaman-Besni region is situated on the Southeastern Anatolian Thrust Belt and is notable for its sulphide mineralization concentrated in geological formations like the Koçali Complex [1]. A comprehensive examination of copper and other metallic minerals in the region by geophysical methods is essential for the effective and secure extraction of prospective mineral resources. The Adıyaman-Besni region possesses significant potential for subterranean resources. The geological structure of the region offers favorable environments, especially for the formation of metallic mineral deposits. This study intends to delineate and examine the metallic mineral resources in the region comprehensively by Electrical Resistivity Tomography (ERT) and Induced Polarisation (IP) techniques. These technologies offer efficient instruments for detecting mineralized zones using the electrical characteristics of subterranean formations.

The present study intends to delineate prospective metallic mineral deposits in the Adıyaman-Besni area utilizing IP and ERT methodologies. The geophysical data gathered throughout the investigation offers a comprehensive analysis to ascertain the position, depth, and extent of the mineral deposits inside the ophiolitic mélange in the region. The results will enhance the economic and geological assessment of metallic mineral reserves in the area.

2. Materials and methods

The research was conducted in the Adıyaman-Besni area, situated in the Southeastern Anatolia Region of Turkey. The study area encompasses roughly 5 km^2 and is situated in a location characterized by the prominent exposure of the Koçali Ophiolite Complex. The study region is situated between 37°39′ N latitude and 41°75′ E longitude, signifying a geographical location where ophiolitic rocks are recognized to have metallic mineral resources.

Geophysical measurements were conducted along 23 profiles within the research area. The profiles' positions and orientations were strategically established to encompass the whole study region. The geological map and mineralization potential of the region constituted the foundation for the assessment of the ERT and IP data. A more compact profile architecture was designed in regions with significant mineralization potential. The geographical coordinates of the profiles utilized in the study region are shown in **Table 1**, enabling the analysis of geophysical data in connection to subsurface structures. The region contains a geological structure that is both topographically complicated and appropriate for metallic mineral deposits.

2.1. Geological background

The Adıyaman-Besni region is situated within the Southeastern Anatolian Thrust Belt of Turkey and contains Cyprus-type volcano massive sulfide (VMS) deposits along this belt. The primary geological units in the region comprise intricate formations, including the Upper Cretaceous ophiolitic mélange, Koçali Complex, and Gölbaşı Formation [1,9]. **Figure 1** illustrates that these geological units contain strata abundant in metallic mineralization, highlighting their significance as regions with copper, lead, and zinc deposits [10,11].

The ophiolitic mélange in the region predominantly consists of ultramafic and mafic rocks, typically located in zones of significant tectonic activity. **Figure 1** illustrates that mineralization zones within the ophiolitic mélange signify regions enriched in metallic minerals [3]. These formations were elevated to the surface by intricate tectonic processes and provide considerable potential for mineralization [6].

The Koçali Complex is a significant geological unit where mineralization processes in the area are focused. This complex contains formations composed of basaltic and gabbroic rocks, along with veins exhibiting sulfide mineralization. Research indicates that these mineralizations encompass significant minerals, including iron sulfide (pyrite), copper sulfide (chalcopyrite), and zinc sulfide (sphalerite) [12,13]. These formations are essential for groundwater circulation and mineralization processes.

The Adıyaman-Besni region, influenced by the Southeastern Anatolian Thrust Belt, has experienced alterations in the chemical composition and mineral content of its rocks due to high pressure and temperature conditions resulting from continental collision. This scenario has established an optimal environment for sulfide mineralization, and comprehending the geological structure is crucial for the efficacy of mineral exploration studies.

The metallic mineral reserves in Adıyaman province are intricately linked to the region’s geological structure. Mineralization in the study area is predominantly associated with the diabase and quartz veins within the Koçali Ophiolite Complex. The Koçali Ophiolite Complex comprises tectonites, cumulates, a plate dyke complex, pillow lavas, and deep-sea deposits [14]. These formations were influenced by hydrothermal activities that created an advantageous environment for the circulation and deposition of metallic minerals.

Diabase veins and dykes in the region (ophiolitic mélange) are crucial for mineralization, serving as conduits for hydrothermal fluids and containing sulfide minerals like pyrite, chalcopyrite, and sphalerite. Quartz veins are also significant, containing copper, lead, and zinc due to hydrothermal alteration processes. Fault and fracture systems direct the circulation and accumulation of metallic minerals, controlling the localization of sulfide mineralization, particularly in the ophiolitic complex. The low resistivity and high chargeability values associated with these structures strongly support the presence of metallic mineral deposits.

2.2. Geophysical study

Geophysical measurements were conducted along 23 profiles in the Adıyaman-Besni region. Each profile is 410 m in length and was conducted using the dipole-dipole measuring technique. Forty-two electrodes were utilized in the profiles, with an electrode spacing of 10 m and a profile spacing of 50 m. The AGI (Advanced Geosciences Inc.) SuperSting R8 instrument utilized in these measurements efficiently gathered both resistivity (ERT) and Induced Polarization (IP) data. The acquired data were reviewed in EartImager 2D software to build 2D cross-sections and then examined in accordance with the geological structures.

This study employed Induced Polarization (IP) and Electrical Resistivity Tomography (ERT) techniques to delineate probable metallic mineral deposits in the Adıyaman-Besni region. These techniques utilize the electrical characteristics of subterranean formations to ascertain the depth, thickness, and extent of mineral deposits [4,8]. Mineralized zones were identified based on low resistivity (< 50 ohm-m) and high chargeability (> 30 ms). Resistivity values varied from 15 to 30 ohm-m, with chargeability exceeding 30 ms in mineral-rich locations.

ERT and IP measurements were conducted at several places during the fieldwork. **Figure 1** delineates the ophiolitic mélange and mineralization zones within the research area. ERT measurements identified mineralized zones by analyzing the resistivity distribution of subsurface structures, whereas IP measurements supplied data to ascertain mineral density based on chargeability attributes. **Figures 2** and **3** illustrate the configuration of the equipment utilized during the fieldwork and the data collection procedure.

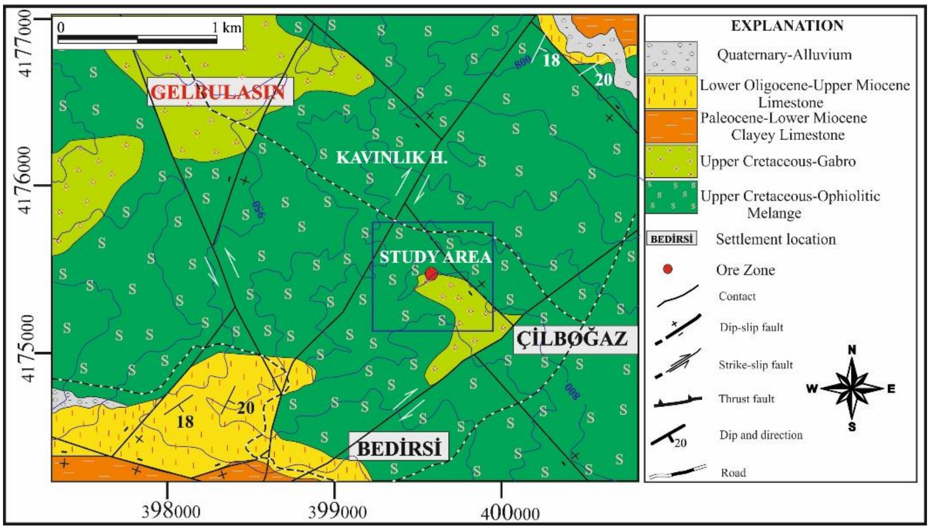

Figure 1. Geological map of the study area (modified from [14]).

Figure 2. General view of the study area and ore zone.

Installation of geophysical equipment and identification of measurement spots utilized during field research in the Adıyaman-Besni region.

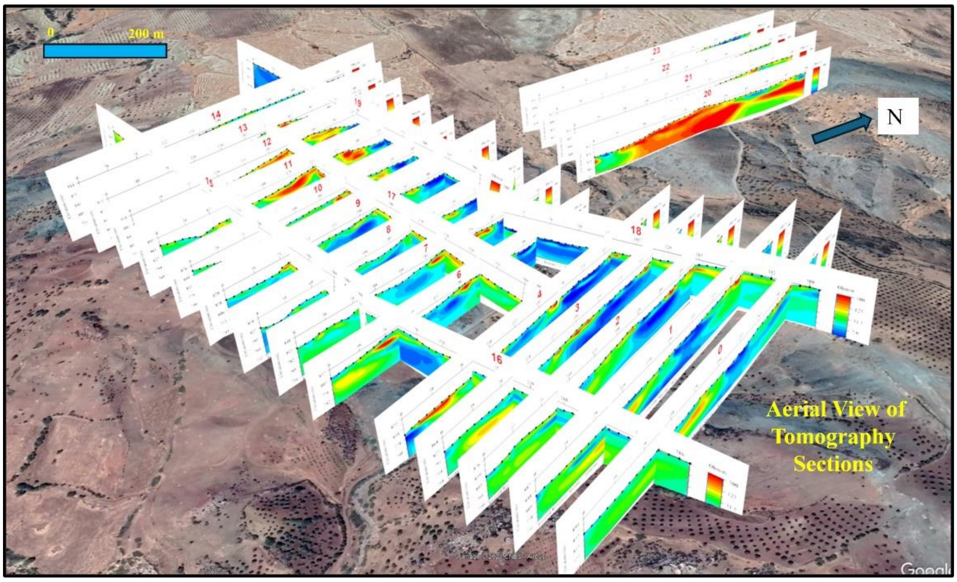

Figure 3. Profiles of Induced Polarization (IP) and Electrical Resistivity Tomography (ERT) measurements in the Adıyaman-Besni region.

The gathered IP and ERT data were analyzed utilizing a unique inverse solution algorithm, resulting in 2D cross-sections for each profile. These cross-sections illustrate the distribution, depths, and widths of subterranean metallic mineral deposits. The results were evaluated by examining the mineralization zones depicted in **Figure 1** [15,16].

ERT data facilitates the comprehension of the structural attributes of mineral deposits by measuring the electrical resistivity of subterranean formations, whereas IP data is employed to identify sulfide mineralization. The data are represented in 2D cross-sections in **Figures 4** and **5**, where elevated chargeability and diminished resistivity values designate mineralization zones [7,17].

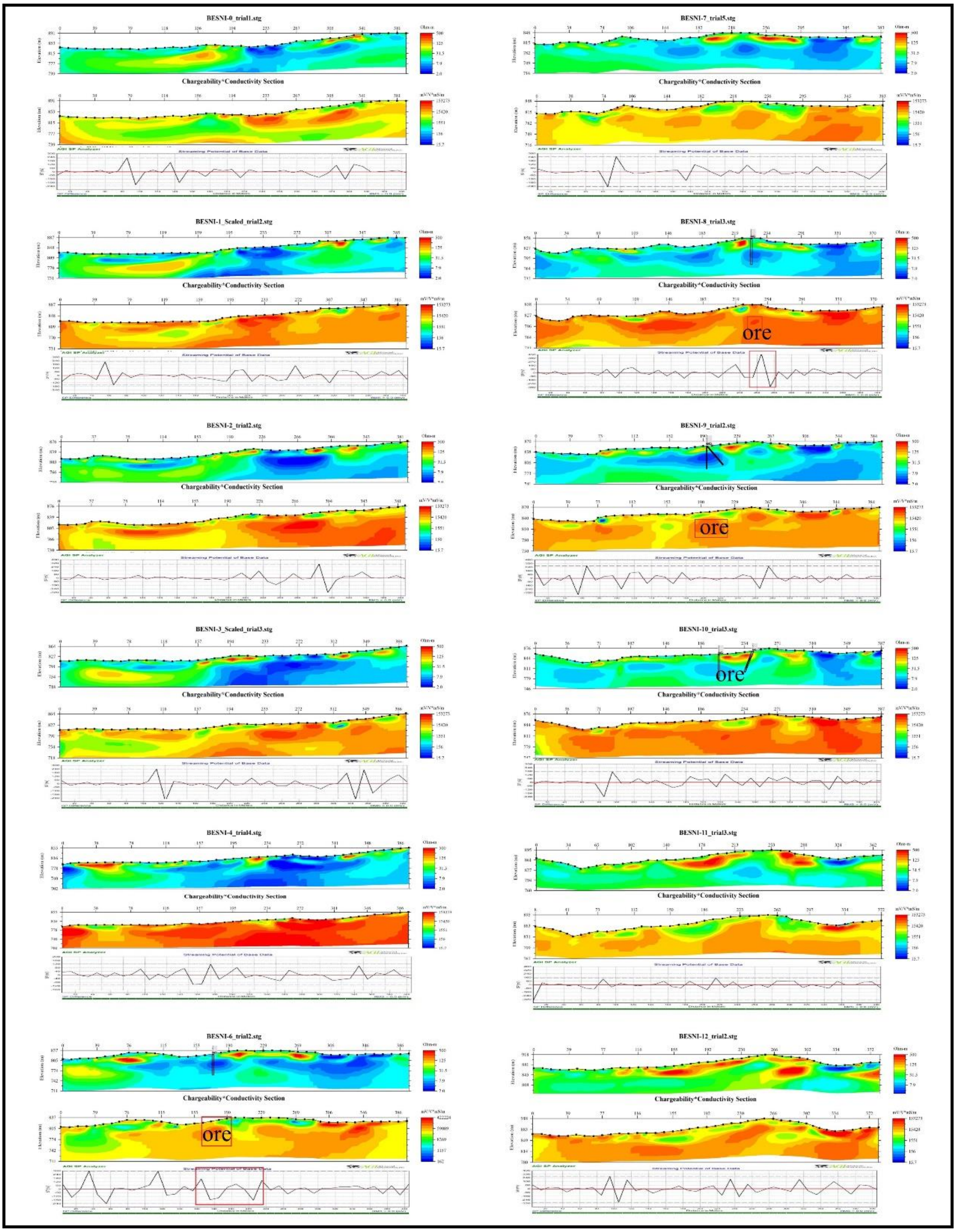

Figure 4. Two-dimensional cross-sectional image derived from Induced Polarization and Electrical Resistivity Tomography data in the Adıyaman-Besni region.

The illustration depicts low resistivity and high chargeability anomalies, signifying metallic and sulphide mineralization, specifically copper and lead, together with distinct structural characteristics.

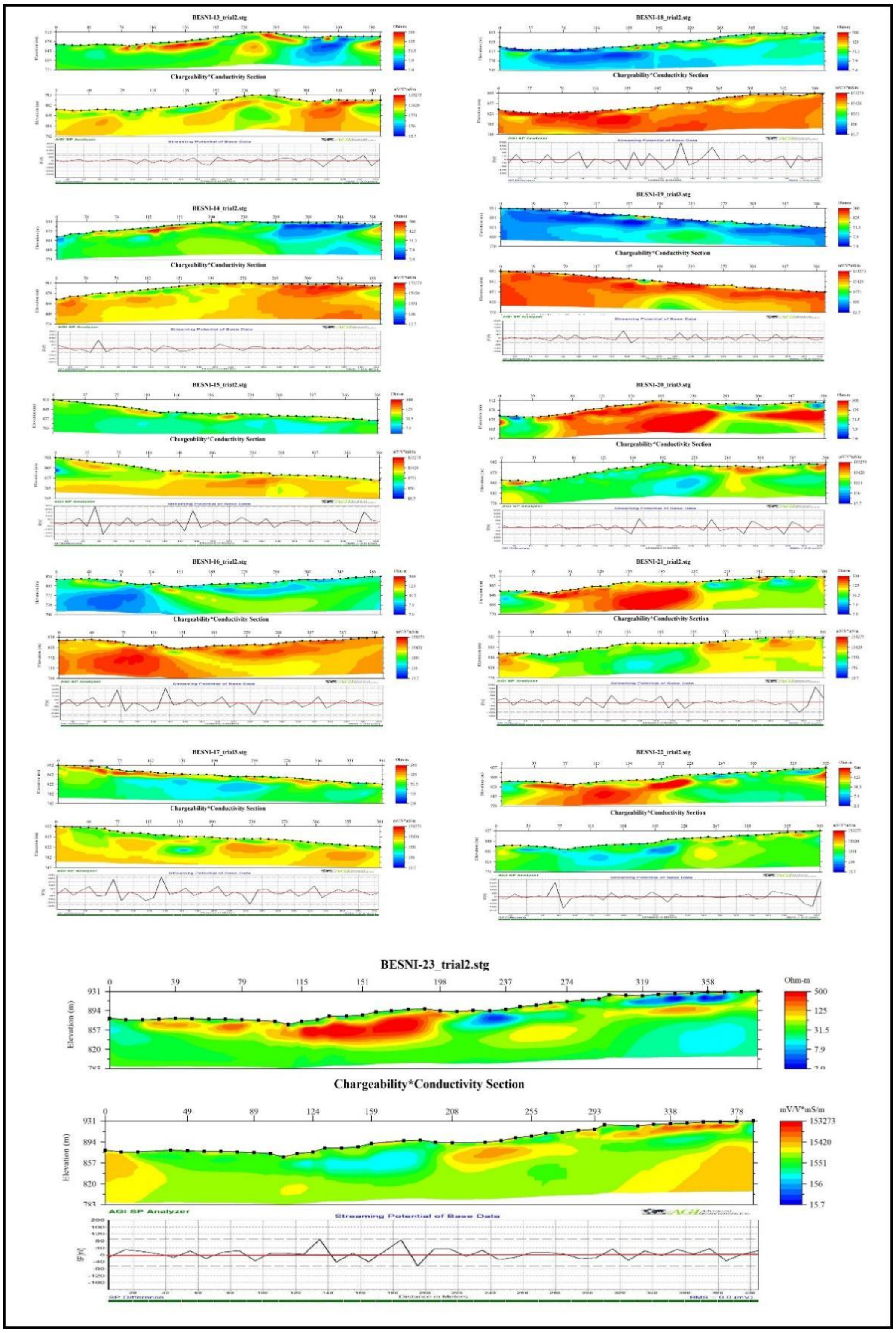

Figure 5. Two-dimensional cross-sectional image derived from Induced Polarization and Electrical Resistivity Tomography data in the Adıyaman-Besni region.

The integration of IP and ERT techniques offers considerable benefits, particularly in identifying sulphide-rich mineral resources like copper and lead. The combined application of these technologies yields more comprehensive and dependable information regarding subterranean structures and enhances the precision of mineral exploration in the Adıyaman-Besni area.

This study encompassed geophysical data across 23 profiles utilizing resistivity, Induced Polarization, and spontaneous potential techniques. The lines measured 410 m in length and utilized an AGI brand 8-channel equipment. EartImager 2D software facilitated resistivity and Induced Polarization measurements, whilst SPAnalyzer software assessed self-potential measurements. The data was examined as two-dimensional subsurface sections and modeled in three dimensions to yield a comprehensive mapping of the geological features in the area.

Table 1 presents the initial and final coordinates of the measurement profiles. These coordinates indicate the positioning and measurement configuration of each profile. The examination of the measurements involved optimizing the ground contact resistance of each electrode to reduce the Root mean square (RMS) error values. This led to enhanced data accuracy. All measurements were analyzed with EartImager 2D software, and the precision and dependability of the results were meticulously assessed.

Table 1. Profile coordinate chart.

Profile	**Beginning/End**	**Latitude**	**Longitude**
Profile 0	1. Electrode	37 399777 E	4175843 N
	42. Electrode	37 399618 E	4176202 N
Profile 1	1. Electrode	37 399728 E	4175831 N
	42. Electrode	37 399571 E	4176190 N
Profile 2	1. Electrode	37 399681 E	4175810 N
	42. Electrode	37 399527 E	4176164 N
Profile 3	1. Electrode	37 399632 E	4175800 N
	42. Electrode	37 399480 E	4176149 N
Profile 4	1. Electrode	37 399584 E	4175780 N
	42. Electrode	37 399426 E	4176140 N
Profile 6	1. Electrode	37 399491 E	4175743 N
	42. Electrode	37 399337 E	4176087 N
Profile 7	1. Electrode	37 399444 E	4175724 N
	42. Electrode	37 399289 E	4176075 N
Profile 8	1. Electrode	37 399397 E	4175700 N
	42. Electrode	37 399247 E	4176041 N
Profile 9	1. Electrode	37 399352 E	4175680 N
	42. Electrode	37 399194 E	4176033 N
Profile 10	1. Electrode	37 399309 E	4175653 N
	42. Electrode	37 399160 E	4175984 N
Profile 11	1. Electrode	37 399263 E	4175633 N
	42. Electrode	37 399110 E	4175966 N
Profile 12	1. Electrode	37 399215 E	4175615 N
	42. Electrode	37 399079 E	4175950 N
Profile 13	1. Electrode	37 399167 E	4175597 N
	42. Electrode	37 399027 E	4175943 N

Table 1. (*Continued*).

Profile	**Beginning/End**	**Latitude**	**Longitude**
Profile 14	1. Electrode	37 399123 E	4175573 N
	42. Electrode	37 398975 E	4175934 N
Profile 15	1. Electrode	37 399024 E	4175621 N
	42. Electrode	37 399376 E	4175782 N
Profile 16	1. Electrode	37 399410 E	4175805 N
	42. Electrode	37 399767 E	4175946 N
Profile 17	1. Electrode	37 399121 E	4175801 K
	42. Electrode	37 399451 E	4175962 N
Profile 18	1. Electrode	37 399316 E	4176011 N
	42. Electrode	37 399670 E	4176165 N
Profile 19	1. Electrode	37 398912 E	4175821 N
	42. Electrode	37 399263 E	4176001 N
Profile 20	1. Electrode	37 399217 E	4176202 N
	42. Electrode	37 399215 E	4176568 N
Profile 21	1. Electrode	37 399166 E	4176202 N
	42. Electrode	37 399159 E	4176587 N
Profile 22	1. Electrode	37 399116 E	4176198 N
	42. Electrode	37 399113 E	4176585 N
Profile 23	1. Electrode	37 399064 E	4176205 N
	42. Electrode	37 399060 E	4176588 N

IP data can signify the presence of sulfide minerals (e.g., pyrite, chalcopyrite), particularly when chargeability levels are elevated. However, this technique alone is not sufficient to unambiguously identify mineral species. The acquired data serves as an effective instrument for pinpointing regions of metallic mineral concentration; however, geochemical investigations are necessary for the accurate identification of mineral kinds. The correlation between mineralization and specific lithological units indicates a potentially elevated sulfide concentration in these regions.

Resistivity measurements were evaluated to ascertain the existence of mineralized zones. Metallic minerals were recognized for their low resistivity values attributable to their strong conductivity. The mineralized zones observed in the study typically exhibit values between 2 ohm-m and 31.5 ohm-m.

IP data is essential for identifying the existence of sulfide minerals. Chargeability values of 30 ms were observed in regions with significant mineralization. These values were important in delineating the limits of mineralized zones based on geological data.

Self-potential (SP) measurements used as an adjunct tool to detect structural alterations and non-mineralized regions. In particular, SP data supplied supportive information for the identification of fractures and fault zones in the subsurface.

3. Results

Results from ERT and IP measurements in the Adıyaman-Besni area elucidate the distribution and depth configuration of metallic mineralization in the region. **Figures 4** and **5** depict 2D cross sections that illustrate the subsurface electrical characteristics of the mineral deposits in the area, indicating regions of low resistivity and high chargeability. These characteristics are crucial for identifying metallic deposits that signify sulfide mineralization. The zones were identified by their low resistivity (usually between 15 ohm-m and 31.5 ohm-m) and high chargeability (greater than 30 ms). These values agree with sulfide-rich mineralization.

Uncertainty analysis was conducted throughout the modeling of ERT and IP data, and the precision of all models was assessed using Root Mean Square (RMS) error rates. All RMS values were maintained below 5% in the study of 23 profiles. Especially in the profiles where mineralized zones were discovered, RMS error rates were computed as follows: Profile 6: 3.8%, Profile 8: 4.2%, Profile 10: 4.0%, Profile 10: 4.0%. These values demonstrate the reliability of the modeling procedures and confirm that the data provide an accurate depiction of subsurface structures. The minimal error rates facilitated a more accurate determination of the borders of mineralized zones in the subsurface.

The computed tomography sections depicted in **Figures 4** and **5** reveal specific regions that exhibit abnormalities characterized by elevated chargeability and reduced resistance. The anomalies are scattered throughout the ophiolitic mélange, with metallic mineral occurrences situated according to the prevailing geological structure. The acquired data indicate that mineralization in the region is predominantly oriented in a specific direction from the surface to the depths [3]. **Figure 5** delineates the limits of the mineralized zones with precision. Elevated resistivity values (> 30 ms) derived from IP measurements signify areas of significant sulfide mineralization. The zones, along with low resistivity values (< 50 ohm-m), strongly indicate the possible occurrence of sulfide mineralization in the study area.

An in-depth investigation of the data indicated that the mineral deposits in the region typically display low resistivity and high chargeability traits, which are directly associated with the structural properties of the ophiolitic mélange in the area. Furthermore, these mineralization zones are delineated on the surface, as evidenced by the images captured in the field shown in **Figure 3**, and the correlation between the geophysical data and surface observations is noteworthy.

The geophysical measurement findings revealed mineralized zones in the studied area. On the sixth profile, a mineralized zone was discovered at a depth of around 80 m in the area beneath electrode 19. Mineralization was discovered on the eighth profile at a depth of around 80 m below electrode 27. At a depth of 80 m–100 m along the 9th profile, two distinct mineralized zones, one angled 60° N and the other vertical, were discovered between electrodes 21 and 22. Similarly, on profile 10, a vertical mineralized zone was detected below electrode 23 at a depth of 80 m–100 m, and another mineralized zone was identified below electrode 27 at a depth of 80 m–100 m, orientated 70° S.

These mineralized zones are often linked to the diabase and quartz veins of the Koçali Ophiolite Complex. The geophysical findings are compatible with geological investigations in the area and provide valuable information about the position and depth of the mineralization. These discoveries in the research region serve as the foundation for recommended drilling locations, allowing for a thorough analysis of prospective metallic mineral resources.

4. Discussion

The present study meticulously mapped metallic mineral deposits in the Adıyaman-Besni region utilizing Induced Polarization (IP) and Electrical Resistivity Tomography (ERT) techniques. The results indicated that sulphide mineralization in the region is localized in zones of low resistivity and high chargeability. The findings reveal notable similarities and some discrepancies when juxtaposed with analogous geological features in Turkey and other worldwide studies. The results corroborate the occurrence of low-resistivity (15 ohm-m–30 ohm-m) and high-chargeability zones (> 30 ms), which are indicative of sulfide mineralization. These anomalies are consistent with the geological environment and anticipated properties of metallic mineral deposits.

4.1. Comparison with studies in Türkiye

Cyprus-type volcanic massive sulphide (VMS) deposits in Turkey are linked to ophiolitic complexes, especially along the Southeastern Anatolian Thrust Belt [10]. Yalçın and Canlı [5] employed IP and ERT techniques to examine Pb-Zn deposits in the Sudöşeği and Küre areas, demonstrating that low resistivity and high chargeability anomalies are characteristic of these deposits. Likewise, mineralization in the Adıyaman-Besni area is correlated with ophiolitic mélange, aligning with other VMS deposits in Turkey.

The research of Akyıldız and Yıldırım [1] provided a detailed analysis of the metallic mineral deposits in the Koçali complex, revealing that their geological properties are analogous to other mineralizations in Southeastern Anatolia. The identification of metallic mineral deposits in intricate formations like the Koçali Complex is enhanced with the application of IP and ERT techniques. The results of this investigation enhance the precision of the findings by demonstrating geological commonalities and analogous anomalies with other places, including the Koçali Complex and Sudöşeği.

4.2. Comparison with global research

Research investigations worldwide demonstrate that IP and ERT technologies are efficiently employed in the exploration of metallic mineral resources. Al-Fares et al. [3] employed IP and ERT techniques to identify metallic mineral deposits in ophiolitic complexes in the Middle East, demonstrating that elevated chargeability and diminished resistivity values indicate the presence of metallic sulfide minerals. This study aligns with the findings in the Adıyaman-Besni region and validates that IP and ERT methods are universally applicable for identifying mineral deposits in ophiolitic mélange.

A research by Shirazy et al. [2] on copper deposits in Iran demonstrated that anomaly data acquired by IP and ERT methods serve as optimal markers for identifying sulfide mineralization. This study aligns with the findings in the Adıyaman-Besni region and corroborates that IP and ERT methods yield excellent precision in ascertaining the depth, width, and density of metallic mineral deposits.

4.3. Effectiveness of IP and ERT techniques in various geological contexts

The IP and ERT technologies have been effectively utilized in mineral discovery across various geological environments globally, not solely restricted to ophiolitic complexes. Su et al. [15] shown in China that regions with low resistivity and high chargeability, found by IP and ERT approaches, serve as significant markers of metallic mineralization. This work is significant for identifying analogous geophysical signatures across diverse geological contexts, in contrast to the mineralization observed in the Adıyaman-Besni region.

Furthermore, the gold exploration research by Liu et al. [17] in the Sumatra region of Indonesia utilized high-resolution data from the combined application of IP and ERT technologies, facilitating precise mapping of metallic mineral resources. The findings of this study align with mineral exploration research in the Adıyaman-Besni region, demonstrating that IP and ERT technologies yield comprehensive insights into subsurface structures.

4.4. Comparability and divergences with other research in Turkey and globally

Comparable research in Turkey and globally demonstrates that IP and ERT methodologies are efficacious instruments for the exploration of metallic mineral resources. Nonetheless, owing to the distinctive geological attributes of each region, certain disparities have also been noted. In the study conducted by Al Hakim et al. [18] on gold mineralization in Indonesia, low sulfidation epithermal gold deposits display a distinct geophysical signature compared to VMS deposits in Turkey. The disparity arises from the mineralogical diversity of subsurface structures, indicating that the efficacy of IP and ERT approaches may change according to mineral kinds.

The alignment of findings in the Adıyaman-Besni region with other VMS deposits in Turkey and elsewhere enhances the credibility of this study and reinforces the overall validity of the results. Moreover, the combined use of IP and ERT methodologies establishes a framework for forthcoming research in Turkey and other nations. The integration of these methodologies with precise data gathering, inverse solution algorithms, and comprehensive analysis enhances the accuracy of mineral exploration studies [16].

The results of the Adıyaman-Besni investigation largely correspond with Martínez et al. [19], who utilized IP and ERT techniques to delineate galena-rich veins in southwestern Spain. The investigation successfully identified low-resistivity and high-chargeability zones, which corresponded with areas of significant mineralization, akin to our findings in Adıyaman, where probable sulfide mineralizations had comparable geophysical signatures [19]. Yalçın and Canlı [20] in Yahyalı, Turkey, illustrated the effectiveness of IP and resistivity methods in evaluating carbonate-hosted Pb-Zn deposits, emphasizing the role of geophysical surveys in elucidating the geometry and extent of mineralization, even in intricate geological environments. Moreover, Yalçın et al. [21] illustrated the efficacy of these techniques in the Kavşut region, where integrated Induced Polarization and resistivity investigations effectively identified Cu-Pb-Zn polymetallic deposits linked to fractured and karstic formations in carbonate settings. Our research in Adıyaman corroborates these findings by affirming the effectiveness of IP and ERT methodologies for comprehensive subsurface mapping, especially in orogenic and structurally intricate environments prevalent in southeastern Turkey and elsewhere [20,21].

The geophysical data collected throughout the investigation gave valuable insights into the location and geological context of possible metallic mineral deposits in the area. Low resistivity and high chargeability values highlighted significant mineralization zones, which were then connected with structural aspects of the Koçali Ophiolite Complex. Mineralized zones were found to have low resistivity (< 50 ohm-m) and high chargeability (> 30 ms) values, indicating sulphide mineralization.

Mineralization in the studied area was found to be primarily associated with diabase and quartz veins. This is compatible with the geophysical results, which show low resistivity and high chargeability values. In particular, the link between the mineralized zones discovered along profiles 9 and 10 and geological units gives strong indication that these areas represent possible mineralization zones.

The IP cross sections illustrated in **Figure 5** were useful in delineating the limits of the mineralized zones within the study area. The simultaneous occurrence of elevated chargeability (> 30 ms) and low resistivity (< 50 ohm-m) data suggests the possible existence of sulfide mineralization. The data provide essential insights into the depth, width, and strike extent of the mineralized zones.

Nevertheless, IP data merely indicate the presence of metallic minerals. While elevated chargeability readings may correlate with sulfide minerals such as pyrite and chalcopyrite, geochemical investigation is essential to ascertain the specific kind of these minerals. In the study, IP data served as an effective instrument to ascertain the overarching properties of mineralization; nevertheless, a definitive classification of mineral kinds was not established.

The findings in the Adıyaman-Besni region align with analogous geological structures and mineral deposits in Turkey and globally, indicating that IP and ERT methods serve as effective tools for identifying metallic mineralization. This study's methodologies offer a comprehensive delineation of prospective metallic mineral deposits in the Adıyaman-Besni region, serving as a reference for future extensive geophysical investigations.

5. Conclusion

This study seeks to examine the prospective metallic mineral deposits in the Adıyaman-Besni region by geophysical methods and provides a comprehensive mapping of the subsurface structure utilizing Induced Polarization (IP) and Electrical

Resistivity Tomography (ERT) techniques. The findings indicate that mineralization in the region is localized in zones of low resistivity and high chargeability, signifying the existence of sulfide mineralization and metallic minerals.

The study assessed the distribution and density of metallic minerals, including copper and lead deposits, particularly inside the ophiolitic mélange. Comparisons with other VMS deposits in Turkey, including Sudöşeği and Küre, validate the findings in the Adıyaman-Besni region and demonstrate the efficacy of IP and ERT technologies in exploring such deposits. Moreover, when juxtaposed with other global investigations, these methodologies have demonstrated considerable precision in delineating the borders and depth configurations of mineral deposits.

The findings of this study indicate that the synergistic application of IP and ERT methodologies provides a significant benefit in the comprehensive mapping of metallic mineral deposits. The technologies utilized in the Adıyaman-Besni region offer a geophysical comprehension of the subsurface structure and the requisite information for the economic extraction of metallic mineral deposits in the area. The research establishes a systematic framework for forthcoming geophysical explorations in other areas with prospective mineral resources, including Adıyaman-Besni.

Future research should incorporate supplementary geophysical techniques, such as Magnetotellurics (MT), to examine deeper structures. The incorporation of sophisticated approaches will enhance the accuracy and thoroughness of the evaluation of existing mineral resources and provide a more dependable assessment of the metallic mineral potential in the Adıyaman-Besni region.

Author contributions: Conceptualization, CY and AK; methodology, CY; software, CY; validation, CY, and AK; formal analysis, CY; investigation, AK; resources, AK; data curation, CY; writing—original draft preparation, CY; writing—review and editing, CY; visualization, CY; supervision, CY; project administration, CY; funding acquisition, AK. All authors have read and agreed to the published version of the manuscript.

Acknowledgments: We express my gratitude to MESED MADENCİLİK İNŞAAT LTD. ŞTİ. Staffs.

Conflict of interest: The authors declare no conflict of interest.

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