Delineation of resistivity anisotropy of schists using ERT data in the Sighbhum Shear Zone, Ghatshila

S. Agrahari[1], A. Singh[1], A. Yadav[1], A. Shlykov[2], A. Saraev[2]

[1] Indian Institute of Technology, Kharagpur (India), [2] St. Petersburg State University (Russia)

Summary

This study focused on investigating the schist rock-rich areas near the Singhbhum shear zone in Ghatshila, Jharkhand. The objective was to identify sheared, fractured, and highly foliated schist rocks in both shallow and deeper horizons. Electrical resistivity tomography (ERT) measurements were conducted using a 2x21 electrode configuration, with nine profiles covering inter-electrode spacings ranging from 3 m to 10 m. The data were inverted using a newly developed code called Anisotropic DC resistivity Forward and Inverse (*ADCFI*) to perform the 2D isotropic and anisotropic inversion.

The results of the 2D anisotropic inversion in Ghatshila revealed the presence of high anisotropy coefficients beyond a depth of 20 m. This depth coincided with the appearance of chalcopyrite-containing strata, suggesting a layered deposition resulting from a volcanogenic environment. The presence of schistic rocks in the shallow borehole depths also contributed to the observed anisotropy. Notably, regions with higher anisotropy exhibited thicker layers in the isotropic section compared to the anisotropic section across all profiles.

Two ERT profiles were measured at nearly perpendicular orientations, and the interpreted 2D sections along these profiles indicated non-continuous resistivity values at their intersection. Additionally, areas with discontinuous resistivity values demonstrated anisotropy coefficients greater than one, indicating significant anisotropy in those regions. The irregular resistivity values further supported the presence of strong anisotropy in the area.

The anisotropy coefficient values obtained in the schist rock-abundant areas in Ghatshila were approximately 2.00. This high anisotropy can be attributed to the foliation and schistosity of the predominant rock type, namely schist. These findings enhance our understanding of the geological characteristics and anisotropic behavior of the studied region, which has implications for geological mapping and resource exploration.

Introduction

The Singhbhum region, known for its geological activity over a long period of time, serves as a valuable source of metallic and non-metallic minerals. It possesses abundant reserves of copper, iron, manganese, and chromium, as well as viable deposits of uranium and vanadium (Anand and Rajaraman 2006). This particular area, located in close proximity to Ghatshila and Musabani towns, is renowned for its copper and zinc mines, while the surrounding regions are highly abundant in minerals such as uranium.

Study area

The study area, depicted in Figure 1, is situated within the Singhbhum shear zone, near a place called Ghatshila. The area hosts a very interesting geological past, which was evident from the outcrops visible in the area during the field visit. The outcrops in the study area indicate the presence of anisotropy due to foliation and schistosity. Figure 1(a) illustrates the precise location of the study area on the map. Subsequently, Figures 1(b) and 1(c) provide a closer view of the ERT profiles, each one zooming in further. Additionally, the Subarnarekha River flows parallel to the Singhbhum shear zone (SSZ). Figure 1c displays a borehole that serves as a means to verify the subsurface lithology derived from the inversion of DC resistivity data. The borehole provides information on the subsurface up to a depth of 102 m. The dominant rock types encountered within the borehole are Chlorite-schist and Mica-schist, occasionally interspersed with quartz-chlorite, as well as separate occurrences of Chlorite and quartz. Furthermore, the presence of chalcopyrite is observed at various depths, specifically from 19.9 to 29 m, 42.6 to 48 m, 71.6 to 74 m, 80.7 to 83.4 m, and 86.1 to 96.8 m. Fracture indications are visible from 79.8 to 80.7 m. The presence of Chalcopyrite favors a volcanogenic deposition environment.

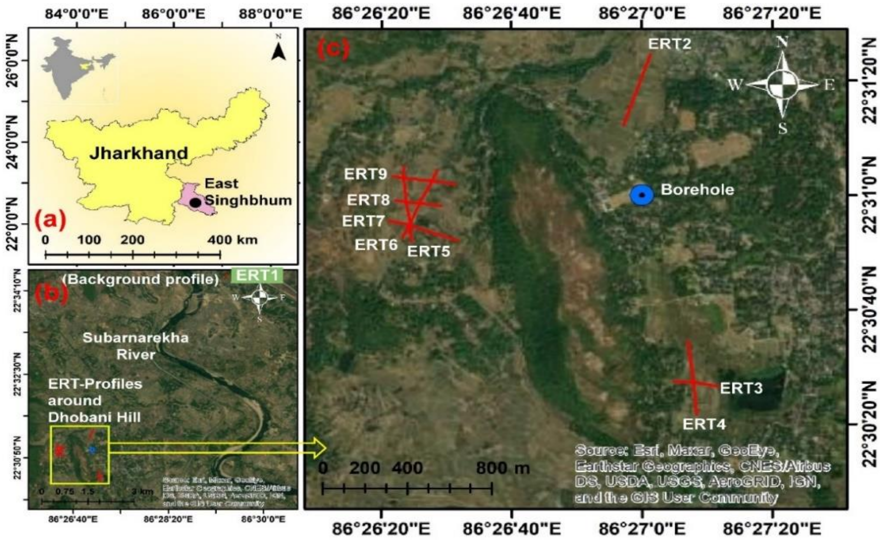

Figure 1 *(a) Location map of the study area inside India and the state of Jharkhand, (b) the lithological map of East Singhbum district highlighting the study area, (c) the ERT profiles plotted on aerial imagery of the study area. The profile name is written close to the position of the first electrode.*

Field measurements

In a section of the Singhbhum shear zone characterized by heavy mineralized meta-igneous and meta-sedimentary terrains, multi-electrode ERT data were collected. The ABEM Terrameter LS (ABEM 2012) was utilized for these resistivity measurements using a Wenner-Schlumberger configuration with 2x21 electrodes. The selection of the Wenner-Schlumberger configuration was made to achieve enhanced resolution and a favorable signal-to-noise ratio at various depths. The primary objective was to gain insights into both the deeper (30-50 m) and shallower (0-29 m) occurrences of interbeds, including macro anisotropy, as well as the sheared or fractured copper-bearing horizons and the highly foliated bedrocks, which are schists serving as host rocks. To achieve the survey objectives, interelectrode spacings ranging from 3 m to 10 m were employed, resulting in varying profile lengths between 120 m to 400 m. A total of nine ERT profiles were conducted in the northeastern region of the Singhbhum shear zone (Figure 1) to assess the subsurface resistivity anisotropy. To provide a systematic and comprehensive description of the ERT profiles, they have been categorized as follows: the first profile (ERT-1) acts as a background profile, and the second profile (ERT-2) is located near the borehole. The remaining seven profiles are divided into two clusters or groups (ERT-3 & ERT-4; ERT-5 to ERT-9). The first group (ERT-3 and ERT-4) is positioned towards the eastern side of the Dhobani Hills, while the second group consists of five profiles and is located on the western side of Dhobani Hill.

Results

Figures 2 and 3 display the isotropic and anisotropic inversion results of selected ERT profiles. In Figure 2, the first profile (ERT-1) is depicted which is the background profile. The second profile (ERT-2) is closest to the borehole. In Figure 3, ERT-4 and ERT-5 profiles are depicted which are taken from group I and group II respectively. The 2D code (*ADCFI*) uses a finite element for isotropic and anisotropic inversion of ERT data (Singh, 2023). The electrical anisotropy coefficient is defined as $\lambda = \sqrt{\rho_V/\rho_H}$ (ρ_V – vertical resistivity, ρ_H - horizontal resistivity).

The background profile (ERT-1) was conducted over a distance of 120 m with a 3 m electrode spacing. The profile extended from a road and ran parallel to a southeast-oriented hill. The presence of clay ensured good electrode-to-ground contact. In Figure 2(a), ERT-1 exhibits a transition from the hard rock at the starting point (northeast) to softer sediments towards the end of the profile, closer to the road. The resistivity in the range of 30-50 Ωm indicated the presence of clay towards the center and end of the profile. Additionally, the depths of the clay sediment (30-50 Ωm) decreased in the anisotropic section (Figure 2(b)). The deeper horizons in the southwestern part of the section showed significant anisotropy with high anisotropy coefficient values (1.74) (Figure 2(c)). The subsequent profile, ERT-2 (Figure 2(d, e, f)), is situated closest to the borehole. It is oriented in the northeast-southwest direction, with the end of the profile extending towards the borehole and the northeast side of the Dhobani hills. The area surrounding the profile is an agricultural field. In the anisotropic inverted section of ERT-2 (Figure 2(e)), there is an increase in resistivity in the shallow portions of the profile. As a result, the features that previously appeared as single and continuous in the isotropic section now become isolated. The anisotropy coefficient values tend to increase after 20 m.

ERT-4 was conducted in an eastward direction, running parallel to a hill, while ERT5, along with five other profiles, was taken on the northwestern side of the hill, also parallel to it. In ERT-4, the southern half of the profile (Figure 3(a)) shows lower resistivity in the shallow zones, possibly due to the presence of a nearby water body. The second half of the profile indicates resistive areas extending to shallow depths, suggesting a thin sediment cover. In the anisotropic resistivity section of ERT-4 (Figure 3(b)), a relatively resistive anomaly is observed between a profile distance of 320-360 m compared to the isotropic section. Furthermore, the anisotropy coefficient values increase in deeper horizons from a profile distance of 300 m onwards. For ERT-5, a small stream intersects the profile between a profile distance of 240-250 m (Figure 3(d)). The sections near the stream exhibit lower resistivity, while the sediment depth is shallower along the southern part of the profile compared to the northern part. The end of the profile is marked by a mine-tailing mound. In both the isotropic (Figure 3(d)) and anisotropic (Figure 3(e)) sections of ERT-5, there is a continuous sediment cover along the southern half of the profile. The sediment depth increases along the northern part of the profile. The anisotropy coefficient plot (Figure 3(f)) shows a decrease in the anisotropy coefficient in the deeper strata (depth >40 m) when moving away from the middle of the profile towards the northern end, which is away from the hill.

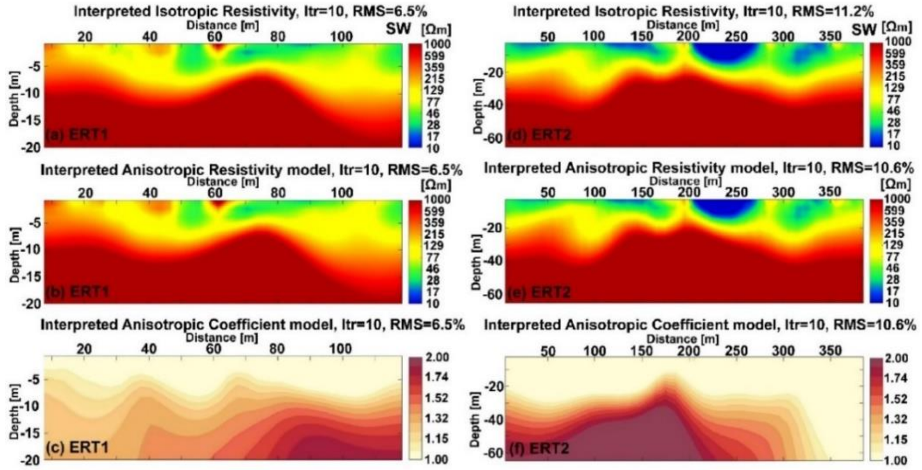

Figure 2: 2D interpreted models of DC data corresponding to (a, d) isotropic inversion, (b, e) anisotropic inversion, and (c, f) estimated anisotropy coefficient along the profiles ERT-1 and ERT-2.

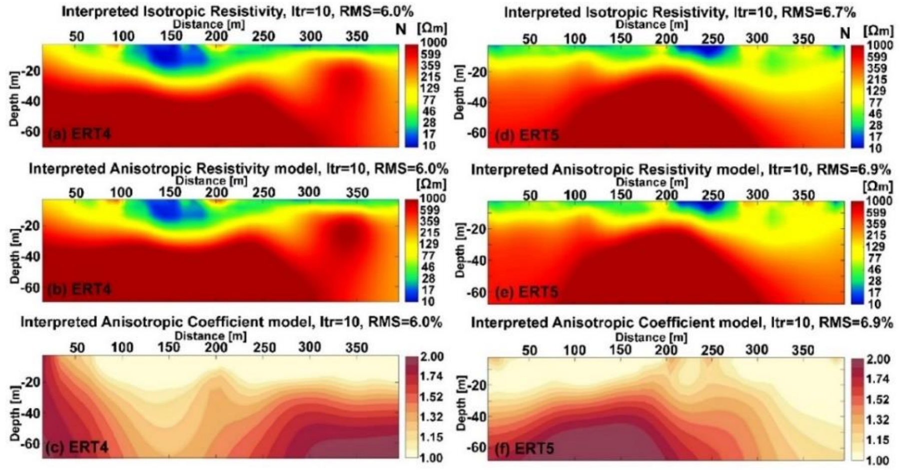

Figure 3: 2D interpreted models of DC data corresponding to (a, d) isotropic inversion, (b, e) anisotropic inversion, and (c, f) estimated anisotropy coefficient along the profiles ERT-4 and ERT-5.

The background profile, ERT-1, displayed the lowest level of anisotropy, which could be attributed to its shorter profile length (120 m) and limited depth penetration. In ERT-2, conducted near the borehole, a significant anisotropy is observed from a depth of 20 meters and beyond. Notably, the borehole analysis revealed the presence of chalcopyrite between depths of 19.9-29.0 m, indicating a volcanogenic deposition environment. This layer-by-layer deposition could account for the higher magnitude of anisotropy (>2) observed. ERT-4 was conducted on relatively flat terrain compared to ERT-5, and the central portion of the profile exhibited less pronounced anisotropy. On the other hand, ERT-5, which was performed on the western side and parallel to the hill, displayed notable anisotropy from a depth of 50 m and below.

ERT-3 and ERT-4 profiles were measured at nearly perpendicular angles to each other. The 2D interpreted sections along these profiles reveal that the resistivity values at their intersection point do not exhibit similar values (Figure 4). It is important to note that the profile measured parallel to the geological strike (ERT-4) and the one measured perpendicular to the strike (ERT-3) demonstrate distinct resistivity values beyond a certain depth. Another thing that can be observed is that the anisotropy coefficients are more than one in the areas of discontinuous values of resistivities. This irregular resistivity pattern suggests a pronounced anisotropy in the region. Upon closer examination, it can be deduced that, at the intersection location, the resistivity values of profiles measured perpendicular to the strike are higher than those measured parallel to the strike for a certain depth.

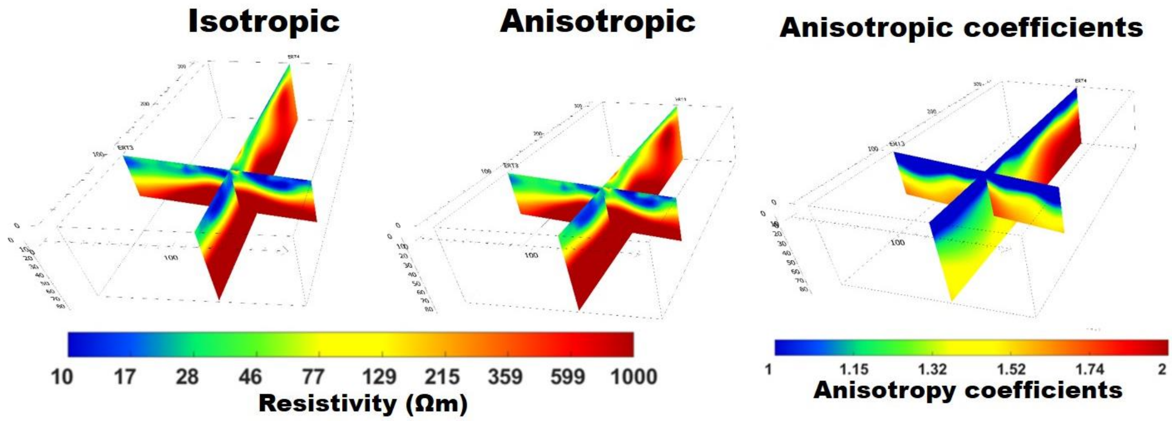

Figure 4: 2D interpreted models of DC data corresponding to isotropic inversion, anisotropic inversion, and estimated anisotropy coefficient along the profiles ERT-3 and ERT-4.

Conclusions

In conclusion, the conducted survey in the schist rock-rich areas near the Singhbhum shear zone in Ghatshila, Jharkhand has provided valuable insights into the geological characteristics and anisotropic behavior of the region. The 2D DC resistivity measurements, along with the use of the ADCFI code for isotropic and anisotropic inversion, allowed for the identification of sheared, fractured, and highly foliated schist rocks. The results revealed a significant increase in anisotropy coefficients below a depth of 20 meters, which coincided with the presence of chalcopyrite-containing strata. This observation suggests a layered deposition process influenced by the volcanogenic environment. The presence of schistic rocks in the shallow borehole depths also contributed to the observed anisotropy. The measurement of two ERT profiles at nearly perpendicular orientations demonstrated non-continuous resistivity values at their intersection, indicating variations in the subsurface characteristics. Moreover, areas with discontinuous resistivity values exhibited anisotropy coefficients greater than one, further emphasizing the strong anisotropic nature of those regions. The irregular resistivity values also served as an indicator of the overall anisotropy within the area.

Acknowledgments

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