Electrical anisotropy of mineralized and non mineralized rocks

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Summary

Significant electrical resistivity anisotropy, up to 1OO0:1, has been observed in rock samples containing sulphides and samples barren of sulphides. Anisotropy associated with sulphides generally has nsistivity in one direction within the typical ground EM detection limit (less than IO Ω-m), but in the perpendicular directions the resitivity can be well above this limit (100 to 19,000 Ω-m). Such examples have been observed in rocks from Snow Lake (Manitoba), the Bathurst Mining Camp (New Brunswick) and the Trans-Hudson orogen (Saskatchewan). The Snow Lake study was the first of these studies and was carried out to seek an explanation for the weaker than expected electromagnetic (EM) responses of several of tbe sulphide bodies in the region. This continuing study attempts to understand the electrical mechanisms involved in such anisotropic processes in order to provide information for development of improved EM interpretation and survey methods, and of improved EM instrumentation.

Introduction

Interpretation of EM responses associated with massive sulphide exploration often leads to inconsistancies and surprises. Massive sulphide bodies may be less conductive than anticipated. For example, tectonics (shearing and folding), mineral grain size, vein structure and mineral types all affect the bulk conductivity. Several of these affects can also lead to a preferred direction for the conductivity and hence anisotropic affects. Anisotropy can also exist in host (non sulphide) rocks as well leading to unanticipated resistivity structure.

Understanding the mechanisms that explain conductivity variations in a sulphide body and understanding how anisotropy affects bulk conductivity is important for interpreting EM responses. The development of better methods of EM interpretation, surveying and instrument design may be possible because of our improved understanding of these mechanisms.

Method of Investigation

Laboratory electrical measurements (bulk resistivity and formation factor) have been carried out on seven samples (15 specimens) representing various types os sulphide mineralization in the Flin Flon - Snow Lake volcanic belt (Katsube et al., 1996a), on ten representative samples (19 specimens) from the Brunswick 12 deposit in tbe Bathurst Mining Camp (Katsube et al, 1996b), and on seven surface rock samples (gneiss, graywacke and argillite) from a biotitic metasedimentary unit of the Trans-Hudson Orogen (Katsube et al., 1996c). The specimens, generally of rectangular shape, were cut from these samples to allow electrical measurements to be made in three perpendicular directions. The electric.4 resistivity (ρ_r) values measured in this study were determined using complex electrical resistivity measurements (1 to 1O^6 Hz) described in the literature (see for example Katsube and Scromeda, 1994; Katsube et al., 1992, 1991; Katsube and Salisbury, 1991).

Basic Anisotropic Mechanisms observed in the Bathurst Camp

Three anisotropic mechanisms have been observed in the samples from the Bathurst Mining Camp (Katsube et al, 1996b). These are (a) layered sulphide structures, (b) disseminated sulphide structures, and(c) insulating veinlet structures. Mechanism (a) is represented by strong directional effects in the electrical resistivity distribution of a chloritized iron formation sample (Figure 1). This material

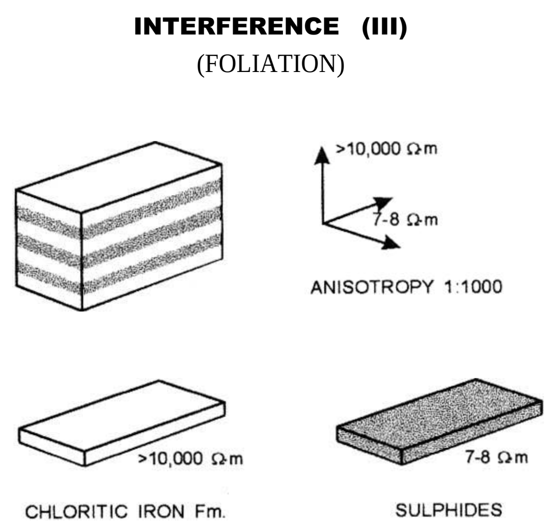

Figure I: One of the anisotropic mecbanisms (Katsube et al, 1996b). The chloritized iron formation sample consists of inter-layerd sulphide-rich material (7 to 8 Q-m) and non-sulphide material (greater than 10,000 n-m). resulting in *electrical resistivities of 7 to 8 Q-m in directions parallel to the foliation, and of greater than 10, 000 Ω-m in the directions perpendicular to the foliation.*

consists of an inter-layering of sulphide-rich material (7 to 8 Ω-m) and non-sulphide material (greater than 10,000 Ω-m), resulting in electrical resistivities of 7 to 8 R-m in directions parallel to the foliation, and of greater than 10,000 R-m in the direction perpendicular to the foliation. Mechanism (b) is represented by a number of thin veins (less than 1 mm thick) containing sulphides that cut across metamorphosed foot wall sediment material (Figure 2), thus reducing the electrical resistivity of the bulk metamorphosed rock from over 10,000 R-m (estimated) to 8 to 1,000 Ω.m. Mechanism (c) is represented by a quartz vein (1 mm thick) cutting across an iron formation sample, raising the electrical resistivity of the original material from 10,000 to 22,000 R-m. This implies, that if this vein were to cut across conductive material (e.g. a sulphide ore body) it could raise the bulk resistivity from less than 5 Ω-m to more than 10,000 Ω-m.

INTERFERENCE (II)
(SULPHIDE DISSEMINATION)

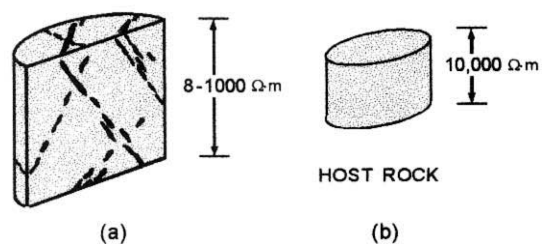

Figure 2: Another anisotropic mechanism (Katsube et a1, 1996b). Thin veins (less than I mm thick) containing sulphides cut across metamorphosed foot wall sediment material, reducing the electrical resistivity of the bulk rock from over 10,000 Ω-m (estimated) to 8 to 1,000 Ω-m, in the direction of the vein.

Shearing Mechanisms observed in the Snow Lake region

The anisotropic mechanisms discussedabove have also been observed in samples from Snow Lake massive sulphide deposits (Katsube et al., 1996a). These rocks are metamorphosed volcanics (Katsube et al., 1996a). Samples with anisotropic textural characteristics displaying foliations containing sulphide mineralization, exhibit electrical anisotropy as expected. Lower resistivity (less than 2 n-m) values are seen in the direction parallel to the foliation and higher resistivities are observed (100 to 500 Q-m) in the perpendicular directions. Surprisingly, several samples displayed considerable resistivity anisotropy in a direction opposite to the textural trends, in other words what was expected to be the more conductive direction was actually more resistive (Figure 3). Anisotropic ratios as high as 70:1 (**2100** *to* **22** Ω-m) have been observed in such cases. Preliminary examination of these samples suggests the existence of shearing in a direction approximately normal to that of the foliation (Katsube et al., 1996a). Shearing therefore can break the good electrical connectivity that may have existed parallel to the foliation. The shearing is most likely the main cause of the strong resistivity anisotropy.

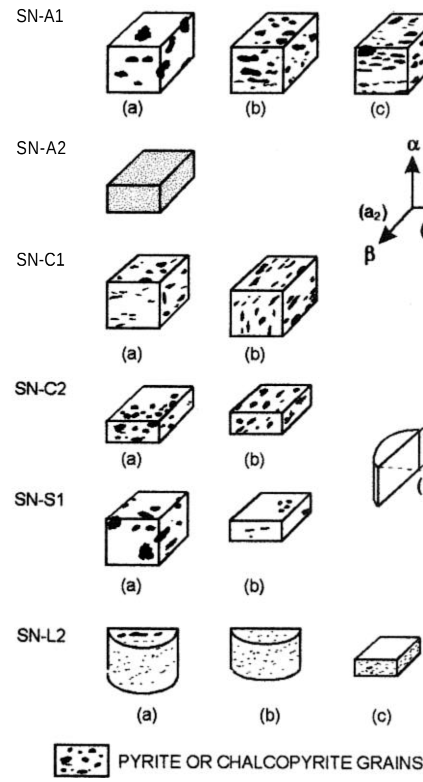

Figure 3: Sample displaying considerable resistivity anisotropy in the opposite direction to that expected from the textural trends (Katsube et al., 1996a). For example. samples SN-Ala and SN-Sla give some indication, from their tectural characteristics, that the β direction may be more conductive than other directions. However, that direction actually has the smallest conductivity values for these samples, with SN-Ala and SN-S1a having values of 92 Ω-m and 2100 Ω-m in this direction respectively.30 to 100 times the resistivity values in the perpendicular directions.

Folded Mechanisms observed in the Trans-Hudson Orogen

Tectonic control of electrical anisotropy due to folding has been observed in samples from the Tram-Hudson Orogen, Northern Saskatchewan (Katsube et al., 1996c). Resistivities of the rocks from this region display a wide range of values (**3000 to 20,000** O-m). While the larger values are typical for the gneissic rocks in this area the smaller ones appear to be due to layers (thicknesses of about 1 to 5 mm) of sulphide concentrations. These layers can also lead to significant electrical resistivity anisotropy. When these rocks are folded, with sulphide layers accumulated near the head of the fold (Figure 4), they create a zone of high electrical conductivity along its axis. The resistivities are 3 to 8 Ω-m in the direction of the axis, and 2,000 to 20,000 R-m in the two perpendicular directions, resulting in anisotropic ratios between 2OO:1 and 7,000:l (Katsube et al., 1996c).

Implication for Improved EM Interpretation and Survey Design

These results imply that electrical anisotropy may be an important factor in interpreting and designing electromagnetic surveys. Improved EM survey design may increase our ability to interpret geological bodies with large electrical anisotropy. In addition, improved EM systems could also lead to better quality data that is easier to interpret in these complex areas. Katsube et al.(1996c). for example, suggestedthat either broadband frequency domain EM systems with at least one coil pair operating in the 30 to 60 kHz range, or timedomain EM systems with an in-pulse channel may offer greater ability to detect these anisotropic conductors.

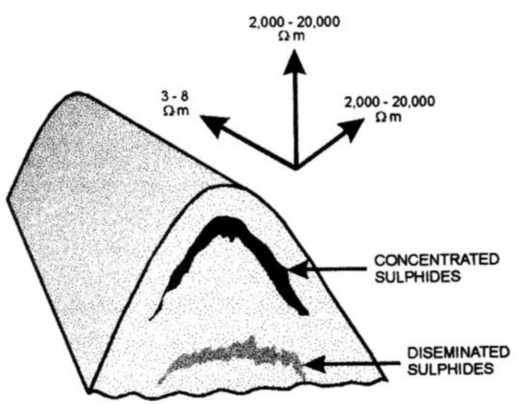

Figure 4: A folded gneissic rock sample with sulphide layers accumulated near the head of the fold, forming a zone of high electrical conductivity along ifs axis ***(Katsube*** et al.. 1996c).

Conclusions

These results indicate nsistivity anisotropy can be significant and can occur in both mineralized (sulphide) rocks and non-mineralized rocks. Indeed, the large resistivity differences encountered indifferent directions can cause major problems in interpreting EM surveys. Further research is needed to characterize these affects in different environments so that new EM methods can he produced to properly interpret them.

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