

TECHNICAL NOTE #97/60

Factors Influencing the Inductive Measurement of Conductivity of Rocks and Ores.

[This note does not deal with practical considerations of measurement such as the avoidance of 'edge effects', magnetisation, etc. which are discussed in the Operations Manual for the Geo Instruments hand-held conductivity meter, model GCM-2. Otherwise most of the information below is from Emerson and Yang (1994).]

Many factors influence the measurement of the electrical conductivity of a rock or ore sample by inductive (EM) means causing the values to be different from values reported for pure minerals. The first and most obvious reason is that the sample to be measured will generally not be a large homogeneous lump of a single mineral. Mostly it will contain several minerals and barren country rock, or gangue. Commonly this gangue is quartz which is a good insulator. Thus, an inductive measurement of conductivity with a sensor that encompasses an area containing a variety of minerals will give a value which is a combination of the conductivity of the individual minerals.

Secondly, the **manner of association** of the various minerals can also take many different forms and each different form of assemblage results in a different conductivity value. Examples of these types of forms are **porphyritic, stringer and banded**. It can be imagined that depending on the nature of these assemblages, each individual conductivity will combine in a complex way to produce the overall result.

Emerson and Yang (1994) found that for a mineralised rock with a **porphyritic** fabric, i.e. isolated sulphide grains in a resistive matrix, the induced currents that provide the measurement are confined to the individual grains and the EM response becomes dependent on specimen size, so the reading usually is not representative of the conductivity that would be obtained from readings in the field with large EM arrays. On the other hand, pyrrhotite, chalcopyrite and graphite often tend to form effective **stringers and networks** and can show good conductivities even at what seems to be minor concentrations.

Grain factors have also been found to limit or optimise sulphide conductivity. (Emerson and Yang, 1994.) For example, pyrite which has a high nominal conductivity may rarely approach this value due to grain factors. Pyrite and magnetite, even at high concentrations, may not show much conductivity because their crystalline aggregates are dominated by cubic grains with high intergranular contact resistances. But when these cubic grain contacts are obliterated, say by tectonic activity, pyrite and magnetite may show quite high conductivities. Also, pentlandite has an excellent nominal conductivity (10^6 S/m) but its cubic habit can impair its conductivity contribution in nickeliferous sulphides. Pyrrhotite, on the other hand, often has a pervasive habit and its presence usually enhances conductivity.

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In the study conducted by Emerson and Yang (1994) on a range of sulphide mineralised ores from well known mineral provinces in Australia, they found that each sample gave a range of values, often over 3 decades of Siemens / m., the unit of conductivity, and the usual values were only of low to moderate order (about 100 S/m). Very high values (more than 100,000 S/m) were totally absent. This is due mainly to the fact that all samples were a mixture of several metallic minerals.

Texture, where present, can have an overwhelming effect on sulphide conduction at the micro (grain) and meso (banding levels). Texture also generates **anisotropy** which can be readily recognised in electrical and EM measurements. Anisotropy exists when the value of conductivity depends on the direction in which it is measured. Such samples are said to be electrically anisotropic. For example, if an anisotropic mineral was cut into a cube, measurements on each of the faces would yield a different value.

The conductivities of **magnetic** rocks can be difficult to assess by inductive means, especially when electrical conductivity is low and magnetic susceptibility is high. The EM conductivity response senses both a component due to a magnetic loss process (an imperfectly understood mechanism) and another due to the ohmic characteristics. The resolution of the components requires an interpretation of response data gathered over a wide frequency range.

Galvanic determinations (with contact electrodes) of conductivity or strictly "resistivity" which is the inverse of conductivity, provide very useful auxiliary data in the EM testing of textured and/or magnetic mineralised rocks. For example, if galvanic readings are different to inductive readings on the same sample it is an indication of anisotropy. However, these procedures (see: Emerson, 1969), do not have the speed or convenience of the inductive techniques.

In summary, our experience has been that EM conductivity studies are usefully complemented by information on mineralogy, magnetic susceptibility, galvanic resistivity/conductivity and rock fabric. For mineralised rocks other than semi-massive or massive low susceptibility sulphides the significance of an EM conductivity reading requires careful consideration of these factors.

A hand-held EM conductivity meter cannot match the accuracy and range of a good laboratory bridge and induction coil system. However, the portability, convenience and rapidity of reading make such a meter a very useful and productive tool for the conductivity scanning of cores and rock faces and the selection of sample suites for thorough laboratory testing.

References

Emerson, D.W. 1969. Laboratory electrical resistivity measurements of rocks. Proc. Aust. Inst. Min. Metall., No.230, p. 51-62

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Bibliography

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