Electrocuting Rocks;

A Look Into Induced Polarization

and its Application

GOPH 559

Lawrence Lines

Eneanwan Ekpo

Safian Qureshi

ID 10086638

Contents

Summary

This paper briefly touches on the fundamentals of the Induced Polarization (IP) method and a specific type of orebody that may be located via it; porphyry copper. Induced polarization is a geophysical surveying method that involves supplying a current through the subsurface to measure electrical properties of rock that lie within. Once the supplied current is turned off, the voltage decay is measured. The voltage decay is a direct result of the overvoltage effect caused by the storing of charges within mineral grains in the subsurface. Different rocks and minerals tend to have varying ability of holding onto the supplied charge due to their specific physical and chemical properties. As such, these rocks can then be categorized by interest. One such case study is examined; locating positions of porphyry copper deposits via the IP method. In the Philippines, a fault (the Philippine Fault) exists near a subduction zone which provides voids for copper-rich fluids to crystallize. The IP method was employed in the region to reasonably locate deposits of interest.

Introduction

Porphyry deposits are large areas of hydrothermal alteration formed primarily by felsic igneous intrusions. These alteration zones assemblages often contain ore deposits; common porphyry deposits include gold, molybdenum, lead, zinc and, most concerning for this specific paper, copper. Copper porphyry deposits are comprised of a complex system of hydrothermal alteration and mineralization. There are multiple economically valuable ore deposits to be found and exploited within these zones. Exploration techniques for these deposits are diverse and involve geochemical and geophysical signatures for defining these deposits.

The IP method is one of those techniques that contributes significantly to this type of exploration. Often used cooperatively with electrical resistivity tomography (ERT) survey, the IP survey allows to create a geophysical image of the subsurface by measuring how long a rock may hold a charge. To simplify, two electrodes first generate a current passing through the subsurface which is then measured by another two potential electrodes. When the current being supplied is turned off, the potential electrodes observe a voltage difference for a certain amount of time instead of instantaneously returning back to zero as one might expect. This gradual voltage decay, a result of the overvoltage, is what is responsible for the induced polarization (or IP) effect.

Theory and Methodology

Induced polarization may be measured in two ways; with respect to time or frequency. The following steps provide a basic understanding to time domain IP;

Summary: How Time Domain IP Works

1. Current is supplied *(V)* by current electrodes, and is continuously being observed by the potential electrodes
2. Charge builds up on metallic grains
3. Current induces a potential difference in the metallic grains *(V_i) – this is the* ***overvoltage***
4. A voltage (V_T) is observed at potential electrodes *(where $V + V_i = V_T$)*
5. Current is switched off → $V_T - V = V_i$
6. V_i decays at a rate depending on the conductivity of the grain and the amount of time the grain was subjected to the current

V_i is of high interest as it tends to correlate with the properties in the subsurface geological units. It takes a while for the potential difference Vi to disperse, it being a function of time. This is measured at the potential electrodes and is defined as the 'overvoltage effect', which is the IP response.

Frequency domain IP methods are also employed which are often more commonly used. To conduct frequency domain IP, current is applied at two different frequencies (high and low) and the resulting voltage waveform is observed. A clear phase shift can be measured between the two waveforms which is then characterized as the apparent resistivity, defined as the frequency effect. These collections of varying frequency effects are observed due to the differing composition of the substrates.

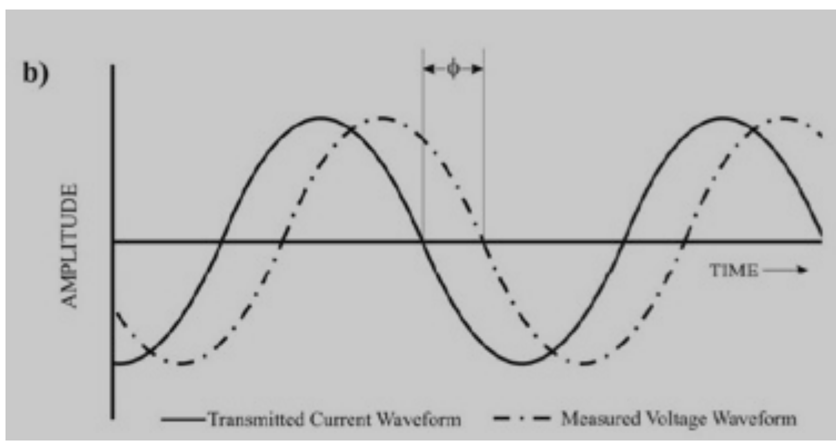

Figure 1: supplied current waveform plotted against measured voltage waveform, showing a phase shift. Phase shift is then characterized as an apparent resistivity and so different phase shifts/apparent resistivities provide insight to different rock types (Glaser, 2007).

Porphyry Copper Deposits in the Philippines

To provide preliminary context, copper porphyry deposits originate from large igneous intrusions that develop at convergent plate boundaries. As the intrusion enters into the overlying country rock, it begins to incorporate elements of the country rock into its magma and also begins to cool due to a decrease in pressure and temperature as it rises from within the Earth. The granitic intrusion continues to cool while the copper remains in solution. As the intrusion cools, it alters the rock units around it by contact metamorphism, creating zones of alteration where certain mineral assemblages develop. When the intrusion completely cools, the copper-rich solution is the only thing that remains; it begins to make its way into available fractures, fissures, fault lines or other openings within the rock and crystallizes as a copper-rich ore.

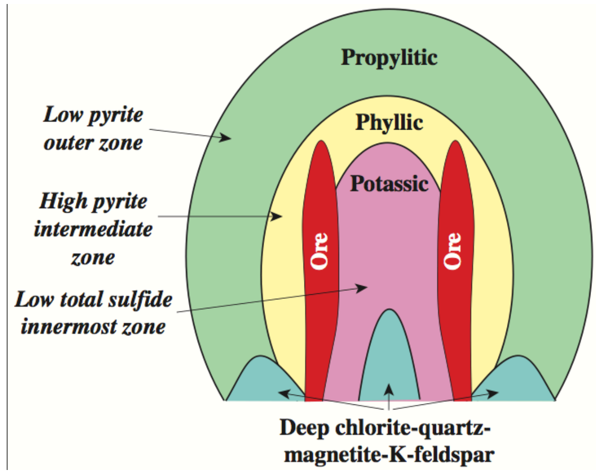

Figure 2: cross section of a porphyry copper deposit showing idealized alteration zoning (Lowell and Guilbert, 1970).

An area for potential porphyry copper deposits in the Philippines was found by noting a convergent plate boundary, subduction zone setting. Near the Philippines Fault region, it was found there were copper-rich rock units occasionally outcropped. This is indicative that the mineral targets are likely shallow and the outcrops provide an introductory reference point on where to conduct geophysical surveys.

The zoned deposits within the shallow subsurface in the Philippines were found through the use of spectral IP surveying. Spectral IP is essentially same in theory as frequency domain IP though rather than just applying two frequencies, it applies a range of frequencies from which multiple phase shifts and phase angles are produced. These phase angles are characterized like previously into apparent resistivities though are now more 'fined tuned' to the greater breadth.

Through conducting Spectral IP survey, it was found that there was an anomalous area that responded to survey with a low frequency effect. This area was interpreted as being the core of the deposit (the igneous intrusion). The potassic core would be highly resistive, corresponding to a high apparent resistivity therefore giving a low frequency effect.

The potassic core has little sulphide content, whereas the phyllic zone has high sulphide content due to the pyritization. In referring to models of zoned porphyry deposits, it is likely that the economic ore is deposited between the Potassic and Phyllic zones. These zones were given reasonable positioning due to the use of the Induced Polarization method.

Thoughts on Induced Polarization Near Term

The subset of the induced polarization method that may be lucrative is refining the Spectral IP method. By using a range of frequencies over the subsurface, resulting ranges of apparent resistivities are obtained. Studies are underway to characterize certain parameters (τ and c) in the Spectral IP equations based on the Cole-Cole relaxation model, tying them to underlying physical and chemical rock properties;

$$Z(\omega) = \rho_0\left[1 - M\left\{1 - \frac{1}{1+(i\omega\tau)^c}\right\}\right] \qquad \text{(Cole \& Cole, 1941)}$$

τ (which is a time constant) is being used to discriminate between fine and coarse-grained polarizable mineralization. Exponent c (which is a relaxation constant) is being researched as a diagnostic of the uniformity of the grain size of the target. By supplying a varied large range of frequency values in the case of Spectral IP and by performing further laboratory and field exercises, correlations between parameters c and τ are sought to specific types of ore bodies.

Conclusions

Copper porphyry deposits are prolific sources for ore exploration. IP surveys have allowed for identification of the different alteration zones within shallow depths. Using electrical current through two electrodes, voltage can be measured and used to map the subsurface based on its ability to maintain charge. This can be measured with respect to time and frequency, with each response providing information of the physical and chemical properties of the subsurface. This is a useful technique when a model has not yet been developed for a particular area, as it is able to pick up dense clusters of disseminated sulphides. After this survey, target zones can be further defined by drilling and geochemical testing. Induced polarization surveys can provide important preliminary information as well as supplementary information to build a solid model for copper deposits, as was seen in the Philippines case study.

References

Fink, James B., 1990, Induced Polarization: Applications and Case Histories, Society of Exploration Geophysicists, Tulsa, Okla.

Fu, Lei, 2011, Induced Polarization Effect in Time Domain: Theory, Modeling and Applications, The University of Utah

Morrison and Gasparikova, 2012, DC Resistivity and IP field systems, data processing and interpretation, <http://appliedgeophysics.berkeley.edu/dc/EM46.pdf> accessed on April 1, 2017

Pelton, William H. and Smith, Peter K., 1976, Mapping Porphyry Copper Deposits in the Philippines with IP, Geophysics, v. 41, no. 1 p. 106-122

Reynolds, John M., 2011, An Introduction to Applied and Environmental Geophysics, 2nd Edition, Chichester, Wiley, 712 p.

Sharma, Prem V., 1997, Environmental and Engineering Geophysics, Cambridge, Cambridge University Press, 500 p.

Toovey, L.M., 2011, Copper exploration techniques: induced polarization surveys, Copper investing news http://copperinvestingnews.com/6465-copper-exploration-techniques-induced-polarization-surveys.html > accessed on April 3rd, 2017

Toovey, L.M., 2011, Porphyry copper: the world's most valuable deposits, Copper investing news http://copperinvestingnews.com/6465-copper-exploration-techniques-induced-polarization-surveys.html > accessed on March 26th, 2017