Distribution Analysis of Sulphide Mineral (Pyrite) Using Induced Polarization Method in Libureng, Bone, South Sulawesi

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Abstract. Sulphide minerals are any member of a group of compounds of sulphur with one or more metals. Some of these sulphide minerals are economically important. This study used induced polarization method to identify distribution and mineralized zone of sulphide mineral (Pyrite), in Libureng, Bone Regency, South Sulawesi. The data processing yielded resistivity value, percent frequency effect (PPE) value, and metal factor (MF) value which were then used to produce 2-D and 3-D section model. Based on the data interpretation, an anomaly linked to pyrite deposits was seen in four trajectories with resistivity value <= 50, PFE => 3%, and MF >= 150, deposited in hydrothermal alteration zone, sericite zone.

1. Introduction
Sulphide minerals are a group of compounds of sulphur with certain substances such as metal, silver, copper, lead, zinc, and mercury. Some of these minerals are economically important in the form of ore, such as Pyrite, Chalcocite, Galena, and Sphalerite [1, 2]. The method able to detect the existence of subsurface sulphide mineral distribution is Geoelectric method. This method studies the nature of the flow of electricity in the earth and how to detect it in the earth's surface [3]. Geoelectric method consists of several methods such as method of geoelectric resistivity, IP (Polarization Index), self potential (Self Potential) and others. Induced method Polarization (IP) is a geoelectric method that is widely used in the exploration of base metals (base-metal) because of the phenomenon of polarization in a medium rock [4]. This phenomenon of polarization signifies metal content below the surface that are not detected properly when using the resistivity method [5].

Measurement and analysis of data in the form of a cross-induced polarization of 2D and 3D distribution of sulphide minerals. The data used is primary data obtained from research sites in Libureng, Bone, South Sulawesi. The main objective of this research is to create 2D and 3D cross sections based resistivity data, the data PFE and MF to identify the distribution of sulphide minerals (pyrite) [6].

Induced polarization measurements are usually made at or below a frequency of 10 Hz in order to remain in the area of non-induction. Two measurements are generally carried out namely Percent
Frequency Effect (PFE) and Metal Factor (MF). PFE is defined as the ratio between the difference in voltage at low frequencies with a voltage at high frequency is measured on the electrode voltage. FE value or PFE is a response from the existence of minerals contained in rock pores. The higher the concentration of minerals in rocks the greater the value of PFE and vice versa [7, 8, 9]. PFE value can be obtained using the following equation:

\[
PFE = 100 \frac{(\rho_2 - \rho_1)}{\rho_1}
\]

Where

- PFE: Percent Frequency Effect (%)
- \(\rho_1\): apparent resistivity measured at 10 Hz
- \(\rho_2\): apparent resistivity measured at 5 Hz

The following table shows PFE value as a reference in this study.

**TABLE 1.** PFE value for several rocks [5 & 10].

| Material                        | PFE  |
|--------------------------------|------|
| Sulphide-containing rocks      | >10  |
| Cu ore porphyry (2-10) % Sulfida| 5 – 10|
| Rocks with sulphide content 2 %| 2 – 5 |
| Volcanic Tuffs                 | 2 – 4 |
| Sandstone, Siltstone           | 1 – 3 |
| Basalt                         | 1 – 2 |
| Granite                        | 0.1 – 0.5 |

Metal Factor is defined as the amount of sulphide minerals contained in rocks, in which the amount depends on the value FE [8]. Metal factor can be formulated as follows:

\[
MF = 2\pi \times 10^5 \frac{(\rho_2 - \rho_1)}{\rho_2\rho_1}
\]

Where

- MF: Metal Factor
- \(\rho_1\): apparent resistivity measured at 10 Hz
- \(\rho_2\): apparent resistivity measured at 5 Hz

The following table shows MF value of some types of rocks

**TABLE 2.** MF value for several rocks [11].

| Material                      | PFE   |
|-------------------------------|-------|
| Massive Sulphides             | 10.000|
| Fracture – Filling Sulphides  | 1000 – 10.000 |
| Massive Magnetite             | 3 – 3000 |
| Porphyry Copper               | 30 – 1.500 |
2. Methodology

2.1 Location
This research was conducted in Libureng, Bone Regency, South Sulawesi. The following picture shows a map of the location of the study [12].

![Location of The Study](image)

**Figure 1.** Location of The Study

2.2 Data Acquisition

- Data from field measurements processed using equation (1) for the PFE value and equation, (2) to obtain the value of M.
- Apparent resistivity, PFE and MF plotted using software for 2D section,
- 3D modelling done using inversion and pseudo

3. Analysis, Interpretation and Discussion
The process of analysis and interpretation of each track was based on the apparent resistivity values, PFE and MF supported by surface geological data. The difference of the apparent resistivity values, PFE and MF is proportional to the concentration of sulphide minerals contained in a rock [5, 13]. The
The mineralized sulphide area was then determined by comparing the qualitative anomalies seen in the 2D cross section with the possibilities that exist in Table 3. Based on the table, it is generally assumed that sulphide minerals present in a rock if it has [14, 15]:

- Low resistivity value, for sulphide minerals have electrically conductive properties (conductive),
- PFE prices high, because the larger the presentation PFE value, the higher the concentration of sulphide minerals in a rock,
- High MF, because the higher the MF value, the greater the metal content in a rock.

Data processing produced resistivity values, PFE and MF which were then used to create 2D subsurface tomographic cross section in 4 lines. These 2D cross sections only show areas with resistivity values ≤50 Ωm, PFE values ≥3% and MF values ≥150 mhos / m which indicated the presence of pyrite. This area is characterized by the presence of an overlay among the three physical parameters. The four lines of each measurement have the same value for resistivity, PFE and MF. The results of the analysis of each line can be seen in the following presentation:

![Graphs](a)(b)(c)
Figure 2. (a) Overlay Between Resistivity Section, PFE and MF For Track 1, (b) Overlay Between Resistivity Section, PFE and MF For Line 2, (c) Overlay Between Resistivity Section, PFE and MF For Line 3, (d) Overlay Between Resistivity Section, PFE and MF For Line 4

Figure 2 each has line has different direction, 310° NW, 220° SW, 310° NW, and 40° SW, respectively.

The figures are an overlay between apparent resistivity cross-section, PFE and MF on each trajectory measurements. The figures show that there are six locations that showed the prospect of sulphide minerals. Layers of sulphide minerals have 0.01-100 Ωm of resistivity values, 2-5% of PFE and 3-300 mhos/m of MF, bedrock layer has > 300 Ωm of resistivity value. In each image can be seen blue-striped polygons which are the distribution of resistivity values with values ≤50 Ωm. Orange polygon is the distribution of sulphide minerals with PFE values ≥3% and polygons with black dots is the distribution of sulphide minerals with ≥150 mhos of MF / m.

The indicated area in the research location is a zone of sericite alteration. The main characterization of this zone is the emergence of intensive mineral sericite and quartz mineral alteration (secondary). This alteration zone is characterized by the emergence of minerals in the form of clay minerals, whereas secondary biotite and chlorite found in very small amounts. Sulphide minerals in this zone are dominated by pyrite whose content is growing towards the outside of this zone. The most prospective continuity of the mineralized zone is on line 1 and at the intersection of line 1 and line 2, also at the intersection of the line 2-3 and line 3-4.

Based on the analysis above, a 3D model was then made to map the prospect area of sulphide mineralization in the area, according to resistivity values anomaly, the value of PFE and the MF as shown in Figure 3. In this figure, only the area with resistivity values ≤50 Ωm, PFE values ≥3% and MF values ≥150 mhos / m is shown, which is interpreted as a zone of sulphide mineralization prospect in the study sites.
Conclusion
The conclusions drawn from this study are as follow:
- The apparent resistivity value resulted is 0.28 – 14036, range of PFE value is 0.12 – 8.5 and MF is 20.3 – 1336.
- The 2D section of the apparent resistivity, PFE and MF indicates prospective sulphide mineralization i.e pyrite.
- Sulphide minerals in this zone are dominated by pyrite whose content is growing towards the outside of this zone. The most prospective continuity of the mineralized zone is on line 1 and at the intersection of line 1 and line 2, also at the intersection of the line 2-3 and line 3-4. This condition signed based on the 3D modelling of apparent resistivity, PFE and MF, with mineral distribution direction at 310° NW indicating hydrothermal alteration zone of sericite.
- From the test results of sulphide mineral sample containing pyrite using XRF analyser, the elements contained are SO3 72.13%, 27.16% Fe2O3, P2O5 0.51%, 0.043% MnO, ZnO 0.0014%.

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