SUB-AUDIO MAGNETIC (SAM) GEOPHYSICAL TECHNOLOGY FOR MINERAL EXPLORATION AND SUBSURFACE REGOLITH MAPPING

Assoc Prof Jayson Meyers
CRC LEME, Exploration Geophysics, Curtin University of Technology,
GPO Box U1987, Perth WA 6845
meyersj@geophy.curtin.edu.au

1. SAM Methodology

SAM is an active source geophysical method that channels current into conductive sub-surface features, generating an electromagnetic field that is detected at the surface. The transmitter is a time variant electrical source using a frequency of 1 to 20 Hz, injecting 2 to 10 Amps of current into the ground over a survey area. The electromagnetic field generated at right angles to the flow of electrons is usually less than 5 nT, and is measured at surface by a very sensitive magnetometer that takes more than 200 readings per second. The part of the time varying signal relating to conductivity in the ground is called the total field magnetometric resistivity (TFMMR). Another part of the SAM signal relates to induced polarization (IP) effects, and is called total field magnetometric induced polarization (TFMMIP). Useful TFMMIP data cannot always be extracted from SAM field data, but efforts are underway to improve SAM TFMMIP data acquisition and processing. Total field magnetic data are also recorded during SAM surveying.

SAM surveys are usually carried out within a 1 by 1 km area, and transmitter current electrodes are placed along geological strike, at least 500 m from the edges of the survey area. The electrode wires and transmitter system are also set at 500 m or more from the edge of the survey area (Figure 1). Survey transect lines are oriented perpendicular to the strike of the transmitter electrodes, and transect line spacing can vary from 100 m to less than 10 m, depending on survey requirements. After data stacking and noise editing, along line sample readings become spaced at about 0.5 m to 1 m, depending on the walking speed of the field crew.

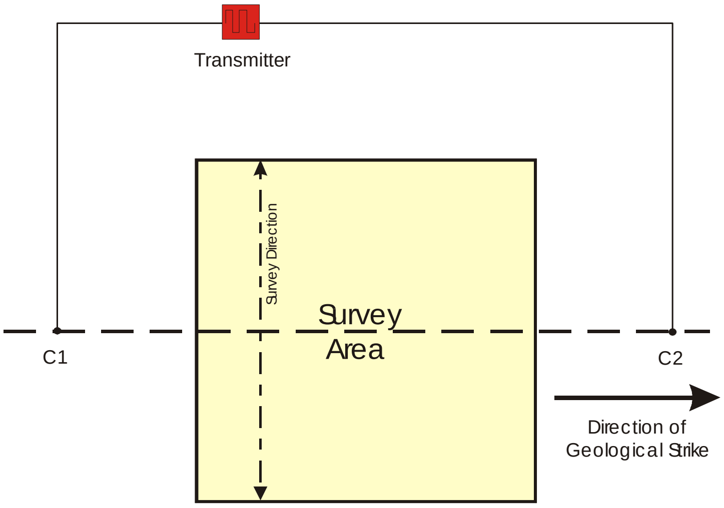

Figure 1. Typical ground layout for a SAM survey area of 1 by 1 km.

The forward calculated fields from the transmitter wire and electrodes are removed from the data, and the residual TFMMR, TMI, and TFMMIP data are gridded and imaged to show patterns relating to subsurface geology, regolith, and mineralisation. Depth information cannot be directly estimated from the TFMMR data, but the data can be treated like a monopole potential field and modeled to predict subsurface geometry of conductive sources.

2. SAM Data

The TFMMR response is provided in units of pT/A (pico-Teslas per Amp), and the subsurface pattern is very similar to apparent conductivity that can be obtained from gradient array IP surveys. The advantage that SAM has over gradient array IP surveying is that stations are collected at intervals of 1m or less, while operators walk over the ground carrying a magnetometer and DGPS. Gradient array IP stations require electrical contact with the ground, dipole receivers, and heavier equipment, which all limit station spacings to usually greater than 20 m. Therefore, SAM surveys are more time efficient, collect data at much higher resolution, are not greatly effected by bad readings, and can be run over areas where it is difficult to apply electrodes. TMI data is also provided. Furthermore, SAM TFMMR measures the relative changes in current density as a potential field, and therefore it can be used in highly conductive areas such as salt lakes, where gradient array IP will not work. A major advantage that gradient array IP surveying has over SAM is that reliable IP data can be collected, whereas the TFMMIP data generated from SAM surveying is not always reliable, and is measuring a weaker signal.

The ability of SAM to detect shallow, subsurface conductivity at such high resolution means that this technology can be used to fill the gap in survey resolution between conventional surface and airborne geophysical methods and very localised downhole and in-mine geophysical methods.

3. SAM and the Regolith

The SAM TFMMR response detects variations in current channeling in the strike direction of the transmitter electrodes, and can penetrate down to 200 m in some areas. Figure 2 shows an idealised cross section of the regolith over a gold mineralized shear zone and a steeply dipping black shale unit. Electrons flowing out of the page become channeled into more conductive regions in the subsurface, such as paleochannels, zones of deeper weathering, conductive bedrock lithologies, and conductive minerals. The amplitude of the TFMMR anomalies, and their shapes reflect information about the geometry of the subsurface conductors. Highly chargeable features, such as carbonaceous shales and sulphide deposits, may also produce TFMMIP anomalies.

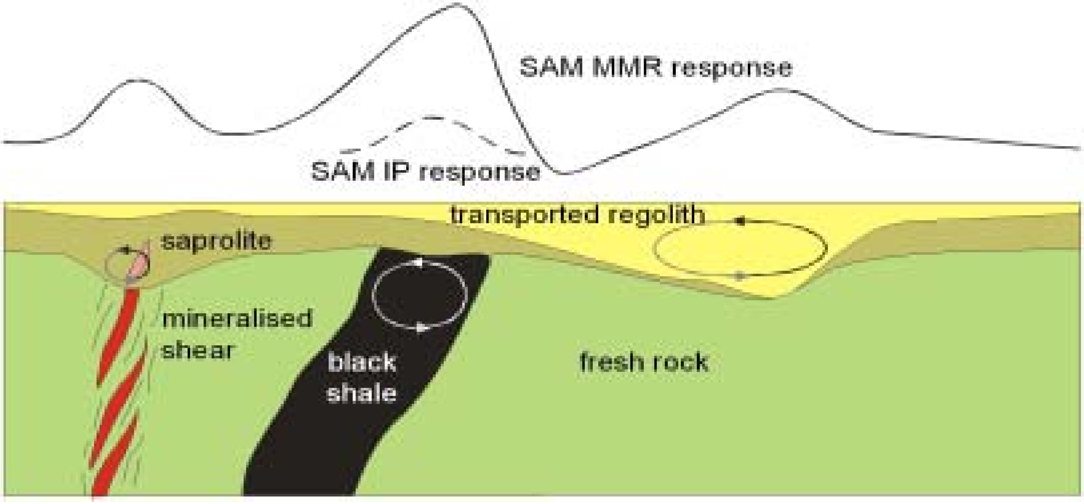

Figure 2. Schematic profile of simplified regolith and the shape of SAM anomalies expected to be caused by current channeling in conductive subsurface features.

4. SAM Case Studies

Several case studies of recent SAM surveys will be shown during the oral presentation. The SAM data in all cases are compared to other geophysical data, such as: gradient array IP, transient electromagnetics, gravity, magnetics, and downhole logging. Geology and drillhole data are also used to validate the sources of the SAM responses.

Results are shown from a number of SAM surveys collected over the same area, where different transmitter and survey line geometries produced radically different results. This includes the use of downhole transmitter electrodes to get TFMMIP images of sulphide bearing gold ore at greater than 100 m depth. Examples of geophysical interpretations using SAM and other complementary data sets will be presented to show how such high-resolution data sets can be used to greatly enhance the understanding of the subsurface geology and regolith at prospect scale. Below is a list of case studies to be presented:

4.1 Woodie Woodie Manganese Mine: The SAM TFMMR shows the location of conductive manganese ore where it is shallower than 50 m. When pods of manganese ore sit below 50 m, they are not detected in the TFMMR data, and this is likely due to current channeling being focused in the regolith above the ore bodies, and weak signal from the ore bodies being masked by the shallower regolith features.

4.2 Songvang Gold Deposit: The SAM TFMMR has identified a gold mineralised shear zone, as well as zones of deep weathering over ultramafic rocks. The TFMMR response is very similar to apparent conductivity obtained from gradient array IP surveying, but the SAM data has much greater resolution. Rotation of the SAM survey grid by 90 degrees over the same area shows radically different results, where only conductive features running sub-parallel to the direction of the transmitter electrodes become detectable, due to the preferred orientation of current channeling. Downhole transmitter electrodes were placed into the ore zone, and the TFMMIP response was recorded at the surface using 25 m line spacing. The overall outline of the ore zone is similar between the gradient array IP chargeability and the SAM TFMMIP, but there is much more of detail in the TFMMIP data. Localised TFMMIP highs were drilled and shown to correlate to increased pyrite alteration and high gold grades. Therefore, the TFMMIP and TFMMR at Songvang were useful for planning resource definition drilling (Figure 3).

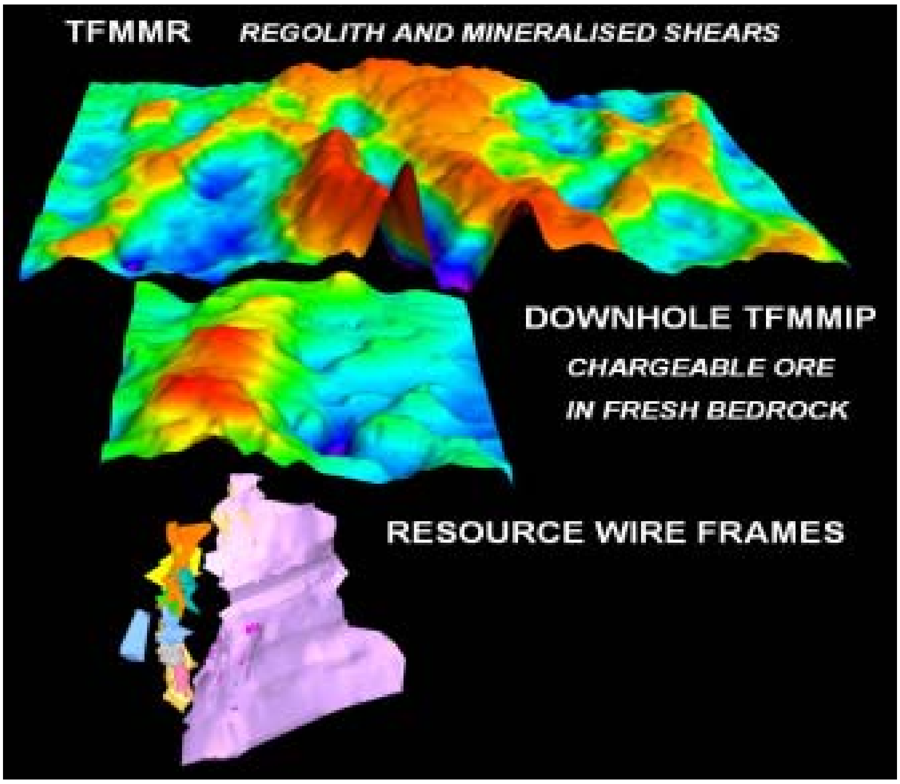

Figure 3. Three dimensional perspective of SAM responses over the Songvang gold deposit near Agnew, WA.

4.3 St. Ives Gold Mine: This is an example of how SAM can work in salt lake environments.

4.4 Indee Gold Prospect: The examples show similarities between gradient array IP and SAM results, and integrated geophysical interpretation for gold deposits in highly weathered siliciclastic sediments.

4.5 **Bogada Bore Gold Prospect:** This is an example of an integrated study using several high-resolution geophysical data sets, where differential weathering between rock types allows for geophysical detection of the regolith to help interpret bedrock geology and structures in covered and deeply weathered terrains.