Geological Mapping with Multiparameter Airborne Geophysics

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Traditionally, magnetic data have been the major airborne geophysical parameter used for geological mapping. However, the increasing quality of data from apparent resistivity and radiometric surveys has made these products much more useful for geologic mapping. These mapping parameters can be used in a complementary fashion, each adding different geologic information to the entire knowledge database.

Helicopter-borne electromagnetic (HEM) surveys have long been used to explore for mineral deposits, chiefly as anomaly detectors—looking for variations in the response due the deposit itself or the local geology associated with it (alteration). Multi-frequency HEM surveys can also map the regional geology according to its apparent resistivity, which can be a function of mineralogy, alteration state, weathering, porosity and water content.

Figure 1 shows an apparent resistivity map of a portion of a coal mine in South Africa. The coal seam is cut by diabase (dolerite) dykes, and a sill lies at a varying distance under the coal. Not all of the dykes appear on the magnetic data. The heat of the intrusions devolatilises the coal, reducing its economic value, and the hard dykes are a hazard to the coal mining equipment. Drawn on the geophysics map are the locations of the dykes and the areas of devolatilised coal (grey). The map shows a parallel pair of anomalies straddling each dyke, the dual anomaly representing the dual peak normal for coplanar coil pairs over a narrow vertical conductor. The coaxial resistivity responses show a single peak over each dyke, but are more sensitive to flight direction/strike coupling. Both data sets are collected on a normal Dighem survey.

There is excellent correlation between the anomalies and the known dykes, and there are also some previously undetected dykes apparent in the data. The non-linear resistivity highs match those locations where the underlying sill comes in close proximity to the coal (<20 m), and devolatilises the coal. Again there is good correlation to the information gained from drill holes. A Dighem survey in advance of the drilling could help design the drilling pattern, after which the drill results and the HEM data could be combined into an accurate map of the problem areas.

Apparent resistivity derived from different electromagnetic frequencies, maps the resisitivity in three dimensions. Higher frequencies are more sensitive to more resistive geology, but penetrate the earth less than lower frequencies. This can be used to produce three-dimensional maps of the resistivity structure, and the depth of penetration must be considered by the geoscientist when interpreting the data. The higher frequencies are more sensitive to the near surface, especially overburden. The lower frequencies penetrate the overburden to map the geology beneath, but are much less sensitive to subtle variations in resistivity, particularly of resistive units.

Figure 2 shows the 480-Hz apparent resistivity for a survey conducted by Dighem in Ethiopia for the Ethiopian Institute of Geological Surveys and the United Nations.

Radiometric data are sensitive to the mineralogy of the near-surface geology, and provides a powerful mapping tool for unaltered or in situ weathered geology. Figure 3 shows a ternary diagram of normalised potassium (magenta), uranium (yellow) and thorium (cyan) for a survey from the Adola area of Ethiopia. The geology overlay shows apparent contacts mapped from the radiometric data, with the rock types identified from geology maps published by the Ethiopian Institute of Geological Surveys. This combined approach demonstrates a powerful method of combining geophysical data with geologic data for mapping. The geology provides positive rock identification at spot locations (outcrops). The geophysical data can be used to extend the geologic observations to map the extents of the units.

Combining the geophysical methods enhances the interpretation beyond a simple sum of the parts. The border facies of the Gariboro massif (Bgg), a granite gneiss, shows a similar radiometric response to the graphitic schist/quartzite unit (Grs), but the graphitic schist unit is clearly much more conductive on the resistivity map. Conversely, the granites (Gg) and biotite gneisses (Bg) are indistinguishable on the resistivity map, but definitely appear different on the radiometric survey. The olivine basalt is mapped by both the resistivity (lower resistivity) and by the radiometrics (high thorium).

The geoscientist must consider what parameters the geophysical survey is mapping, and how these relate to geology. While a unit may be mapped as consistent by a geologist, such processes as alteration or regional variation in degree of metamorphism can affect the resistivity and so change the appearance of the unit on a geophysical map. Alteration and selective leaching can remove the radioelements from the near surface, affecting the radiometric response. Accurate geologic description of the rock is necessary to fully define the responses measured.

In "Proceedings of Exploration 97: Fourth Decennial International Conference on Mineral Exploration" *edited by* A.G. Gubins, 1997, p. 865–868

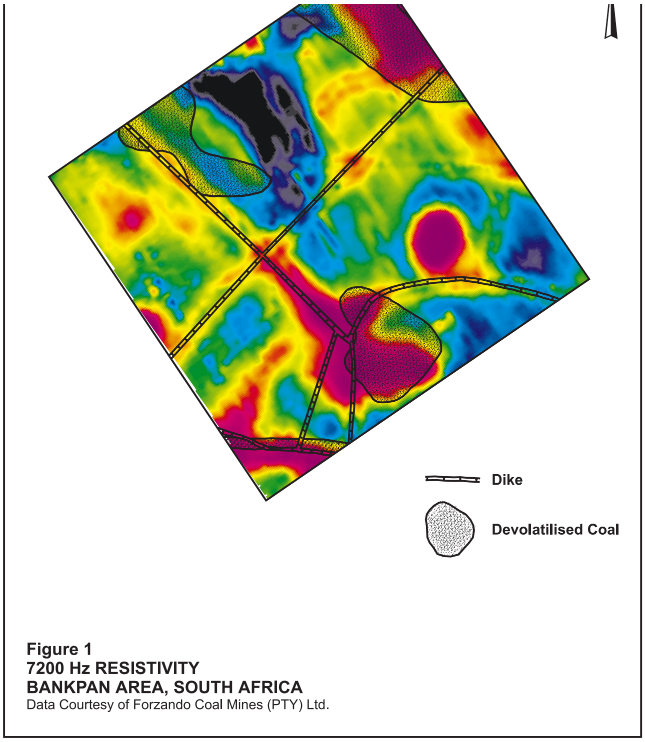

Figure 1: *Apparent resistivity over a coal mine in South Africa.*

This can be demonstrated by the Kenticha formation (Kn—described as a mica schist with frequent garnet and staurolite gneiss) in the east block of the radiometric data. In the central portion of this block the Kenticha shows as a strong potassium (magenta) source, when in the north end of the east block the geology mapped as Kenticha is proportionately higher in thorium and uranium. There is clearly a difference between the two areas of the same formation, which can be used to further define the lithology.

The quality of the data is continually improving due to improvements in instrumentation technology, and data processing. The data processing advances are created through development of more accurate reduction algorithms and processing models, facilitated by dynamic advances in computer software and hardware.

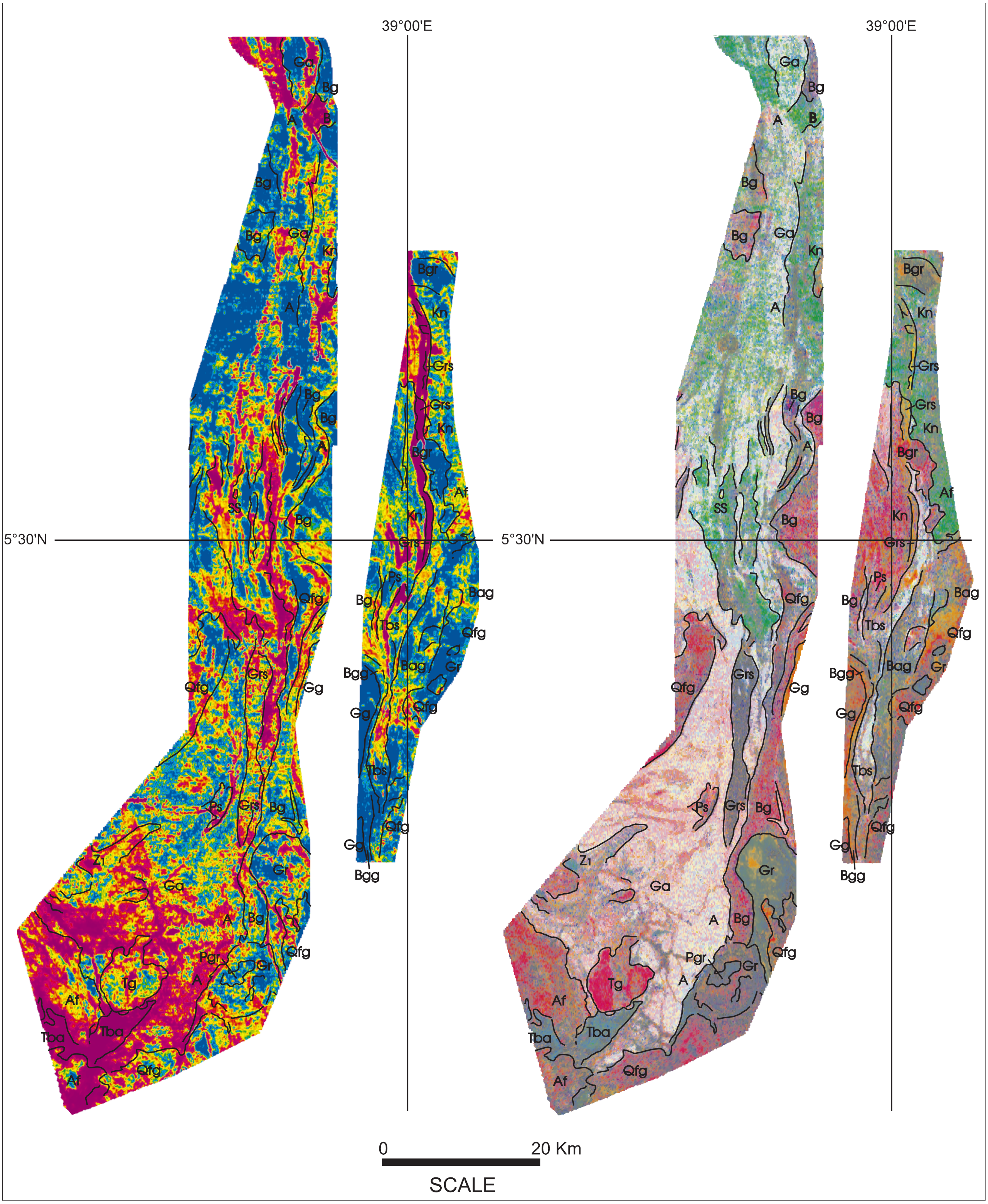

Figure 2
480 Hz APPARENT RESISTIVITY
Data Courtesy of EIGS

Figure 3
RADIOELEMENT - TERNARY
Data Courtesy of EIGS