Introduction

The Baomahun deposit in Sierra Leone is likely to become one of the country's first modern gold mines. With open pit mineral reserves of 23.27 Mt at 1.62 g/t equivalent to 1.21 Moz gold, mining is scheduled for an 8-year period, with processing continuing for a total life of mine of 11.5 years (Amara Mining, 2013).

Naturally, there has been significant interest in exploring adjacent areas for similar deposits. After commissioning a magnetic/radiometric survey to understand regional geology, Cluff Gold accepted a recommendation from Reid Geophysics to use VTEM for direct targeting of sulphide-hosted gold mineralization.

Geology

Most of Sierra Leone is underlain by rocks of Precambrian age (Archaean and Proterozoic) with a coastal strip about 50 km in width comprising marine and estuarine sediments of Tertiary and Quaternary to Recent age. The Precambrian (mainly Archaean) outcrops cover about 75% of the country and typically comprise granite-greenstone terrain (Figure 1). The greenstone belts are the principal hosts of the gold mineralisation of the country (from Sierra Leone Supplement, Mining Journal Feb 2003).

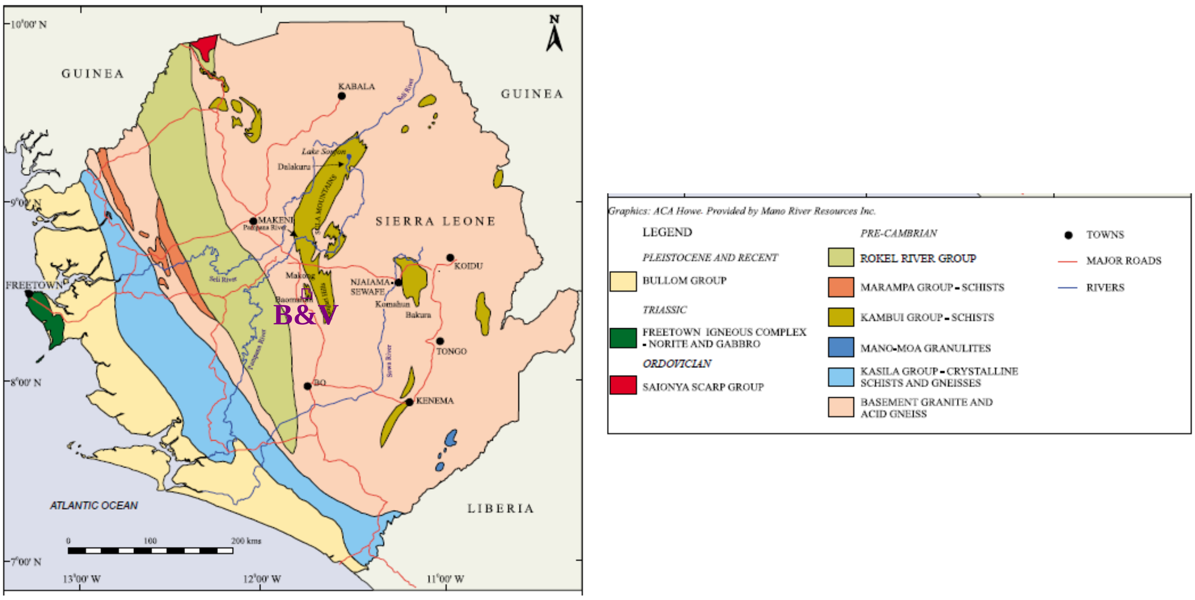

Figure 1: Geological map of Sierra Leone showing approximate location of Baomahun and Victoria project areas (geology from Sierra Leone Supplement, Mining Journal Feb 2003)

The Baomahun deposit is associated with folds transected by a number of faults and shear zones. It comprises a series of steeply dipping zones of sulphide mineralisation in the form of pods and lenses which trend approximately north-northwest along the slopes of the southern limits of the Kangari Hills. The zones which outcrop on the slopes pinch and swell within short distances (50 to 100m) and are associated with sulphide minerals such as pyrrhotite and arsenopyrite in the non-oxidised zone.

The mineralisation identified to date occurs preferentially in the immediate footwall and hangingwall zones of BIF units which are separated by a series of garnet-mica and quartz-mica schists and which vary from a few metres to 40m in thickness (SRK Consulting, 2008).

The dominant magnetic responses in the survey area can be attributed to magnetite in the BIF sequences as well as pyrrhotite, while the most conductive responses would be expected to correlate with pyrrhotite veins.

In summary, the geological model of mineralization was pyrrhotite-hosted gold closely associated with BIF and preferentially concentrated in steeply-plunging fold noses. Thus, the choice of geophysical survey techniques was not particularly difficult.

Airborne geophysics

From 3 to 6 January 2005, Fugro Airborne Surveys flew a MIDAS heliborne magnetic and radiometric survey across the Baomahun and Victoria project areas to identify regionally significant trends which might be controls on mineralization. The MIDAS system deploys two caesium vapour magnetometer sensors on a lateral boom, to measure the cross-line magnetic gradient and use it to improve the resolution of the magnetic total field gridding. Radiometric data are recorded using an Exploranium GPX 256 with a 1024 in^3 downward-looking crystal pack.

From 3 to 19 May 2010, Geotech Airborne flew a VTEM heliborne electromagnetic and magnetic survey across much of the Baomahun and Victoria project areas to identify favourable gold exploration targets and site exploration borehole locations. The VTEM system collects time domain electromagnetic data using a coaxial transmitter-receiver loop suspended approximately 34m below the helicopter. Magnetic data are collected using a caesium vapour magnetometer sensor suspended approximately 11m below the helicopter.

Survey parameter	MIDAS (2005)	VTEM (2010)
Flight line direction	090° - 270°	045° - 225°
Flight line spacing	100m	75m
Tie line direction	000° - 180°	135° - 315°
Tie line spacing	1000m	750m
Nominal terrain clearance	20m (magnetometer boom)	46m (EM loop)
Line kilometres	1592 km	1660 km

Table 1: MIDAS and VTEM survey parameters

Interpretive processing

Radiometric data collected by the MIDAS survey are shown in Figure 2a as an RGB ternary image. The radiometric data are clearly imaging gross changes in lithology, and display some cross-cutting structural features that are not obvious in the corresponding magnetic dataset.

Magnetic data were processed to facilitate mapping of lithological boundaries and structural features. Because of the survey area's low magnetic latitude (IGRF field inclination is -7.7°), reduction to the pole filtering is somewhat unstable, and was rejected in favour of a combination of vertical integral and analytic signal filtering of the total magnetic intensity. Magnetic lineaments traced from this and subsequent filtering operations are shown in Figure 2b.

Electromagnetic data were subjected to several processing techniques to assist with target selection:

- Decay curve analysis - to calculate decay constants
- Profile plots - to pick discrete anomalies
- Plate modelling - to model discrete anomalies
- Conductivity depth imaging - to produce sections, slices and voxets

Contoured EM decay constants are shown in Figure 2c.

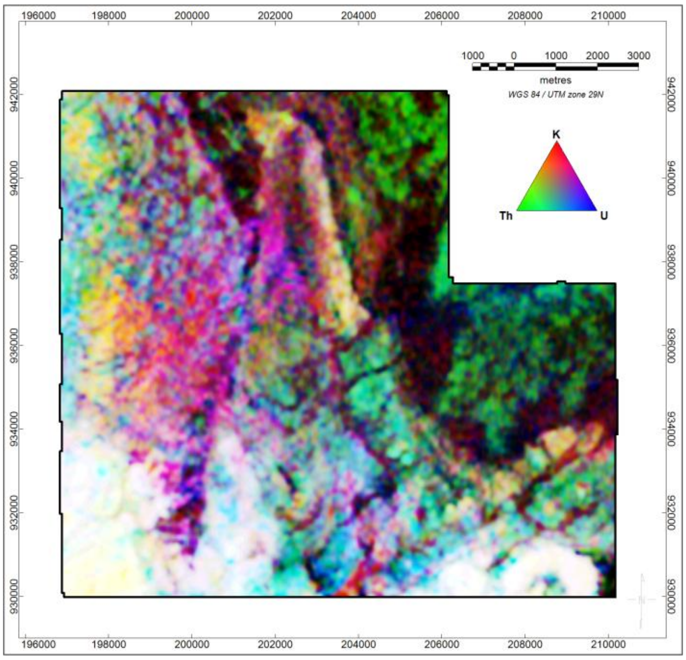

Figure 2a: Radiometric RGB ternary image (red = potassium, green = thorium, blue = uranium)

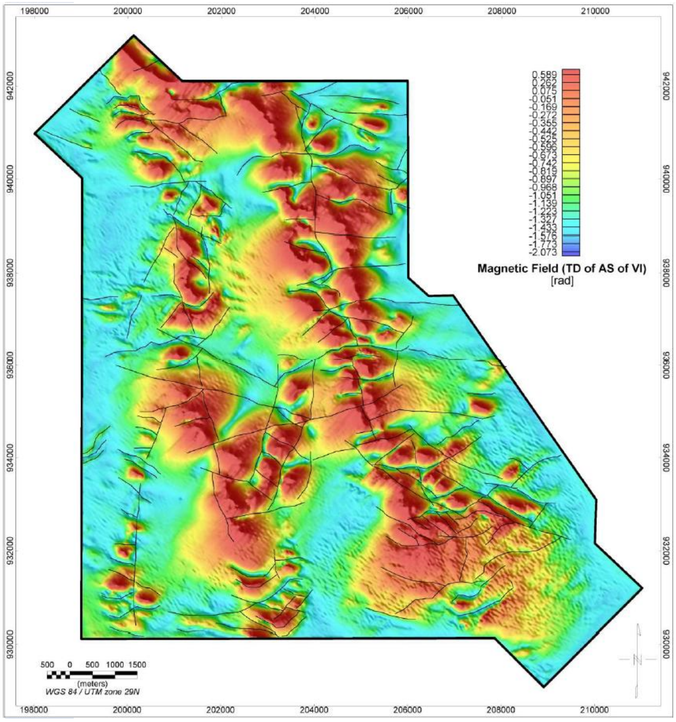

Figure 2b: Interpreted lineaments superimposed on the magnetic data

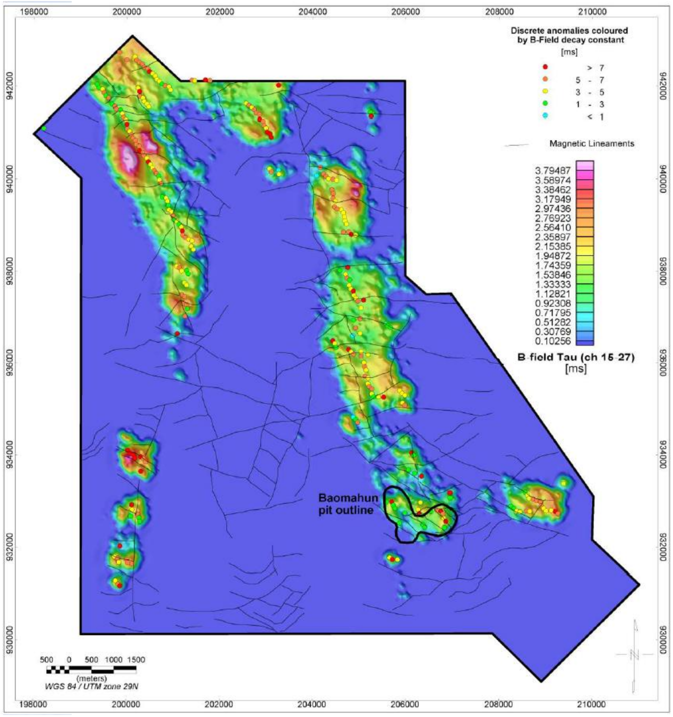

Figure 2c: Contoured EM decay constants for B-field data (channels 15 to 27). Conductor anomaly picks, magnetic lineaments and the Baomahun pit outline are superimposed.

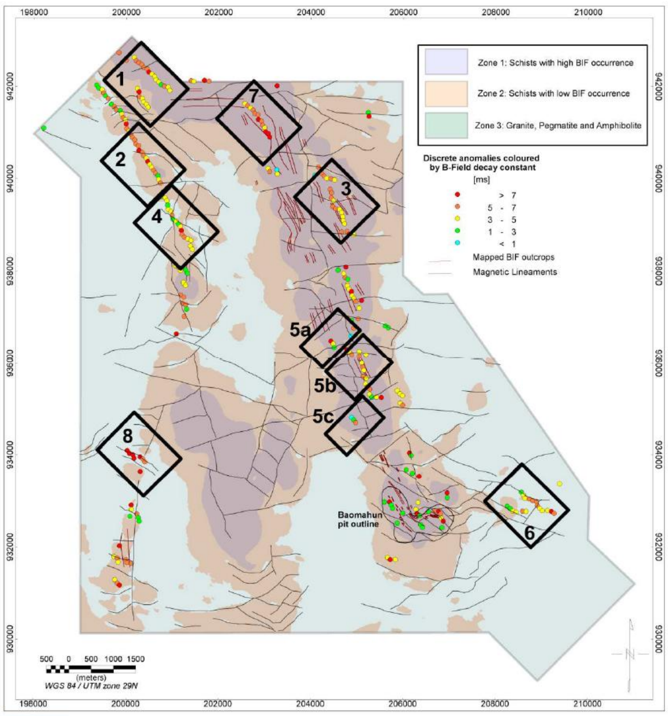

Figure 2d: Target zones, discrete EM anomalies picked from profiles, magnetic lineaments and interpreted geology (based on analytic signal of the total magnetic field compared with BIF outcrops)

Target selection

Selection of exploration targets was based on the geological model of mineralization summarised above and its expected geophysical expression. The measured geophysical response over the existing Baomahun deposit was also incorporated as a key indicator. Complementary geo-scientific information (soil geochemistry and field mapping) were included and used to prioritise geophysical targets.

The following indicators were applied for defining and prioritizing target zones:

- High magnetic susceptibility to indicate BIFs, and specifically zones associated with folding or discontinuities
- High conductivity values to indicate presence of massive pyrrhotite, although medium to lower conductivities (due to more disseminated sulphides) should not be completely disregarded. In fact, the Baomahun deposit maps as a sequence of small, moderate conductors.
- Elevated arsenic and/or gold soil geochemistry values
- Artisanal mining activities in close proximity

Using the above indicators, eight target zones were selected for follow up drilling and/or ground survey programmes. These target zones are summarised in Figure 2d.

Conclusions

MIDAS and VTEM surveys were used to identify regionally significant trends and generate targets for gold exploration respectively in the vicinity of the Baomahun deposit in Sierra Leone. Targeting took account of indicators provided by known mineralisation, geological field mapping, soil geochemistry and artisanal mining activity.

In areas that are highly prospective, but poorly explored and/or inaccessible on land, airborne geophysics can be extremely effective in generating compelling targets for further investigation.

In December 2010, Cluff Gold announced a "targeted and accelerated 6,000m diamond drilling programme" focusing on seven of the eight VTEM target zones presented in this paper (Cluff Gold, 2010). The fish were in the barrel; now it was time to find out whether they could be shot.

Acknowledgments

Permission from Perseus Mining to publish this case study is gratefully acknowledged. Reid Geophysics carried out the interpretive processing of the MIDAS survey and Geotech Airborne carried out the interpretive processing of the VTEM survey. The authors have freely included material from both of the resulting reports in this presentation.

References

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SRK Consulting [2008] Technical Review of the Baomahun Gold Exploration Project, Sierra Leone. NI 43-101 Technical Report.