The Use of Gravity and Magnetic Data to Unravel Structures: The Forecariah Magnetite Mineralisation

M. LACORDE[1], B. DE WAELE[1], N. HANNA[2] and S. MONOURY[1]

Introduction

The Forecariah iron prospect is located in the south-western part of Guinea, near the border with Sierra Leone, Africa. Iron-bearing quartzites were first reported in the area by Russian mapping teams after independence in the nineteen sixties, including the nearby Yomboieli deposit. Limited detailed mapping and sampling were carried out by Millimono in 1977 and highlighted four 30 to 400 m-thick horizons of quartzites with iron grades ranging 36.36 to 61.32% Fe_2O_3.

SRK Consulting was requested by the prospect owners to assist in exploration targeting, exploration programme design, and to provide structural mapping and interpretation of the iron mineralisation.

This abstract summarises how geophysical methods and detailed structural and geological mapping, along with results from diamond drilling, were combined to determine the position and geometry of the identified iron occurrences.

Regional Geology

The project area is located along the western margin of the West African Craton (WAC) in the northern portion of the Rokelides Belt, in south-western Guinea. The Rokelides Belt stretches from western Guinea to northern Liberia, and developed in response to the collision between the WAC and the Amazonia Craton during the Neoproterozoic. In Sierra Leone, the Belt comprises four tectono-stratigraphic units: the Kasila Group, the Kenema Assemblage, the Marampa Group and the Rokel River Group (Allen, 1969). Known iron deposits within the Rokelides Belt include the Yomboyeli and the Marampa (1.078 Gt @ 31.26% Fe indicated and inferred resources, *Intierra*) mines, in Guinea and Sierra Leone respectively.

The Forecariah prospect is situated within the Forecariah Group equivalent to the Kasila Group in Guinea. The Forecariah Group is a paragneiss sequence, sub-divided into four formations including the Kissi-Kissi Formation which hosts the iron-bearing quartzites. It is mainly composed of schist, amphibolite, biotite-hypersthene gneiss and ferruginous quartzite for the lower part, and of biotite- and biotite-amphibole gneiss for the upper part (after Nikoulchine and Zoubstov, 1968). On a regional scale, the rocks are steeply dipping west to south-west, and are oriented as NNW-trending units.

Results from Detailed Mapping

Detailed structural and geological mapping was undertaken by SRK, focusing on the iron-bearing formations. No S_0 fabric is evident, although NNW-SSE-trending magnetite-bearing quartzites (Figure 1) display a metamorphic banding (S_M) defining a steeply west-dipping foliation, interpreted to have developed during D_1. S_2 foliation is observed in outcrop, and is interpreted to have developed in response to tight upright F_2 folding during D_2. This deformation event may be related to late Rokelides orogeny. Pinch-and-swell structures were also recognised along continuous outcrops.

Intersection lineations ($L_{M/2}$) parallel interpreted NE-SW trending regional fold axes, and are shallowly plunging towards the north and south, suggesting large open refolding (D_3 tectonic event, NNW-SSE compression).

Figure 1: Close-up of a coarse-grained magnetite-bearing partly oxidised quartzite

1. SRK Consulting Australasia, Level 1, 10 Richardson Street, West Perth, Western Australia, 6005, Australia. Corresponding author: mlacorde@srk.com.au
2. SRK Consulting Australasia, Sydney

Results from Airborne Geophysical Survey

A high-resolution helicopter-borne geophysical survey was conducted over the most prospective portions of the tenement (spacing of 100 m with infill lines spaced at 50 m) in order to identify the magnetite-bearing formations and help design an exploration programme. Raw magnetic data were processed to identify areas with high magnetic responses, which may represent the magnetite-bearing formations and assist with the geological interpretation. A 5 km-wide and 20 km-long zone of high magnetic response is shown by the survey and is coincident with outcropping magnetite-bearing formations.

Unconstrained magnetic inversions were carried out on the raw data to provide a better understanding of the geology at depth. As the magnetic contrast between magnetite-bearing formations and country rocks was strong, the inversions provided a good first-pass indication of the general structure of the area. In the most probable model, the magnetic bodies formed a series of steep F_2 folds in a possible antiformal structure with refolded axial planes. The model, however, suggested that the eastern limb of the antiform dipped towards east which was in contradiction with field observations that indicated an overturned west-dipping fold geometry.

Based on the magnetic and radiometric survey and the field mapping, a geological and structural map of the tenement was produced.

Results from Diamond Drilling

A diamond drilling campaign was conducted in areas where high magnetic responses corresponded to outcropping iron-rich formations. The drilling program assumed locally-tabular magnetic bodies steeply dipping towards the west. The magnetite-bearing rocks intercepted in the drillings were different in nature from the formations observed at the surface. At depth, magnetite-quartz-hornblende rocks were intersected, whereas magnetite-bearing quartzites are observed at the surface (Figure 1). The difference is likely to be explained by the weathering of the amphiboles and a more siliceous nature of outcropping rocks.

Drilling also showed that magnetite-bearing formations were thinning at depth. A new geological model was proposed involving the concentration of magnetite along the hinges of regional steep folds resulting in elongated "boudins" of magnetite and thinning of the iron mineralisation in the limbs, as well as structural thickening of iron mineralisation in the hinge zones.

Results from Ground Gravity Survey

A high resolution ground gravity survey was designed to help identify the densest mineralised bodies, including hematite-bearing formations, which cannot be detected by the magnetic survey. The two most prospective areas, as based on mapping and airborne survey, were covered by the survey. After processing and corrections, a complex Bouguer density of 2.67 g/cm^3 was chosen for modeling

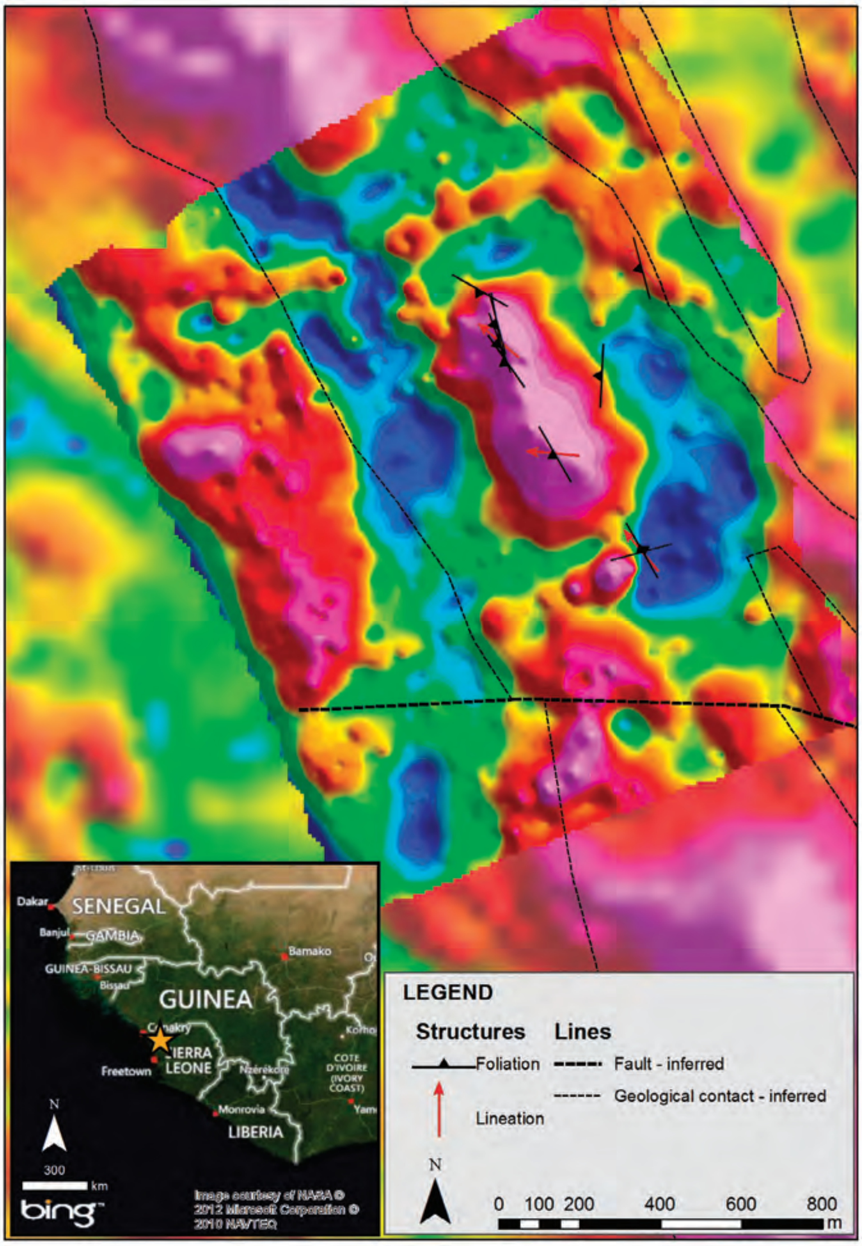

Figure 2. Residual complex 2.67 g/cm^3 terrain-corrected gravity anomaly over the airborne magnetic survey (analytical signal). Structural measurements are displayed and show west-dipping foliations and NNW-trending lineations

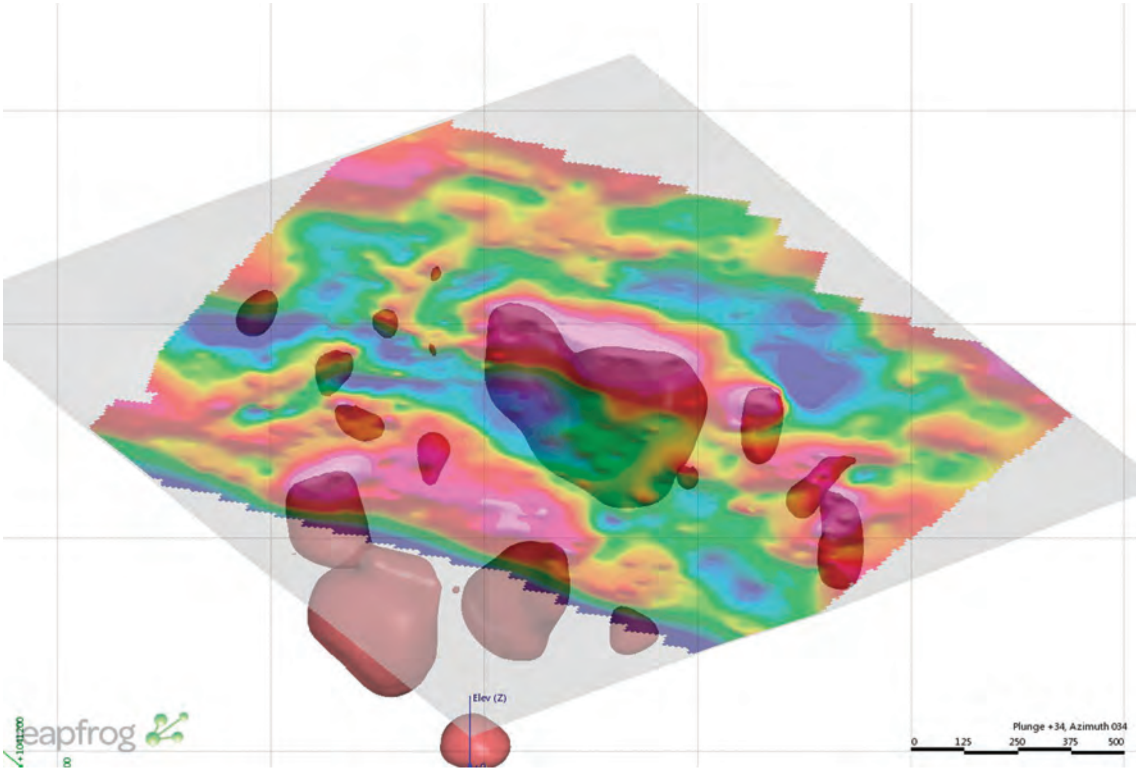

Figure 3: Results of the 3D inversion compared to the map of residual complex gravity anomaly

and interpretation. In both areas, the gravity response is discontinuous and trending NNW-SSE and coincident with a high magnetic signature (Figure 2). A few gravity anomalies are not associated with magnetic highs and are likely to correspond to biotite-hypersthene gneiss whose density is close to low-magnetite content rocks.

The discontinuity of gravity response along strike of the main magnetic highs can be explained by the later D_3 folding event with a wavelength of 1-2 km, parallel to the main NNW-SSE trend, and resulting in locally deeper dense bodies.

Unconstrained 3D gravity inversion modeling was conducted to further constrain the structural model. Downhole densities were averaged for each lithological unit and the magnetite-quartzite unit had the highest average density of 3.82 g/cm^3. The highest density portions of the inversion model were therefore assumed to be magnetite-quartzite and the model has highlighted the discreet nature of the mineralised pods.

Interpretative Structure of the Occurrences (3D Model)

A final geological model was proposed. The mineralisation is mainly constituted of magnetite-rich quartz-amphibole banded rocks (D_1) as highlighted by the magnetic survey. The magnetic bodies are elongated and concentrated along the hinges of tight upright folds (D_2) with attenuation of mineralisation in the limbs, as shown by the drilling. They are discontinuous and form pods of magnetite-rich formations. A later D_3 folding event resulted in the relative burying of the dense pods and explains the discontinuous gravity response. It is consistent with the double-plunging lineations observed on the outcrops.

This example highlights how magnetic and gravity data can be processed and modeled to determine the structures of magnetite occurrences. However, it also shows that any geophysical model needs to be constrained by lithological and structural field observations either from the surface or from core.

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References

Allen, P.M., 1969. The geology of part of an orogenic belt in western Sierra Leone, West Africa. Geologische Rundschau, 58: 588-620.

Bouféev, Y.V.; Kriatov, B.M.; Maxtenek, I.O.; Mitiaev, A.G.; Slédine, L.N.; Prokophiev, S.S.; Cherbakova, I.P.; Nikoulchine, M. and Zoubstov, E. 1968, Notice Explicative de la Carte Géologique de la République de Guinée, échelle 1:200,000, Feuille C-28-XXIII et secteur Nord de feuille C-28-XXIX,182p.

Millimono, T. 1977, Géologie et géochimie des quartzites ferrugineux de Forécariah (Sambalama – Kalyadi), Thèse, Institut Polytechnique Gamal Abdel Nasser, Conakry, 139p.

Nikoulchine, M. and Zoubtsov, E., 1968. Notice Explicative de la feuille Conakry. Carte Géologique de la République de Guinée. In: E.G. Soviétique (Editor)