From a Mining Mindset to Regional Discovery: A Case Study for Hematite Iron Ore Exploration in Mauritania

Bert De Waele
SRK Consulting
L1, 10 Richardson Street, West Perth
bdewaele@srk.com.au

Alex Aitken
SRK Consulting
L1, 10 Richardson Street, West Perth
aaitken@srk.com.au

Michael Van Mourik
SRK Consulting
L1, 10 Richardson Street, West Perth
mvanmourik@srk.com.au

Khalifa Oul Laab
SNIM
BP 42 Nouadhibou, Mauritanie
khalifa.laab@snim.com

Mohamed Elhacen Ould Med Yeslem
SNIM
BP 42 Nouadhibou, Mauritanie
melhacene.myeslem@snim.com

Thiam Mohamedou
SNIM
BP 42 Nouadhibou, Mauritanie
tmohamedou@snim.com

SUMMARY

There has been extensive mining for hematite mineralisation in Mauritania since the 1950s, focused on the Kediat Ijil and Mhaoudat regions in northern Mauritania. These discoveries were largely made during the colonial period, with only limited additional discoveries in more recent years.
In an effort to allow the discovery of additional hematite mineralisation in the district, the Société Nationale Industrielle et Minière (SNIM) has obtained regional airborne VTEM and magnetic data and has tested a variety of ground-based geophysical methods on and near existing mineralisation.
A re-interpretation of these datasets alongside structural mapping on the ground has allowed the development of a series of conceptual models for targeting high-grade hematite mineralisation, and the development of suitable exploration strategies to locate the next generation of prospective hematite iron ore mines to develop into the future.

Key words: iron ore, VTEM, magnetics, structural mapping, hematite.

INTRODUCTION

Iron ore deposits in Mauritania are hosted in BIFs that have been ascribed to the Archaean in the Tiris Complex, and the Palaeoproterozoic in Kediat Ijil, Mhaoudat and Sfariat, which make up the western part of the Archaean-Palaeoproterozoic Rgeibat Shield of West Africa. The deposits identified in the Tiris Complex invariably are dominated by magnetite and have typical grades between 30 and 35% Fe, while the deposits identified in Kediat Ijil and Mhaoudat are enriched in hematite and can attain grades of between 56 and 68% Fe (referred to as Hematite Iron Formation (HIF) henceforth). The upgrade of Banded Iron Formation (BIF) protore to HIF happens through natural processes of dissolution and removal of silica and oxidation of magnetite to hematite, either involving hypogene-hydrothermal fluids or supergene waters, or a combination of both.
HIF has been mined in Mauritania since 1952 from Kediat Ijil and Mhaoudat, but depletion of easily-mined high-grade ores has recently led to the development of magnetite projects in BIFs of the Tiris Complex. The latest discovery of HIF in Kediat Ijil is the deep TO14 orebody in the southeastern part of Kediat Ijil, which was identified below Neoproterozoic-Cambrian cover of the Taoudenie basin by drilling for water.
Exploration at Kediat Ijil and Mhaoudat has since been limited to drilling of mineralisation at surface, mostly mapped in the 1980s (Bronner, 1992).
This paper presents the results of the interpretation of regional airborne geophysical datasets (VTEM and magnetics), ground magnetic data and structural mapping across Kediat Ijil and Mhaoudat to assist in the development of an exploration strategy to identify blind hematite mineralisation in the region.

LOCAL GEOLOGY

Both Kediat Ijil and Mhaoudat are considered to be allochthonous units, structurally emplaced within or on top of the Archaean Tiris Complex.

The Tiris Complex is composed of granites, gneisses and schists, metamorphosed to upper amphibolite and granulite facies, and linear segments of magnetite BIF.

At Kediat Ijil, five formations have been identified, from bottom to top these are the Zouérate, El Hamariat, Tazadit, Achouil and El Hadej formations, which are structurally overridden by a thrust nappe entirely composed of silicified conglomerate with fragments of the underlying formations and interpreted to be a syn-tectonic olistostrome deposit (Figure 1). BIF occurs within the El Hamariat, Tazadit and the base of the Achouil Formation, but is most extensive in the Tazadit Formation. The Tazadit formation has been subdivided into a more rhythmic lower member and a more massive upper member, the latter hosting the majority of hematite mineralisation. The entire Kediat Ijil thrust stack has been interpreted to be structurally emplaced upon Tiris Complex, but the basal tectonic contact is covered by extensive scree.

At Mhaoudat, the entire sequence is comprised of BIF, which appears to form a tectonic slice within the older Tiris Complex. The structural contact can be observed in several open pits, and presents a complex set of structurally interleaved BIF and schist slices, retrogressed to greenschist facies.

GEOPHYSICAL INTERPRETATIONS

Several datasets were used in regional interpretation. Regional magnetic and radiometric datasets were acquired in 2003 by Fugro with a line spacing of 700 meters and terrain clearance of 100m above the terrain (PRISM dataset). SNIM also commissioned a heliborne VTEM and magnetic dataset by

Geotech in 2007, using a line spacing of 100 meters and average terrain clearance of 100m for Kediat Ijil and 70m for Mhaoudat (Geotech dataset). A series of ground geophysical campaigns were also conducted on known mineralisation in Kediat Ijil and Mhaoudat, in order to test the suitability of magnetics, gravimetry and Induced Polarisation (IP) to identify hematite mineralisation (SNIM datasets).

PRISM datasets were reprocessed using Geosoft and mosaics to form a single set of grids covering the entire study area. The Geotech data was likewise re-processed and forms a higher resolution overlay on the regional PRISM data (Figure 1). The magnetic data clearly identify the main BIF-dominant Tazadit unit along the northern and eastern boundary of Kediat Ijil. The unit can be subdivided into a more magnetic lower units (the Lower Tazadit Formation) and a less magnetic upper unit (the Upper Tazadit Formation). Local magnetic highs in the Seyala Formation correspond to known mineralised pods, here interpreted to be megalithons of BIF (presumably derived from the Tazadit unit).

The VTEM data over Kediat Ijil show a high response across the Tazadit unit, as well as along important regional faults (Glat El Bil Fault). A depth slice at 200m also shows a high response below the scree to the north and east of Kediat Ijil interpreted to reflect the presence of BIF in the underlying El Hamariate and Zouérate formations. There is also a high response in the eastern part of the Seyala Formation, which is interpreted to reflect thinning of the non-conductive Seyala thrust slice in the east.

A limited ground gravity survey and magnetic survey were conducted in the southern part of Mhaoudat, and clearly demonstrate the presence of BIF units, juxtaposed by regional faults. Whereas the magnetic data fail to clearly distinguish between Archaean BIF of the Tiris Complex, and Palaeoproterozoic BIF of the Mhaoudat Formation, the gravity data appear more successful. Ground gravity and magnetics appear to be a feasible approach to help define targets at Mhaoudat. At Kediat Ijil, the terrain is too severe to allow the easy collection of ground gravity data, so an airborne gradiometry survey is contemplated to provide a regional dataset for interpretation.

STRUCTURAL MAPPING AND MINERALISATION MODELS

Reconnaissance structural mapping in the open pits and along the strike-continuation of known hematite mineralisation, as well as along critical sections across the Tazadit and Seyala formations, has demonstrated the presence of hematitised BIFs as stratiform units within the Upper Tazadit Member, close to the contact between the Lower and Upper Tazadit members. This mineralisation attains considerable depth and has been intersected to 400 meters below surface, remaining open at depth in the F'dérik, Tazadit and TO14 open pits. The continuous nature of this mineralisation along the contact between the Lower and Upper Tazadit members strongly suggest a structural control of mineralising fluid movement along this interface. Geochemical work on BIF's of the Tazadit Formation by Taylor et al. (2016) indicates enrichment of HREE over LREE of HIF when compared to inferred protore BIF, suggesting the involvement of high-salinity hydrothermal fluids with temperatures between 200 and 400°C with the capacity to effectively transport LREE over HREE during mineralisation.

In addition, smaller mineralised units have been recognised higher up in the sequence, and in close proximity to the basal thrust of the Seyala Formation and to the Glat El Bil Fault. This mineralisation appears to be dominated by larger specularite hematite and controlled by cross-cutting fractures. In places, schistose specularite hematite-dominant mineralisation appears to be controlled by moderately plunging fold hinges within the Tazadit units. We consider those mineralised units to be structurally-controlled and hydrothermal in character, associated either with fractures and faults, or with low-strain zones and fold hinges.

The mapping clearly defined a weathering profile superimposed on the mineralisation, with formation of hematite and goethite down to moderate depths (<50m).

CONCLUSIONS

A reinterpretation of regional airborne VTEM and magnetic datasets, together with ground geophysical data (gravity, magnetics and IP) and evaluation of existing drill hole data, as well as a targeted structural mapping campaign over targets developed during a desktop review, have identified a variety of structural controls to hematite mineralisation in Kediat Ijil and in Mhaoudat.

At Kediat Ijil, hematite mineralisation appears to be controlled by the conformable contact between the more permeable Lower Tazadit Member, and the less permeable and more competent Upper Tazadit Member. Even though localised mineralisation occurs higher up in the sequence, the thickest units are located within 100 meters of the Lower/Upper Tazadit interface. The Upper Tazadit is interpreted to have acted as an aquitard to mineralising fluids driven up during thrusting of the entire Kediat Ijil klippe, thereby focusing mineralisation along and close to the contact.

Smaller, more shallow hematite mineralisation appears to occur below the basalt thrust of the Seyala Formation. This mineralisation appears to cross cut stratigraphy and is interpreted to be hydrothermal in origin, with formation of specularite hematite as well as microplaty hematite along fractures.

Small pods of mineralisation occur within the conglomerates of the Seyala Formation, which structurally overlies the rest of the Kediat Ijil succession. These are interpreted to represent megalithons of mineralised Upper Tazadit that were preserved within the Seyala Formation, which itself is interpreted to be an olistostrome developed during active thrusting.

At Mhaoudat, hematite mineralisation appears to be developed within BIF of the Mhaoudat Formation, which has been structurally emplaced within the older Tiris Complex. The bounding faults are inferred to be the fluid pathway along which mineralising fluids have percolated within the Mhaoudat BIF, resulting in the development of stratiform hematite along the BIF. Mineralisation also occurs within the older BIF's of the Tiris Complex, but rarely reaches the high-grade typically associated with the Mhaoudat mineralisation.

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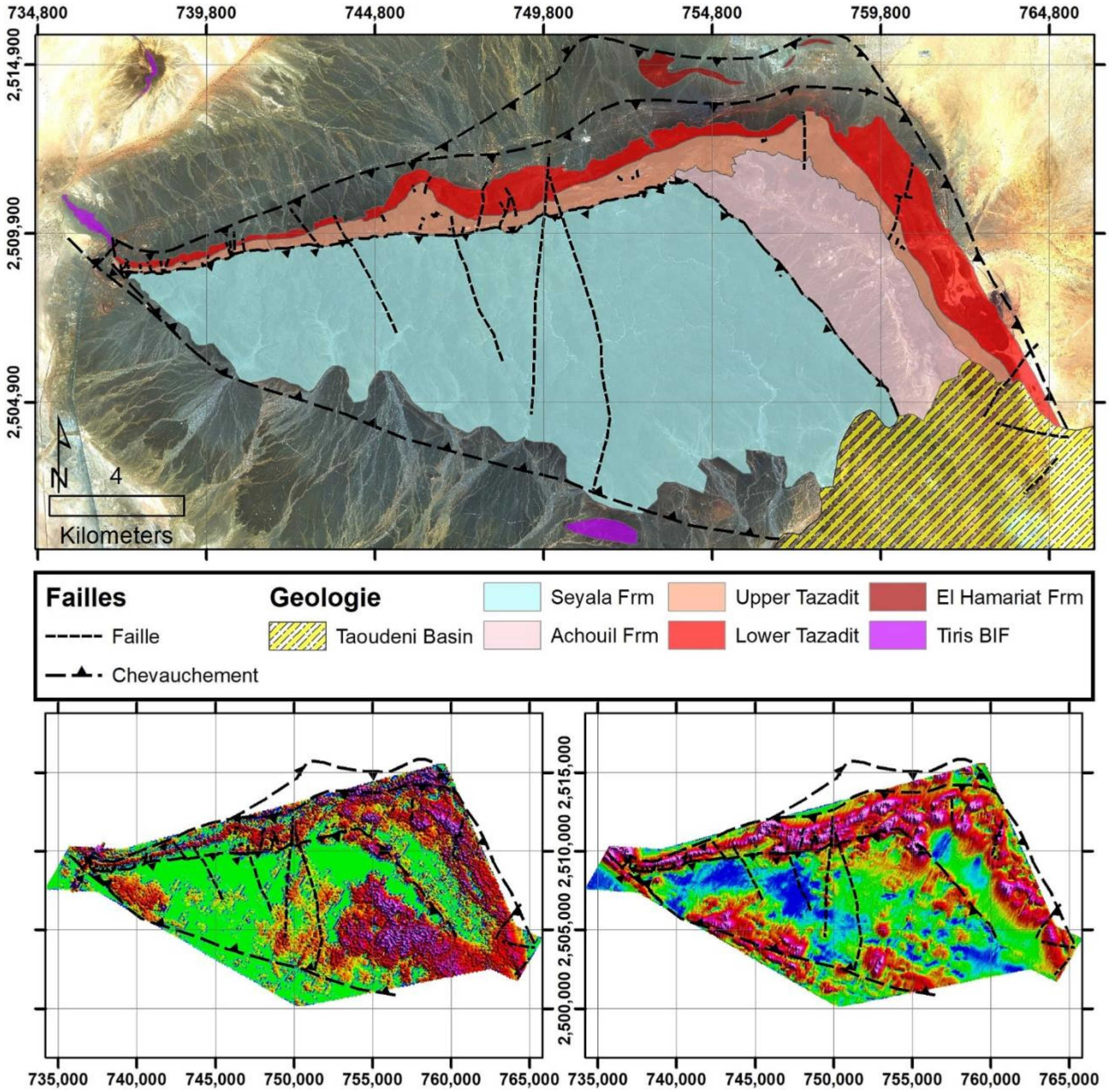

Figure 1. Top: Geological map of Kediat Ijil; Bottom left: Conductivity grid at depth 200m below surface; Bottom right: Analytical signal of the total magnetic field data