Spectral Geology and Remote Sensing used for Mineral Exploration in the Abu Marawat Concession - Eastern Desert - Egypt

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Introduction

Aton Resources have a Mineral Exploration concession at Abu Marawat in the Eastern Desert of Egypt that contains the ~ 400,000oz Abu Marawat gold deposit and the Hamama VMS Gold Cap prospect that is being assessed currently.

Spectral processing of LANDSAT-8 and ASTER imagery reveals all the major known areas of mineralisation within the area plus a significant number of extra targets. A new Photogeological and Target map was generated based on the spectral RS images.

A reconnaissance survey to collect samples for spectral analysis was carried out in August / September 2016. A total of 90 samples were collected over the Abu Marawat concession.

Spectral analysis of samples in and around the zones of mineralisation reveal that the fluids involved were CO$_2$– enriched resulting in deposition of carbonates and calc-silicate alteration minerals. Variations in sericite compositions were also observed that may be related spatially to the centres of mineralisation.

The next proposed step is to bring the spectral processing into the Prospect Scale using WorldView-3 data for detailed mapping of mineralised zones in and around the major deposits and prospects.

In the field at Hamama in Summer. Make sure you have a good hat and a spare pair of boots.
Arabian – Nubian Shield

- The Abu Marawat Concession lies in the Eastern Desert of Egypt in the NW of the exposed Arabian Nubian Shield (ANS).
- The ANS is an assemblage of largely Neo-Proterozoic age crystalline basement. It is formed of the remnants of ancient oceanic crust, Island Arcs and Back-Arc Basins that were accreted over a long period (780-620 Ma) to form continental crust. The exposed part of the ANS covers about 1.6 m² with two halves divided by the Red Sea Rift.
- The ANS has been traditionally viewed as having two main types of precious and base metal mineralisation - Mesothermal polymetallic / Quartz Vein Gold Deposits and Volcanogenic Massive Sulphide Deposits that contain dominantly copper & zinc as well as having gold enriched caps.
- Mesothermal polymetallic gold deposits include Sukari and Abu Marawat in Egypt, Zara in Eritrea and Mahd adh Dahab in KSA (50km SW of Jabal Sayid).
- The major known VMS deposits include Jabal Sayid in KSA, Hassai in Sudan, Bisha in Eritrea and Hamama in the Eastern Desert of Egypt. It is Hamama that is the focus of this presentation along with other possible VMS and Qtz-Vein gold mineralised occurrences within the Abu Marawat Concession.

Schematic map of the ANS showing some of the major mineral deposits and occurrences.®

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• The Abu Marawat Concession lies in the Eastern Desert of Egypt to the south of the main road from the Nile at Qena and the Red Sea Coast at Solfaga. Other major towns in the broader region include Luxor on the Nile and Hurgada and Sharm –el – Sheikh on the Red Sea.

• It takes approximately 2 hours to drive from the international airport at Luxor to the field camp at Hamama which is 32 km from the main tarred road by good quality graded desert tracks.

• The Abu – Marawat Concession is almost entirely underlain by basement rocks of the Arabian-Nubian shield with cover rocks of the Cretaceous age Nubian Sandstone formation appearing on the western fringes of Hamama Prospect in the West.
Abu Marawat Concession – LANDSAT - 8 OLI Clay-Iron Image

• The LANDSAT Clay-Iron image was developed at AAC in 1987 and I have been using it ever since. It was primarily designed for locating hydrothermal alteration zones in geologically recent volcanic terrains but it can also be useful for spotting hydrothermal areas in other terrains as seen here.

• Hydrothermal alteration zones are bright red on this image. However – non alteration lithologies can also produce bright reds – eg the Nubian Sandstone & Dhokan Volcanics.

• The L8 Clay-Iron image indicates the INTENSITY of the alteration and is complimentary to the ASTER Mineral Map which indicates the TYPE of alteration.

• The alteration associated with the VMS at Hamama and the Vein Hosted Gold at Ser Bakis are best displayed on the L8 Image (yellow circles).

The ASTER MinMap-Topo image was developed in 2006. The technique uses the "super-spectral" resolution in the SWIR to divide mineralogy into 3 main lithic groups: Argillic, Phyllic and CPS (carbonates, propylites & serpentinites). The VNIR-SWIR is used to map iron oxides & hydroxides and divide them into haematitic and goethitic types.

Intense zones of hydrothermal alteration typically have strong lithic and iron signatures so the ASTER Mineral Map includes mixtures between the lithic and iron groups to make an 11 unit Mineral Map.

The ASTER Mineral Map divides alteration mineralogy into TYPES where zoning may be observed. The Miranda, Abu Marawat and Akarub locations are best displayed using ASTER although they are also prominent features on the LANDSAT.

ASTER MinMap-Topo Image. Coordinates in metres UTM 36N WGS84. Grid spacing 10 km.
Photogeology & Target Map

The LANDSAT-8 Clay-Iron Image and the ASTER MinMap-Topo Image make excellent interpretation bases for photogeology. Because they also highlight possible hydrothermal alteration zones as well, exploration targets can also be included in the output map. The interpretation was carried out on-screen in ArcGIS at scales of 1:10,000 to 1:25,000 to produce a map presentable at 1:50,000 to 1:100,000 scale. The geological units in the new map are based on their spectral properties displayed in the 2 images and are therefore unique and new.

Above: New Photogeological and Target Map generated from the 2 regional spectral images.
Left: The Geological Survey map at 1:250,000 scale.

The Photogeological Map is not intended to supercede or replace the Geological Survey map but rather to supplement and complement it. The advantages of the new map include greater detail, wadi and drainage map for orientation & access, geological spectral units and exploration targets. Comparison of the two maps shows a large measure of similarity but there are extra details on the Photogeology.
Hamama Prospect – VMS with Gold Cap

The Hamama Prospect in the SW of the concession is Aton’s current focus of attention where a recent drilling campaign has been carried out in part of the mineralised zone at the “Western Gossan” in order to define a Gold Resource in the gold – enriched cap. The mineralised zone continues for a considerable distance to the east and north east of the western gossan. One of the objectives of the Remote Sensing project is to help map the extent and distribution of the mineralisation.

In the VMS model below the stratigraphic hanging wall tuffs and pelites are unaltered but RS and field spectral sampling has shown this not to be the case.

**Idealized VMS Applied to Hamama**

- Entire sequence overturned to the south
- (stratigraphic) footwall andesite & felsite with typical VMS alteration and base-metal feeder veins
- Thick carbonate exhalite horizon, representing main period of hydrothermal activity
- Sharp contact with weakly altered and unmineralized hanging wall rocks
- Abrupt change from andesite-felsite lavas and breccias to volcanoclastic sediments, jaspers and minor tuffaceous units
- Many examples of way-up structures in hanging wall; e.g. graded bedding, flame structures, load casts etc.

Above: View to the North East of the Western Gossan from atop the Nubian Sandstone outlier. The gossan exposure is very much enhanced by the earthworks associated with exploration trenching & drilling.

Right: The mineralised zone at Hamama East looking NE with Dolomites / Gossans on the left in the footwall and Tuffs / Pelites to the right in the (stratigraphic) hanging wall.
Alteration seen in both footwall AND hanging wall. Response from Nubian Sandstones due to low-T kaolinite?

- L-8 Clay-Iron image shows alteration in the footwall – some of these are known or recently discovered sites of mineralisation. Others are targets for investigation.
- There is also a large area of the stratigraphic hanging wall that is apparently intensely altered. Spectral analysis of a sample reveals paragonitic sericite that is also encountered along the main mineralised zone. This area to be further investigated in the field.

**LANDSAT-8 Clay-Iron Image over the Hamama Prospect. Arrows show the location of the mineralised zone. Coordinates in metres UTM36N WGS84. 1 km grid spacing.**

**Spectral types at Hamama**

- Haematite from gossans
- Dolomite from replacement carbonates in mineralised zone
- Sericite from phyllic alteration
- Kaolinite from Nubian at upper contact?
- Sericite – Clinozoisite from mineralised zone
- Paragonite from mineralised zone & hanging wall alteration

**Hamama Representative Mineral Spectra**

*Looking SW along Hamama mineralised zone. Strat hanging wall pelites on the left footwall altered volcanics on the right – mineralisation along contact. Western gossan in the distance on the right skyline.*
Ser Bakis Spectral

The L-8 Clay-Iron image picks up linear zones of alteration along the mineralised veins at Ser Bakis. There is another possible zone of alteration for follow-up across the wadi to the east.

Above: Looking north along the N-S gold-bearing vein at Ser Bakis. The light orange rocks extending along the vein in the centre of the picture are the altered vein margins in a chlorite altered fine to medium grained intermediate to felsic intrusive.

Spectral profiles from the vein margins at Ser Bakis contain:
- Kaolinite – high temperature hydrothermal in origin?
- Chlorite – as observed in the field in the altered host rocks surrounding the vein.
- Sericite / Clinozoisite – a mixed spectrum indication the presence of calc-silicate suggesting elevated CO₂ in the mineralising fluids.
Miranda Copper Valley - Spectral

This is an area of intensely altered volcanics showing some apparent zoning in the ASTER MinMap-Topo image. The highest Cu grades from grab samples are from the western edge of the central zone.

Looking westwards in “Copper Valley” at Miranda. There are numerous pits and old workings in the hillside and malachite is widespread in these altered felsic volcanics. This area appears to be the host to disseminated copper mineralisation.

Miranda has been known as the “Miranda Gossans” following mapping done by previous workers. A team from Aton Resources visited some of the areas mapped as gossans in September 2016. We found intensely altered ferruginous volcanics but nothing that we would consider as gossans (like those at Hamama) in-situ. Float of gossan – similar in appearance to those at Hamama – was found in a wadi at one location. This constitutes a follow-up target to find the outcrop.

Miranda Spectral Types include:

Goethite – from the highly altered volcanics but not dense enough to be called a gossan
Sericite / Clinozoisite a mixed spectrum similar to that seen at Ser Bakis perhaps indicative of raised CO₂ levels in mineralising fluids?
Kaolinite/Smectite - also a mixed spectral type.
The latter two also have haematitic type profiles in the VNIR. The central “Phyllic-Haematitic” zone on the ASTER Imagery yielded Hae-Ser-Czo profiles.
Abu Marawat Gold Deposit Spectral

This is a Qtz vein hosted gold deposit with two sets of NNW-SSE and E-W trending Quartz Veins. The difference from other Qtz-vein hosted deposits at Ser Bakis and Semna Mines is that there is a large zoned hydrothermal alteration system surrounding the central mineralised zone. In this quality the deposit has similarity with epithermal systems.

ASTER MinMap - Topo Image over Abu Marawat. The mapped Qtz veins are from internal company mapping in GIS. Coordinates in metres UTM36N WGS84 1 km grid.

Looking north-westwards towards the central vein system of the Abu Marawat Deposit. Some of the veins can be seen as prominent ridges in the host altered volcanics.

The ASTER Mineral Mapping over this area looks very similar to the Miranda area with a central zone of phyllic-haematitic type (purple) surrounded by a halo of phyllic-goethitic type (cyan). From the reconnaissance sampling (8 samples) we can tie in the spectral profiles with what we see in the ASTER Mineral Map. The central zone is occupied by Haematite - Sericite or Paragonite whilst the outer zone has mixed Sericite – Clinozoisite profiles. The VNIR profiles from this outer zone will produce Goethitic signatures with much higher reflectance in B1 of ASTER.

Abu Marawat Spectral Types include:

- Sericite – Clinozoisite – these profiles would tie in well with the Phyll-goe ASTER unit in the outer zone.
- Haematite – Sericite in the inner phyll-hae zone and Haematite – Paragonite also in the inner zone.

We would need a much denser array of samples to see if the sericite-paragonite compositional change is zoned and spatially related to the mineralisation.
Jabal Abu Akarub - Spectral

This is a new area of interest selected as the largest and most spectrally diverse area that forms an anomaly on both the LANDSAT-8 and ASTER Images.

ASTER Mineral Map over the Jabal Abu Akarub area. This is quite different to the other areas we have looked at on ASTER having an apparent argillic component in the reds / magentas and yellows. Coordinates in metres UTM36N WGS84. 1 km grid spacing.

View looking eastwards on a small outcrop of haematitic jasper / gossan within a dolomitic unit in the southern part of the Akarub anomaly.

The appearance of this area on the LANDSAT-8 and ASTER suggested an area of intensely altered volcanics. The presence of argillic signatures suggested that we might see kaolinite at least if not minerals like alunite, dickite & pyrophyllite that are typical of advanced argillic zones in high-sulphidation epithermals. It was a surprise indeed to encounter very similar geology indeed to Hamama with abundant pods, lenses and horizons of dolomitic carbonates within the altered felsic volcanics. However, we did not see very much sign of metal sulphides or oxides save for the pictured jasper / gossan. The presence of the abundant dolomitic carbonates is encouraging if we take them to be associated genetically with the formation of the VMS deposit at Hamama.

Jabal Abu Akarub Spectral Types include:

- Haematite – from the pictured jasper / gossan.
- Dolomite – from the dolomite carbonate horizon pictured and other occurrences that are abundant
- Sericite – Clinozoisite and Paragonite – Clinozoisite mixed profiles
- Clinozoisite – the only place where we encountered this calc-silicate without a sericite feature mixed in
- Paragonite – this appeared to be more widespread than in the other alteration zones we have sampled.

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Paragonite profiles – Spectrometer vs ASTER

Widespread paragonite at Jabal Abu Akarub MAY explain the ASTER argillic mixed spectra seen there in the ASTER MM11 Topo Image

We have to enlarge the spectral plots of these 3 minerals to make clear the different wavelength positions of their characteristic absorption features – hence the zoom-in to the 2000 – 2500nm range in the field spectra (left).

The close spacing of ASTER bands 5-9 in the 2167, 2206, 2262, 2336 & 2400nm range enhances these differences so we can use ASTER for Mineral Mapping.

Inspection of the ASTER Profiles in the right had side plot shows that ASTER may see Paragonite as an Argillic Type mineral with a significant feature in Band 5. It appears closer to Kaolinite than to Sericite in character from an ASTER bands perspective.

Abu Marawat – spectral profiles of Sericite, Paragonite & Kaolinite over the range 2000 – 2500nm

Spectral profiles of Sericite, Paragonite & Kaolinite re-sampled to ASTER Bands 1 - 9

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Conclusions

• Spectral processing of Regional Datasets over the Eastern Desert of Egypt has enabled production of new, more detailed, photogeological maps and identification of mineral exploration targets. These regional targets will be followed up in a field campaign to fully assess the Abu Marawat Concession.

• Collection of reconnaissance density samples for spectral analysis has enabled some preliminary understanding of the mineralogies involved in the hydrothermal alteration zones associated with gold and base metal mineralisation.

• At Hamama some prospect scale targeting was possible. Additional recently discovered mineralised zones identified in the footwall zone are featured on the RS imagery and there are multiple other footwall target areas to be visited in the field. In the hangingwall zone we have identified a large, intense, alteration zone in the Eastern sector of Hamama.

• The Quartz-vein hosted gold deposit at Ser Bakis is visible on the regional data. There are numerous other possibly similar zones within the Abu Marawat Concession. These will be field-checked in the Concession-wide campaign.

• The copper and gold mineralisation at Miranda and the Abu Marawat Deposit are very different from Hamama in that they have large intense zoned hydrothermal anomalies mappable on the ASTER Imagery.

• The large alteration zone at Jabal Abu Akarub looks very different from Hamama on the ASTER Min-Map Topo image so we were very surprised to find such a similarity in the rock types. Horizons, pods & lenses of dolomitic carbonate, that are intimately associated with mineralisation at Hamama, are widespread at Akarub. The distinctly different appearance on ASTER MAY be attributed to more widespread distribution of a Paragonitic Sericite.

• Spectral analyses revealed that the alteration zones around the mineralisation is largely phyllic in nature dominated by sericites. In addition we have encountered what we have interpreted to be a mixed spectrum of sericite and clinozoisite. These are widespread within the mineralised zones and are an indication of CO\(_2\) rich mineralising fluids along with the dolomitic carbonates that we think are replacement deposits.

• We propose taking spectral mapping to prospect scale using WorldView-3 imagery over selected areas. Further spectral sampling is also proposed to ground-truth the WV-3 and to follow up on possible compositional zoning that might be an indicator for mineralisation.
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References