The discovery and geology of the Galat Sufar south deposit, Republic of the Sudan

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Abstract

The Block 14 joint venture, managed by Orca Gold Inc (Orca) through its 70%-owned subsidiary Meyas Sand Minerals Company Ltd., is located in the northern reaches of Red Sea Hills, Sudan, 1,000km north of the capital Khartoum and covers 3,750sq km of the Arabian Nubian Shield (ANS). The ANS is host to the recent mines of Sukari in Egypt, Ariab in Sudan and Bisha in Eritrea, but has a much longer history of gold mining stretching back to 3,000 BC.

Recently, Sudan in general and the Red Sea Hills in particular have seen an explosion in artisanal gold mining activity with up to 1.5 million people thought to be active in the sector. However, barring regional drainage sampling in the 1990s, the Northern Red Sea Hills have seen little if any modern exploration. Orca identified the potential of the Sudan in 2011 and entered into the Block 14 joint venture in 2012 based on its location straddling the Keraf Shear zone and the widespread artisanal mining activity.

High resolution satellite imagery has been the mainstay of reconnaissance exploration with almost 20,000 ancient and modern artisanal sites identified and mapped. This has been followed by systematic appraisal and prioritisation of targets and extensive surface channel and trench sampling. To date, 282 occurrences have been visited and ranked, 34 targets subject to more detailed exploration and nine prospects drill tested.

The discovery of Galat Sufar South (GSS) was made as a result of this approach with geologists identifying the large alteration system. Initial channel sampling of the main outcrop returned up to 88m @ 2.20 g/t and the first drill hole in November 2012 intersected the Main Zone of the orebody returning 94m @ 2.38 g/t. A maiden resource of 1.7 moz (1 g/t cut off) was published in early 2014 and current combined resources stand at 2.22 moz (1 g/t cut off) of which 240,000oz is from a second discovery at Wadi Doum.

The GSS deposit is hosted within a package of intermediate volcanics, diorites, and syenites that have a penetrative schistosity that both controls and is cut by well-developed shearing, alteration and mineralisation. Gold is closely associated with quartz-sericite-pyrite schists and is present within six geometrically distinct mineralised domains.

Orca has commenced environmental baseline studies, preliminary water exploration and initial scoping investigations on Block 14 and is planning to complete Preliminary Economic Evaluation (PEA) early in 2016.

Introduction

The Block 14 project is located approximately 1,000km north of the Sudan’s capital city Khartoum, 200km north of the small mining town of Abu Hamad and 30km south of the Egyptian border. The Block 14 Exclusive Prospecting Licence (EPL) straddles the boundary between the Nile and Red Sea states (Figure 1).
The Red Sea Hills and Nubian Desert of the Sudan have seen gold mining since 3,000 BC and the Block14 EPL contains numerous documented sites with dilapidated stone huts and historic mining infrastructure. In recent times, artisanal miners have shown remarkable endeavour to prospect throughout the region, often following up on historic mining areas and Orca’s exploration success is built upon the toil of ancient and modern small-scale miners.

The first part of this paper describes the mineral exploration history, with a focus on the Block 14 project. This is followed by a summary of the current geological model developed for the region which is based upon the detailed exploration which has been undertaken.

Exploration history

Modern exploration

Modern exploration was initiated in 1996 by the Bureau de Recherches Géologiques et Minières (BRGM) in joint venture with the Geological Research Authority of Sudan (GRAS) as part of a Nubian Dessert Gold Project’s (NDGP) regional exploration programme.

The NDGP finished in 2001 after successfully completing a stream sediment survey, which identified all of the known significant mineralisation discovered to date. Follow up identified three drill targets, two of which have become advanced gold projects for Managem in Block 15, south of and adjacent to Orca’s Block 14 EPL.

The Galat Sufar South deposit is a new discovery but is situated within a previous NDGP stream sediment anomaly. A summary of modern exploration activity within the region is given in Table 1.

<table>
<thead>
<tr>
<th>Year</th>
<th>Activity</th>
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</thead>
<tbody>
<tr>
<td>1996-98</td>
<td>BRGM complete a low-density stream sediment survey using the Bulk Leach Extractable Gold (BLEG) technique, covering 9,000 km² at an average density of 1 sample/90 km². The survey successfully defines all of the known gold occurrences in the region.</td>
</tr>
<tr>
<td>1999</td>
<td>BRGM/La Source conduct follow-up drainage sit sampling of selected areas in the Gabgaba region analysing for gold and 34 multi-elements.</td>
</tr>
<tr>
<td>1999-2000</td>
<td>BRGM/La Source complete regional prospecting and detailed follow up at the Gabgaba project and the Naba prospect in Block 14, including soil sampling, trenching, ground magnetics, radiometrics and scout drilling.</td>
</tr>
<tr>
<td>2000-2001</td>
<td>BRGM/La Source 2nd phase drilling at the Gabgaba project. BRGM withdraw from Sudan.</td>
</tr>
<tr>
<td>2008</td>
<td>Managem begins exploration at Gabgaba, Block 15 EPL.</td>
</tr>
<tr>
<td>2010</td>
<td>A local Sudanese business, Meyas Nub, begins exploration in Block 14 EPL.</td>
</tr>
<tr>
<td>2011</td>
<td>Orca begins grassroots exploration in Blocks 67 and 68 and appraises Meyas Nub’s Block 14 EPL.</td>
</tr>
<tr>
<td>2012</td>
<td>Managem orders long-lead items for its Gabgaba project and produces gold from 700 tpd pilot plant. Orca JV’s Block 14 with Meyas Nub and identifies Galat Sufar South (GSS) where surface sampling returns a best interval of 88 m @ 2.20 g/t.</td>
</tr>
<tr>
<td>2013</td>
<td>Managem reports a 4 moz “internal resource” in Block 15 and Orca commences resource drilling at GSS.</td>
</tr>
<tr>
<td>2014</td>
<td>Managem reports a plus-2 moz NI-43-101 compliant resource from the Gabgaba project. Orca reports a maiden mineral resource estimate, using a cut-off grade of 1 g/t, comprising an indicated resource of 22.2 Moz @ 1.84 g/t for 1.3 Moz gold and an inferred resource of 6.5 Moz @ 1.9 g/t for 400,000 oz gold. Orca continues regional exploration in Block 14 and discovers new mineralisation at Wadi Doum.</td>
</tr>
<tr>
<td>2015</td>
<td>Orca releases an updated resource statement, using a cut-off grade of 1 g/t, of 27.64 Moz @ 1.83 g/t for 1.63 Moz gold (indicated) and 10.2 Moz @ 1.8 g/t for 550,000 oz gold (inferred). This includes resources from both Galat Sufar South and high-grade mineralisation from Wadi Doum. Regional exploration in Block 14 continues with the discovery of the Lisewi prospect 17 km north of Wadi Doum.</td>
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</tbody>
</table>

Table 1: Modern exploration history of the GSS Project, the Block 14 EPL and the adjacent northern Sudan region
Exploration by Orca 2011-2015

The mineral potential of the Sudan has been understood by Orca’s management for more than 10 years and through various privately held companies, exploration has been active since 2008.

Early activity focused on the volcanogenic massive sulphide (VMS) potential close to the Eritrean border in Blocks 19 and 77. This culminated in the discovery of sub-economic VMS mineralisation at Abu Mahmoud in Block 19 in 2011.

In 2011, as awareness of the scale of the artisanal mining boom in Northern Sudan grew, the focus of exploration switched to the northern part of the Red Sea Hills with the Block 67 and 68 EPLs being granted to the newly formed private company Shark Minerals Inc. These permits covered an area of 13,000sq km, east of Block 14.

As these blocks had received no modern exploration activity, reconnaissance exploration used conventional Landsat TM, SPOT and Aster imagery to identify regional shear zones, alteration and ancient and artisanal mining sites.

Regional work was subsequently refined through drainage silt sampling and ground truthing of areas of interest accompanied by the use of high-resolution satellite imagery.

During 2011, the opportunity arose to appraise the 7,000sq km Block 14 EPL where a local company was actively mining surficial gold. Potential for both VMS base metal-gold and orogenic lode gold was identified and on the basis of the geological setting and the very extensive artisanal mining, Shark Minerals entered into a joint venture with the holder of Block 14, Meyas Nub Multi Activities Company Ltd in May 2012 whereby Shark could earn up to a 70% interest.

Figure 2: Artisanal mining and historic settlement locations. deposits and camp location together with prospects and drill prospects identified. Black polygon denotes Block 14 EPL, background image, Landsat 4-5-7
Meyas Nub had identified gold-bearing base metal gossans at Tanasheib in Eastern Gabgaba. Meyas Sand (the joint venture company), undertook a heliborne electromagnetic/magnetic/radiometric survey over the Tanasheib area in mid-2012 in addition to a magnetic/radiometric survey over an area considered prospective for orogenic gold mineralisation in Western Gabgaba. The EM survey at Tanasheib failed to return significant anomalies and the focus switched to orogenic gold.

Shark drew upon its experience from exploring in Blocks 67 and 68 and refined its search techniques using GeoEye and worldview satellite imagery to identify ancient and modern mining activity. The satellite imagery is of sufficient resolution to differentiate ancient settlements, recent artisanal colluvial and hard rock mining in addition to organised small-scale open pit developments. Within Block 14, a total of 1,928 ancient settlements, 16,543 small-scale colluvial mining sites, 97 large-scale colluvial mining sites and 1,701 hard rock mining developments were identified and digitally mapped (figure 2).

All significant sites were visited by geologists and 282 occurrences were ranked for follow up. Almost 4,500 grab samples have been collected in Block 14 as part of a rapid reconnaissance programme. To date, 34 prospects were afforded detailed examination with 43km of chip channel sampling and 36km of trenching completed and nine targets have been drill tested, with resource estimates calculated for GSS and Wadi Doum.

The GSS deposit was discovered after follow up of artisanal workings identified at Galat Sufar North, where grab samples returned more than 1 g/t gold from a sheared hematite/sericite altered schist (figure 3a). The alteration package was traced 4km southwest to Galat Sufar South where systematic sampling of the Main Zone (figure 3b) identified a broad zone of north trending mineralisation up to 100m wide with average surface grades of more than 2.0 g/t gold (figure 3c).

The first RC drill hole in November 2012 returned an intercept of 94m @ 2.38g/t.

In April 2013, Shark Minerals was acquired by Canaco Resources Inc which subsequently changed its name to Orca Gold Inc., divested all of Canaco’s previous assets and replaced its management and technical team with Shark personnel.

A programme of deposit-wide exploration and resource drilling continued through 2013 and a maiden resource was reported in early 2014. A total of 37km chip channel sampling and 28km trenching together with more than 62km of drilling has been completed at GSS.

Figure 3a: Artisanal Miners at Galat Sufar North. Figure 3b: 2011 view east of Main Zone, Galat Sufar South, note artisanal mining restricted to a single quartz lode on ridge. Figure 3c: 2013 view north east of Main zone, Galat Sufar South, with position of first 3 systematic chip channel sample lines

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Figure 4: View looking west across the East Zone resource at GSS
In 2014, detailed exploration continued at GSS and throughout Block 14 leading to the discovery and drilling of the Wadi Doum resource 55km east of GSS (indicated: 1.3mt @ 3.02 g/t; inferred: 1.6mt @ 2.2 g/t, for 240,000oz). In early 2015, an updated resource was announced comprising 1.63 moz in the indicated category and 590,000oz inferred.

**Galat Sufar project resource estimation**

The GSS maiden resource estimate was reported in February 2014 and its update in 2015 included the satellite deposit identified at Wadi Doum (Tables 2 and 3). The updated resource utilised all drilling up until the end of December 2014, this entailed a total of 71,072m of drilling (5,060m of diamond drilling and 66,012m of RC drilling). Drilling has tested the mineralisation to a maximum depth of 300m but is generally less than 150m with 79% of the resource above that depth.

The resource was prepared using a multiple indicator kriging methodology (MIK). This method is well suited to the estimation of highly variable shear zone-hosted deposits such as Galat Sufar South and Wadi Doum. The MIK methodology avoids the use of complicated and narrow wire-framed domains used in other estimation methods as these often serve only to under-estimate tonnages and overestimate grades.

Within a variable shear zone-hosted deposit, MIK allows for an assessment of the multiple gold populations that exist within the data set. In doing so this allows for estimation within broadly defined domains whilst still honouring the inherent variability of the deposit.

The GSS deposit contains the bulk of the Block 14 Resource; contributing 89% to the total (1.976 moz of the total 2.219 moz (see Table 3). Figure 5 shows the lateral extent of the Galat Sufar South block model, whilst figure 6 shows a cross-section through the East Zone of the deposit and demonstrates the width of mineralisation and the shallow nature of the drilling to date.

This section however also identifies some of the further depth potential at Galat Sufar South, as demonstrated by the high grades intercepted at depth in one of the holes. This depth potential is to be tested in future drilling programmes.

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*Table 2: Combined Resources of GSS and Wadi Doum reported at different COG – Orca Gold Inc. 2015*

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<td>Total</td>
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<tr>
<td>Wadi Doum</td>
<td>Oxide</td>
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<td></td>
<td>Transition</td>
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<tr>
<td></td>
<td>Total</td>
<td>1.30</td>
<td>3.02</td>
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</table>

*Table 3: Resources by deposit and oxidation quoted at 1 g/t COG, note that numbers may not add up due to rounding – Orca Gold Inc. 2015*
Figure 5: Plan view of Galat Sufar South resource model. Annotations indicate the three main zones identified at Galat Sufar South. Within each zone distinct mineralised domains were identified for resource modelling purposes.

Figure 6: Section through the East Zone of the Galat Sufar South resource, see figure 5 for section location. Intercepts include internal waste and are calculated using a 10 g/t top cut.
Regional geological setting

The Red Sea Hills of Sudan hosts in excess of 250,000sq km of the Arabian-Nubian Shield (ANS), an assemblage of green schist metamorphosed, dominantly arc-accretionary belts, of Neoproterozoic age that was accreted to the African craton during the East African Orogen.

The GSS deposit is located within the Block 14 EPL at the boundary of the Halfa and Gabgaba terranes on the eastern edge of the African craton (figure 7). The geological framework of Block 14 is dominated by the Kerf Shear Zone (KSZ) which formed during the Neoproterozoic consolidation of Gondwana. It is approximately 500km long, 50km wide and represents a north-trending suture dominated by sinistral transpressive shear zones (Abdelsalam et al. 1998). The KSZ is considered to represent the collision between East and West Gondwana after the consumption of the “Mozambique Ocean”, with remnants preserved as intra-oceanic island arc/back arc/ophiolite assemblages that define the ANS (Burke and Sengor 1986).

Within Block 14, the Wadi Gabgaba represents the axis of the KSZ separating Western Gabgaba from Eastern Gabgaba (figure 1 and figure 7).

Western Gabgaba (figure 8) is part of the Halfa terrane and is characterised by a package of shallow, calcareous, marine sediments containing iron formations and numerous discrete volcanic centres and is classified as an immature continental tectonic setting (Galley et al. 2007). Abdelsalam et al. 1998 and Johnson et al. 2011 describe Western Gabgaba in Block 14 as a possible aulacogenic oceanic re-entrant as evidenced by the Atmur-Delgo suture.

One such area of volcanics is termed the West Gabgaba “donut” (figure 8) which is represented by an annular feature some 15km across that contains mafic volcanics on its periphery and is cored by a package of intermediate – subalkalic volcanics and calcareous meta-sediments that host the GSS deposit. The donut can be termed a culmination/anticlinal that is best defined by Orca’s airborne magnetic survey (figure 8).

Eastern Gabgaba (figure 8) is dominated by thick sequences of andesitic volcanics with subordinate felsic volcanics and some metasediments of the Gabgaba terrane. The mafic dominated bi-modal volcanic arc is classified according to Galley et al. 2007 as an immature oceanic tectonic setting. The arc sequence is intruded by multiple phases of collisional syn-tectonic diorites and post collisional sub-alkalic intrusives. The subalkalic intrusives are seen across both the East and West Gabgaba areas within Block 14 and may represent the Bayudan phase of igneous activity (<500Ma).

Regional deformation of the ANS within Block 14 is poorly understood and little if any regional mapping has been done throughout the northern limits of Sudan.

In Western Gabgaba, the thick sequences of metasediments and the contrast between volcanics and sediments allows more detailed study of the regional deformation. Prior to assembly of eastern and western Gondwana at least two phases of isoclinal folding are present and a continuum of regional steep folding and segmentation is evidenced by the juxtaposition of coaxial and non-coaxial interference fold patterns across shear zones.

In Eastern Gabgaba, the regional structural setting is less clear due to the dominance of andesitic volcanics that do not readily display folding and penetrative cleavage.

The Kerf Shear Zone dominates the geological framework of Block 14 where it both controls and is controlled by diorite intrusives and discrete alkaline intrusive bodies. Post collisional syenites and granitoids are present in both Eastern and Western Gabgaba and these late plutonic bodies have truncated margins along regional scale shear zones representing the final phase of suture. The Cenozoic rift event in Block 14 is evidenced by NNW trending extensional faults that form the margins of Wadi Gabgaba (figure 8).

Documented Neoproterozoic mineralisation within the ANS is restricted to the VMS style; however recent work in northern Sudan has putatively described porphyry and epithermal systems. In Block 14 the Tanasheib Prospect has the characteristics of a VMS system, comprising of laterally extensive, thin, sub-parallel, Cu + Zn + Pb + Au gossans within a dacitic host. Orca’s EM survey has shown that significant conductors are not present at depth and elevated gold assays are invariably associated with overprinting, later orogenic lode gold veining. Orogenic gold mineralisation can also contain appreciable amounts of base metals (up to percent values) and it is likely that some of the volcanic hosted orogenic gold mineralisation overprints Neoproterozoic volcanogenic mineralisation.
Orogenic gold occurrences in Block 14 can be broadly divided into lode gold and shear zone hosted gold styles. The lode gold mineralisation is often arsenical and has little if any interaction with the host rock. Shear zone gold invariably has a base metal signature and there is considerable interaction between veining and the sheared host rock. Orogenic gold overprints and utilises the regional metamorphic fabric throughout the ANS and in Block 14 the metamorphic grade is lower greenschist facies. The orogenic gold in block 14 is considered to be broadly associated with post collision of the East African Orogen and there have been no subsequent regional deformation events.

A Cenozoic mineralising event that cross-cuts the metamorphic fabric probably associated with Red Sea rifting has been recorded in Block 14 and the adjacent Block 67 (figure 1). Epithermal acid sulphate alteration associated with felsic volcanism is generally un-mineralised although silver and gold values have been recorded.
The ANS is host to a number of significant mines, the most important of which can be broadly grouped into VMS base metal/gold and Orogenic gold.

The VMS mines include the Bisha project in Eritrea (1.2 moz gold, 3,500 mlb copper and 16,300 mlb zinc, Nevsun Resources Ltd, 2014), the Jabal Sayid mine in Saudi Arabia (1,400 mlb copper, Barrick Gold Corp., 2014) and the Ariab project in Sudan (5.9 moz gold, 3,000 mlb copper, La Mancha Resources Inc., 2014).

Orogenic gold mines within the region include the world-class Sukari mine in Egypt (23.2 moz gold, Centamin plc 2015), the Ad Duwayhi project in Saudi Arabia (2.4 moz gold, Saudi Arabia Mining Co., 2015) and the Zara mine in Eritrea (900,000oz gold, Chalice Gold Mines Ltd, 2012).

A number of advanced exploration projects at various stages of development are present in the northern Red Sea Hills, Sudan, with Tahe Mining in the early mining stages of its 500,000oz gold Abu Sara mine and Managem in its pilot mining stage at the 2.3 moz gold Gabgaba project (figure 9).

Figure 8: Regional geology of Block 14 EPL showing the axis of the Keraf Shear Zone and the position of a Post Cretaceous graben in Wadi Gabgaba. High Resolution Airborne Magnetic (HiRAM) total magnetic intensity image is overlain showing the annular high magnetic Western Gabgaba “donut” shape which is related to mafic volcanics cored by an intermediate to sub-alkalic volcano-sedimentary assemblage.

Figure 9: Location of regional mines including a summary of their total resource (including mined to date).
Ancient mining centres such as Umm Nabari, Doishat and Deraheib are distributed across northern Sudan from the River Nile to the Red Sea and mining spans the period from the pre-dynastic era (3,000 BC), through Nubian, Ptolemaic and Turkic times (figure 8).

Within Block 14, large ancient mining centres are less common and this may be in part due to the remoteness of the region. Recent artisanal mining however is widespread throughout the Red Sea Hills, but is especially concentrated in the Block 14 and 15 EPLs with an estimated 20,000 miners active in these areas.

Mining ranges from traditional hammer and chisel mining of narrow veins and shear zones (figure 10g, h) to the use of metal detectors to locate nuggets within the regolith extending to depth with excavators and more recently the use of dry gravity separators to retrieve fine gold from the same regolith (figure 10d,e,f).

Large-scale mechanised artisanal mines such as Mussiay, Big Pits (figure 10i) and Liseiwi are also present within Block 14, but due to the lack of water, production is limited and ores are hand cobbled, screened with metal detectors and ore shipped 200km south to the Nile for processing (figure 10j,k).

Figure 10a: Pharaonic Grinding stones at SE Gabgaba, Figure 10b: Pharaonic settlement at SE Gabgaba, Figure 10c: Colonial settlement at Onib Mine. Figure 10d: Large scale colluvial mining, GSS, Figure 10e: Front end loader feeding air screens, GSS, Figure 10f: Artisanal miners adjusting dry gravity separators, GSS. Figure 10g: small scale hand mining of discrete quartz carbonate lode vein, NW Gabgaba, Figure 10h: large scale hand mining of shear zone hosted gold, Wadi Doum, Figure 10i: Mechanised artisanal mining at Big Pits, Western Gabgaba (worldview image of open pit trending NNE, showing spoil heaps where coarse gold is identified and sorted using metal detectors, the southern half of the image shows extensive mechanised colluvial mining.) Figure 10j: Hard rock mining product is hand cobbled and sent to small scale grinding sites close to the river Nile. Figure 9k: 2 – stage ground ore is panned using a mercury amalgam
**Galat Sufar South geology**

The Galat Sufar South (GSS) deposit is located in the central portion of the Western Gabgaba anticlinorium (donut) on the southern flanks of a fold interference culmination with an axial surface trace trending east-northeast.

The northeast apices of this doubly plunging antiform hosts the Galat Sufar North prospect and other prospects are located on its northern flanks. A silicified dolomite is a marker to the core of the structure which contains an interleaved package of lower greenschist facies metamorphosed carbonates, marls and volcanics (figure 11).

The GSS deposit is located within a package of intermediate volcanics, diorites, and syenites that have a penetrative schistosity that both controls and is cut by well-developed shearing, alteration and mineralisation (figure 11). 1:25,000 scale mapping has identified a chlorite epidote bearing sequence of monotonous andesitic volcanics distal to the sericite dominant core of GSS. Directly south of GSS, the presence of chlorite-epidote is controlled by through-going faults and close to the mineralisation these fault zones contain quartz-epidote (epidosite).

The dominant trends of shearing at GSS are 110° (sub-parallel to the S1 cleavage) and 010°, they dominate alteration and vein development, are steep and display well developed C–S fabrics. The 010° set of shears are generally better developed in Main Zone and are mylonitic (figure 13). An intersection lineation of the two main shears is defined by ore shoots that plunge steeply to the northwest. The north-south structural break between the eastern and western zones of GSS is poorly exposed and not completely understood.

Alteration is pervasive and deposit-scale units are defined by their alteration assemblages which are variably zoned outward from the gold mineralisation (Figure 12, Table 4).

The first phase of mineralisation is a milky white, fused quartz blow that is randomly oriented and cross-cut by shear zones and associated veining. On the eastern margin of GSS, the k-feldspar alteration clearly overprints a foliated diorite (MDI) and porphyritic diorite (IDI) forming the potassium altered diorite (KDI). The KDI forms a rigid body that is sheared on its contacts and overprinted by the quartz-sericite schist (QSS) and quartz-sericite-pyrite schist.

![Figure 11: Galat Sufar geology – Blue line contains package of interleaved carbonates and volcanics, Green line marks boundary of proximal quartz-sericite altered series of intermediate volcanics, diorite and syenite intrusives that host the GSS deposit with distal chlorite epidote altered andesitic volcanics. Red line marks principal shears oriented 010° and 110° that control mineralisation](image-url)
Where the k-feldspar alteration is intense, a texture destructive black red diorite (BRD) with incipient hornfelsing is preserved within highly sheared QSP altered high-grade mineralisation, but generally the k-feldspar alteration contains weak, variable mineralisation. Altered tectonic breccias are common in the East Zone where they are often pervasively overprinted by potassium feldspar alteration and subsequent shear foliation.

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<td>Quartz sericite pyrite schist</td>
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<tr>
<td>QSS</td>
<td>Quartz sericite schist</td>
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<td>IDI</td>
<td>Porphyritic diorite</td>
<td>none</td>
<td></td>
</tr>
</tbody>
</table>

Table 4: Progressive alteration assemblage at GSS

Vein quartz is present within all of the mineralised intersections but is rarely mapped at surface due to its exploitation by artisanal miners and is best represented by the position of artisanal workings. The quartz veins show multiple generations of development and are themselves mylonitised and brecciated in Main Zone (figure 13). Quartz blow is present throughout the region and outside of GSS carries no gold. However, at GSS it is brecciated, has sheared contacts and can contain significant gold.

Gold at GSS is associated primarily with intense sericite-carbonate alteration, moderate silicification, pyrite content and quartz veining from a millimetre scale to a maximum of 1.5m.
Six Domains of mineralisation have been differentiated and resource modelled (figure 13):

- **The 320 Zone** is present as discontinuous ribbons and plunging shoots located within a shear zone oriented 140° that is parallel with the local schistosity. The 320 Zone contains high-grade shoots (plus-10 g/t) that plunge steeply to the northwest in the same direction as the intersection lineation of 010° and 110° shears.

- **The Main Zone** is a wide laminar zone oriented 020° that links in to the 320 Zone in the south and has a strike length of 150m. The Main Zone represents a set of 010° trending shears that link two through-going 110° trending shears across a rigid body of syenite/k-feldspar altered diorite in the footwall. Shear fabrics in Main Zone are extreme and mylonites have been identified. The zone is up to 90m true width and is host to some of the best intercepts in the project. Grade is strongest at the southern end, closest to the intersection of the 320 Zone.

- **The 050 Zone** is a small domain that links the East Zone with a north-south trending set of vein mineralisation within a covered area termed The Gap. The 050 Zone is considered to be a compressional duplex that translates movement from the East Zone into a large through-going 010° trending shear within The Gap. Recent drilling has shown that in the south, the 050 Zone links into a 110° trending shear known as Target J.

- **The East Zone** is hosted within a 100° oriented corridor within which several small dismembered intrusive stocks, often brecciated, have been mapped and logged. Shear fabrics wrap around the intrusive bodies although the kinematics of this fault system are not fully understood. True width again exceeds 90m in the central East Zone with subsidiary, parallel mineralisation being present to the north and south with a similar, although not fully defined, trend. Shear fabrics in oriented core are dominated by a 110° orientation dipping steeply to the west. Sub-ordinate 010° trending shear is also present although these north going areas of mineralisation are often obliterated by silicification. A third sub-ordinate fabric oriented 030° is related to steep, irregular, coarse grained, gold bearing cataclastite that is interpreted to be a late stage deformation. A barren plug of alteration in East Zone is adjacent to high-grade tectonic breccias and may be associated with the quartz blow seen at surface.

- **The Far East Zone** has a similar trend to the East Zone and the mineralisation is hosted within a sheared sericitised microdiorite. Steep-to-vertical mineralised trends are open to the north and west, where discontinuous grade extends under cover.

- **The Shareg Zone** is a north/south trending steep trend of mineralisation hosted within a sericite-carbonate altered diorite-microdiorite. The Shareg Zone separates the modelled resource domains of GSS from the NE Zone (figure 5); a mineralised trend made up of braided shearing containing components of the main shear trends. The NE Zone has not been modelled as a resource domain.
Deposit model

The Galat Sufar project is located in Western Gabgaba and is hosted within a sequence of Neoproterozoic volcanoclastics formed within a West Gondwana aulacogen. The Galat Sufar South volcanoclastics represent a proximal calc-alkaline to sub-alkalic assemblage deposited together with shallow marine calcareous sediments. The volcanics contain coeval diorites, microdiorites and syenites and the entire package has undergone Lower Greenschist facies metamorphism and at least two phases of upright regional folding to produce a pronounced schistosity in all but the cores of intrusive bodies.

Mineralisation is associated with a shear zone-hosted orogenic gold deposit model and shearing affects all of the lithologies within the project area. Sulphide contents rarely exceed 5% and its mineralogy is simply pyrite plus trace sulphosalts. However, base metals are present at Galat Sufar which has a zinc + copper + arsenic + antimony + lead + molybdenum pathfinder association and is distinct from local lode gold vein mineralisation which only has an arsenic association.

Hydrothermal alteration is, at least in part, controlled by shearing and an early k-feldspar alteration overprints metamorphic fabrics producing rigid bodies that are in turn sheared and altered to quartz-sericite and quartz-sericite-pyrite alteration assemblages. Gold mineralisation invariably contains quartz veins that have quartz-sericite selvages that overprint k-feldspar alteration.

Gold tenor is related to sericite-carbonate alteration, silicification/veining and pyrite content, but none of these factors is mutually exclusive. Robust mineralisation is associated with increased deformation and the widest, best developed shear zones contain the largest resources. Small-scale shear fabrics in core are dominated by 110° and 010° trending fabrics that are in accord with regional kinematics and large-scale cryptic lineaments seen in high resolution satellite imagery.

High-grade shoots are developed at the intersection of these two shear fabrics, creating pipe-like bodies that follow the intersection lineation. A later (more brittle) shear oriented 030° both controls and truncates gold mineralisation. Potassium alteration, syenite intrusives, felsic stocks and early quartz blow form rigid bodies that act as indentors forcing strike swings in shearing which creates brecciated pipes and laminated shear zones, e.g. East Zone and Main Zone respectively (figure 13).

Regionally, late stage granitoids considered to be part of the Bayudan post-collisional phase of igneous activity (<500Ma) are truncated by 010° trending shears and their splays. These structures are sub-parallel to the Kerf Shear Zone and host lode gold vein mineralisation within large diorite intrusives considered to be associated with collision and suture of East and West Gondwana (~650 – 600Ma). The kinematic geometry of lode gold veins within the district is in accord with the Galat Sufar deposit model and suggests that the same structural regime was in operation throughout the closure of the Mozambique Ocean.

Gold mineralisation may have overprinted a pre-existing mineralising event using sulphides as the sulphur source for gold precipitation and this may account for the base metal signature of GSS, but at this stage it is too early to draw such parallels and the exploration implications in this specific environment are considered minimal.

Conclusions

The willingness to work in an unexplored gold province with clear gold endowment that has huge untapped potential, despite the perceived sovereign risk of the Sudan is the foundation of Orca’s discovery at Galat Sufar South; the low technical risk of exploring in such an area outweighing any perceived political risk.

The process began in 2008 when a private company recognised the country’s VMS potential and began negotiations on a concession agreement to explore. The company showed a high level of commitment and professionalism to the Sudanese Government, plus a real intent to explore for and develop a modern, large-scale gold mine. As a result, the Government has continued to provide strong support and encouragement to the company as it looks to build a long term mining industry in the country.

A switch from VMS exploration to orogenic gold exploration was made as a result of the large increase in artisanal mining activity in Sudan. Early grassroots exploration of a previously unexplored, remote region allowed Orca to build knowledge of the area, geology and mineralisation styles and identify the opportunity represented by the joint venture on Block 14 despite the lack of previous exploration.

The discovery of GSS was grounded in reconnaissance exploration using high resolution satellite imagery to identify ancient and modern artisanal mining and the application of boots on the ground to assess, rank and prioritise the very large number of gold occurrences.
Exploration in a remote and politically sensitive part of Africa may not appeal to all explorationists. However, perceptions are deceptive and working in the Sudan is far safer, easier and more efficient than many other countries in Africa, and for that matter the world. High quality, well-educated technical staff and strong government support mean that the Sudan is a great place to explore and more importantly to develop gold mines.

In Orca’s view, the clear endowment of the ANS coupled with the discovery of a robust resource at Galat Sufar South and satellite deposit at Wadi Doum may presage the dawn of a new gold province.

References


