VMS Exploration in Oman
Update on Discovery history, Mining and stratigraphy.

by Robert Close
Consultant to Gentor Resources Inc

SMEDG Talk  July 2015
Copper and related gold mining commonly from basaltic VMS deposits sustained several early civilisations in the Middle East-Mediterranean (MEM) region, key copper centres were in Cyprus, Turkey, Iran and Oman.

Island Arc related VMS deposits formed during early Tethyan extension through to late post closure subduction tectonics, particularly in Turkey.

Cyprus-type Ophiolitic deposits were mostly related to early Tethyan seafloor spreading and were preserved in large obduction sheets mostly onto the northern edge of the Pan African Arabian Platform during the Cretaceous.

The Ophiolites and copper deposits in the Troodos Massif of Cyprus and the Semail Ophiolite of Oman are among the best exposed and least-deformed examples of Cyprus-type VMS mineralisation in the world.

However, Ophiolitic terrains have not been a prime target for modern International investment due to perceived low potential for major Cu or Au deposits compared to Porphyry systems.
Proterozoic Arabian-Nubian Shield Deposits

Exploration companies in this region have generated significant enterprise value for their shareholders mainly from subduction-related Cu-Zn VMS deposits:

A few examples:

**Jabal Sayid Cu-Zn** VMS (Saudi Arabia), was acquired for AUS $1.2 billion by Equinox Resources (now controlled by Barrick Gold)

**Hassai Cu-Au** VMS (Sudan), was the main deposit acquired for $493 million by Weather II Fund (Sawiris Family)

**Bisha Cu-Zn-Au** VMS (Eritrea), generated a market capitalization for Nevsun Resources from $650 million to $1.4 billion
Jabil Sayid, Saudi Arabia - Mineral Resources

Total 100Mt Resources
Bisha District Eritrea - Mineral Resources

High-grade copper and zinc
Combined Bisha & Harena Reserves (Effective December 31, 2013)

<table>
<thead>
<tr>
<th>Zone</th>
<th>Tonnage</th>
<th>Copper</th>
<th>Zinc</th>
<th>Gold</th>
<th>Silver</th>
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<td>Supergene</td>
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<td>3.57 %</td>
<td>0.61 g/t</td>
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<tr>
<td>Primary</td>
<td>19,550 kt</td>
<td>1.00 %</td>
<td>5.54 %</td>
<td>0.67 g/t</td>
<td>45 g/t</td>
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</table>

27.5Mt Reserves

Based on $2.90/lb Copper, $0.92/lb Zinc, $1175/oz Gold and $20/oz Silver

Notes:
- All reserves are probable category
- Qualified person for mineral reserves is Jay Melnyk P.Eng. of AGP Mining Consultants Inc.
- Please refer to February 18, 2014 News Release for detailed assumptions pertaining to the above reserve estimate
- Total includes small oxide reserve to be processed at end of mine life.
Semail Ophiolite Nappe VMS Northern Oman

Fig. 1. Simplified geologic map of the Semail ophiolite in northern Oman (modified from Calvez and Lescuyer, 1991), showing the main VMS and gossan deposits associated with Late Cretaceous seafloor volcanism. Deposit symbols denote gold contents.
Jabil Achdar Ranges Northern Oman

1500-3000m elevation
Oman Ophiolite – Summary Geology & Exploration Blocks

Mawarid’s deposits

Block 5

Mahab 4

Block 6

Yanqul

50 km

Lasail

Crustal Sequence

Copper Deposits

Copper Smelter Complex

Mantle Sequence

Washishi
SEMAIL OPHIOLITE
VMS Prospective U & L Volcanics on Landsat base
Crustal Stratigraphy - Revised Mineralised Units

• Deposits occur at various stratigraphic horizons within the dominant basalt pillow lava sequences. 
  Near and at top of Geotimes (V1) * Lower Volcs
  Within and top of Lasail (V1-V2)
  Within and top of Alley (V2)  Upper Volcs
  Within Boninitic Alley (V2)

• Sequences may be difficult to identify in field but have magnetic and Imagery characteristics related to mineralogy

• Clear identification possible only with geochemistry
  Whole rock geochemistry
  Clinopyroxene relics
  Trace element patterns

After Gilgen et al Econ Geol v109  2014
OMAN OPHIOLITE – VMS Deposit Stratigraphy

VOLCANOSTRATIGRAPHIC CONTROLS ON MASSIVE SULFIDE DEPOSITS IN THE SEMAIL OPHIOLITE, OMAN

From Gilgen et al Econ Geol v109  2014

V1

V2
Oman Ophiolitic extrusives- Petrogenic Stratigraphy

From Gilgen et al Econ Geol v109 2014
VMS Deposits: MORB Cyprus-Type genetic model

[Diagram showing seawater inflow, exhalation of hydrothermal fluid, precipitation of metals, fractures, repeated circulation (convection), and magmatic fluids.]
Outline for the two stage Genesis of Oman VMS deposits

From Gilgen et al Econ Geol v109 2014
Oman Ophiolite – Typical VMS Deposit Styles

Cyprus-type half graben model

- massive sulphide ore body
- stockwork ore body
- intense argillization and silicification
- epidotization and slight silicification with pyritization
- slight silicification with pyritization
- VI-2 upper basaltic pillow and massive lava
- VI-1 lower basaltic pillow and massive lava
- metalliferous sediments

After JICA
Hayl As Safil (footwall) Gossan and surrounding VMS deposits
Ruined Mining village in Sohar region
Oman Ophiolite – Exploration & Mining History

+6000 Years  VMS Copper deposits mined in Oman since the Bronze Age

1970s-1990s  Modern Multinational exploration discovered >44Mt of 1-2% Cu

1973-1979  Prospection Ltd (Can) explored Ophiolite Belt - discovered 6 deposits


1996-2002  JICA (Japanese) regional exploration with >150 copper prospects:
  - discovered Ghuzayn (14Mt), improved Feasibility of Yanqul (17Mt)

2000/2013  Mawarid Mining (NMC)–100% privately owned by Omani MB Pet Group
  - acquired Exploration Blocks 1, 2 and Ghuzayn
  - found 5 outcropping VMS in <6mths - Shinas & Hatta (4x): 3.5Mt @ 2.5% Cu with a 3-4yr mine life – processing @ 1Mtpa ore at Lasail 20 km from port
  - Open pit mining commenced at Hatta in 2007– free cash US$60m in Yr1
  - VTEM survey in 2009 - 5 new discoveries, 3 being mined or under development

2010-2013  Gentor Resources uses VTEM to discover 2 deposits Mahab - drilled resources
  - Alara Resources upgrades Daris and Washishi - drilled resources

2014-2015  Savannah Resources takes over Gentor’s projects and Block 4
## Copper Production in Oman at 2013

### Oman Ophiolite VMS Deposits

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<thead>
<tr>
<th>Mined Out Resources</th>
<th>Mt</th>
<th>%</th>
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<tbody>
<tr>
<td>OMCO</td>
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</tr>
<tr>
<td>Lasail</td>
<td>12.99</td>
<td>2.01</td>
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<tr>
<td>Yanqul</td>
<td>16.20</td>
<td>1.90</td>
</tr>
<tr>
<td>Mawarid</td>
<td></td>
<td></td>
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<tr>
<td>Shinas</td>
<td>3.57</td>
<td>1.16</td>
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<tr>
<td>Hatta</td>
<td>1.94</td>
<td>3.38</td>
</tr>
<tr>
<td>Safwa</td>
<td>1.16</td>
<td>2.66</td>
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<tr>
<td>Mandoos</td>
<td>8.24</td>
<td>1.48</td>
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<td>Aswad</td>
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</tr>
<tr>
<td>Khazah</td>
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<tr>
<td>Ghuzayn</td>
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<td>1.81</td>
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<tr>
<td>Gentor</td>
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<tr>
<td>Mahab 4</td>
<td>1.50</td>
<td>2.50</td>
</tr>
<tr>
<td>Maqail S</td>
<td>0.30</td>
<td>2.00</td>
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<tr>
<td>Allara Washish</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Darius</td>
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<tr>
<td>Total</td>
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<td>1.99</td>
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<tr>
<td>Grand Total</td>
<td>69.93</td>
<td>1.88</td>
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- **3,000- 4,000BC** – Mesopotamian Era Production from Magan – unknown size
- **1000-1700 AD** – Islamic and Portuguese mining in Sohar district - production unknown
- **1983-1994** – **OMCO Mines** and Cu Smelter - Lasail district deposits
- **1994-2003** Low copper price stymied production
- **2007- 2015** – **Mawarid / NMC** open pit mining of Shinas, Hatta, Safwa, Mandoos; UG development of Ghuzayn, Aswad?
- **2016**– Yanqul copper development by Mawarid?
- **Near Future** – Mahab 4, Maqail S, Washishi
- **New Deposits at depth under cover**
Current Oman Exploration Blocks and VMS deposits
- from Savannah Resources 2015
Sohar Region VMS Deposits & JICA Targets

Known VMS deposits
New VMS discoveries
JICA VMS prospects
Yanqul deposits
Shinas and Hatta Area Deposit Locations

- Shinas Deposit – 5km east
- Hatta Ext
- Hatta South
- Footwall Altered Pillow Lavas. Geotimes V1 Unit

Indian Ocean
Hatta TEM coverage over gossans

HATTA AREA RESOURCES
WITH DRILLHOLES AND TEM CH 14

Resources
Mineralised Drillholes
Hatta area GA IP anomalism over gossans and footwall zone
Hatta Gossan - 80m long in Wadi wall

HW Flows
Hatta gossan with incorporated BRGM exhalite - 2003
Hatta Mine Pit in 2011 two years after completion

Gossan remnant in Wadi

MS
Hatta Massive sulphide – Chalcopryite rich mound breccia chimney fragments
Unaltered well developed vesicular pillow lavas at base and columnar jointed lava flow above dipping 25deg east.

This unit contains the Shinas deposit one km to the north.
Shinas Deposit FW Gossan - Early Drilling 2001

Au gossan and MS at 15m under wadi gravels
Mawarid Mining’s Shinas open pit in 2012

MS mined - 1.42Mt at 2% Cu
Remnant FW stringer sulphide breccia below gossan to west
Footwall Gossan breccia and Stringer Zone

Remnant MS

Alley Unit Basalts
Gold distribution in selected deposits: Shinas

From Gilgen 2011
Gold distribution in selected deposits: Rakah

Gold (5 ppm) — Copper (5 %) —

Oxide

Stringer Zone

MS

Deposit Enrichment factor

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<td>Av</td>
<td>Max</td>
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<td>Av</td>
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<tr>
<th></th>
<th>Min</th>
<th>Av</th>
<th>Max</th>
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<tbody>
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<td>Au</td>
<td>Min</td>
<td>Av</td>
<td>Max</td>
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<td>1.7</td>
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<tr>
<td>Av</td>
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<td>Min</td>
<td>Av</td>
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<tr>
<td>Av</td>
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<tr>
<td>Max</td>
<td>3</td>
<td>6</td>
<td>7.1</td>
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• Targeting open pittable, low cost, copper/gold operations

• Cyprus type VMS deposits represent a low geological risk
  ➢ Clusters of numerous 1Mt -15Mt deposits typical
  ➢ Opportunity for accelerated discovery and development
  ➢ Initial assets – 2 copper blocks in the producing Sohar region
  ➢ Excellent exposure and geological maps

• Operating targets - highly profitable with low embedded costs
  ➢ Open cut resources with low waste: ore ratios sought
  ➢ Metallurgically simple ores – marketable copper concentrate produced
  ➢ Low personnel, power & fuel costs, rapid development potential

• Excellent infrastructure, attractive fiscal terms, safe environment
  ➢ Close to port, roads, power & water
  ➢ 5 year tax holiday, then 12% corporate tax, 5% royalty
  ➢ Relatively benign Government approvals process
OMAN OPHIOLITE – VTEM Coverage
Pre 2014

Legend
- Highway
- City
- Gentor Tenement
- Tenement
- Semail Upper Seafloor Position
- Semail Lower Seafloor Position

Seman Conductivity
0
2
4
6.36

- VTEM Conductivity

Alara Resources 2010
Savannah Resources 2015
1. Geophysical Survey (VTEM and Magnetic)

At both Mandoos and Safwa the EM signatures directly indicate the presence of Massive Sulphide. Magnetic data were used as well to interpret possible structures and zone of alteration both of which from zone of low magnetization (figure 10 and figure 11).
Mawarid Mining VTEM data Ch 25 showing Mandoos deposits under Wadi cover within Alley Unit
In 2013 Drilling upgraded the deposit to JORC Mineral Resource status:

- **6.84Mt** Indicated at 0.90% Cu and 0.17g/t Au
- **7.27Mt** Inferred at 0.71% Cu and 0.20g/t Au

- At 0.25% Cu cut off
- Feasibility underway
- Heavy media ore separation then trucking of sulphide to Sohar plant
- Development partners sought - Mawarid deal likely

Washishi Resource outline on magnetic base from Alara Resources
Gentor Resources Block 5/6 Heli-borne VTEM Survey

Note: Strongly conductive over thrusted Tertiary Cover to east
Mahab 4 Deposit Discovery Site
Resource of 1.5 Mt drilled out on 25m-50m spaced sections.
At open pittable depth (20-100m).
Total of 50 core holes for 6,123m
330m long massive sulphide body
10-50 m thick MS wedge +QVS below
Mahab 4 Deposit – Long Section

Mahab 4 Summary
- Massive Sulphide
- Semi-massive Sulphide
- Quartz Vein Stringer
- Gossan
- Lasail Basalt (V1-2)
- Umber
- Geotimes Basalt (V1-1)
- Sheeted Dykes

QVS

Geotimes (V1-1) - FW

50m
## Mahab 4 Drill Results Summary (to January 2012)

<table>
<thead>
<tr>
<th>Hole No.</th>
<th>From</th>
<th>To</th>
<th>Mineralisation</th>
<th>Intercept</th>
<th>Copper</th>
<th>Gold</th>
<th>Zinc</th>
<th>Silver</th>
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<td>GRB5D020</td>
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<td>MS</td>
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<td>17.40</td>
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<td>3.62</td>
<td>0.24</td>
<td>0.90</td>
<td>11.8</td>
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**Codes** (Umber = Fe sediment, Jasper, MS = Massive Sulphide, SMS = Semi-massive Sulphide, QVS = Quartz Vein Stringer, GOS = Gossan)
Oblique view of the Mahab 4 block model Resource
- strike extensions may be open across faults at depth

Coloured by copper grade
Mahab village 500m away is a development issue
Alternate prospect discovery technique – using a magician
Maqail South – Geology & Cross Section
Maqail South Drill Results Summary (to December 2011)

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<tr>
<th>Hole No.</th>
<th>From</th>
<th>To</th>
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<th>Gold</th>
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**Codes** (MS = Massive Sulphide, SMS = Semi-Massive Sulphide, QVS = Quartz Vein Stringer)
Gentor’s Oman Resources

Gentor commissioned H&SC to make an independent resource estimation its Oman deposits in April 2012 and they assigned estimated resources at Mahab 4 and Maqail South to the Inferred and Indicated Resource categories as tabulated below, in accordance with NI 43-101 guidelines.

**Oxide Resources at Mahab 4 at a gold cut-off of 0.3 g/t**

<table>
<thead>
<tr>
<th>Tonnage (kt)</th>
<th>Density (t/m³)</th>
<th>Cu (%)</th>
<th>Au (g/t)</th>
<th>Ag (g/t)</th>
<th>Pb (%)</th>
<th>Zn (%)</th>
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<tr>
<td>Total</td>
<td>Inferred 28</td>
<td>2.4</td>
<td>0.2</td>
<td>1.0</td>
<td>11.5</td>
<td>0.03</td>
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**Sulphide Resources at Mahab 4 and Maqail South at a copper cut-off of 0.3%**

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<th>Density (t/m³)</th>
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<th>Au (g/t)</th>
<th>Ag (g/t)</th>
<th>Pb (%)</th>
<th>Zn (%)</th>
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<td>Mahab 4</td>
<td>Indicated 916</td>
<td>3.5</td>
<td>2.8</td>
<td>0.2</td>
<td>8.5</td>
<td>0.080</td>
<td>0.54</td>
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<td>Mahab 4</td>
<td>Inferred 590</td>
<td>3.3</td>
<td>0.9</td>
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<td>2.5</td>
<td>0.012</td>
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<td>Maqail South</td>
<td>Inferred 160</td>
<td>3.6</td>
<td>3.8</td>
<td>0.1</td>
<td>2.4</td>
<td>0.002</td>
<td>0.02</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>Indicated 916</strong></td>
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<td><strong>8.5</strong></td>
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<td><strong>0.010</strong></td>
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</table>
OMAN VMS – KEY EXPLORATION CRITERIA: 1

- **Seafloor control to VMS**: Identify key seafloor positions – primarily the Geotimes-Lasail position but also other stratigraphically higher positions (i.e. Lasail-Alley position (Mandoos, Aarja) and intra-Alley Unit positions (Shinas, Rakah).

- **Structural control**: Identify key syn-seafloor growth structures.

- **Heat sources**: Identify areas likely to have hosted enhanced hydrothermal systems – underlying trondhjemites and discrete volcanic centres.

- **Surface expression**: Gossan, slag & footwall silica-chlorite-ep-hem alteration.

- **Geochemical anomalism** in grab samples: Cu, Zn, Au and Ag.

- **Geophysical anomalism**:
  1. Massive sulphide strong conductors identified by VTEM/ground TEM.
  2. Disseminated and stringer sulphide mainly in footwall zones is IP chargeable.
  3. Hydrothermal alteration creates magnetic lows mainly in footwall halos.
OMAN VMS – KEY EXPLORATION CRITERIA: GOLD

- Oman VMS deposits vary widely in their gold content with MORB –type deposits such as Ghuzayn commonly having low gold content.

- Increasing “subduction input” in more evolved Alley lavas correlates with higher gold grades in VMS, this might be related to primary seafloor refining or sub-seafloor boiling processes but source enrichment is also a factor.

- The Shinas and Yanqul deposits show similarities with the gold-bearing VMS deposits of the Cu-Au-Zn-Ag-(Pb) association (Huston 2000). Primary gold grade determines overall gold grade.

- Shinas shows gold enrichment on the roof of the massive sulfide body, which could be primary or secondary, whereas feeder zones typically have low gold.

- Secondary enrichment at the weathering interface appears critical in order to make gold-bearing deposits have gold-rich gossans.
VMS EXPLORATION - USEFUL TARGETING TOOLS

- **Excellent regional geology maps** result from high outcrop exposure in this arid mountainous terrain, thus **detailed prospect mapping** is an important tool.
- Knowledge of **volcanic centres and units** in the host stratigraphy helps focus on specific target horizons and **key structures** controlling MS deposits.
- **Good GIS maps** with multi source data can highlight target prospectivity.
- **Rock analysis** of metalliferous seds can define prospective seafloor positions.
- **Airborne magnetics** is useful to correlate volcanic stratigraphy under cover and define blind magnetite depletion zones caused by hydrothermal alteration.
- **Heliborne VTEM** is a key regional tool for direct–shallow VMS discovery.
- **TEM and IP** are necessary for in depth evaluation of prospective sequences.
- **Downhole surveys** are important for defining near miss MS zones.
- **Landsat** with Spot technology can define broad footwall alteration systems.
- **Hyperspectral** mineral mapping at visible to thermal infrared wavelengths may help refine alteration mapping and deposit targeting.
Limitations to current technology and Oman expertise

- Most past exploration has focused on gossan exposures and developing open pit mines. Since 1995 most discoveries were found by geophysics.

- VTEM appears to only see deposits down to 150m in resistive terrain and possibly much less when there is conductive cover or thick wadi gravels.

- No deposits have been found that start below 200m depth, but neither has sufficient drilling or TEM been made to test underground mining targets.

- Discovery of new blind deposits at depth and under shallow cover can be aided by finding synvolcanic growth faults in hydrothermal upflow zones.

- Multiple seafloor positions inc V2 units contain significant ore deposits, prior to 2000 only the Lower pillow lavas (V1) were considered prospective.

- Much of the Upper Volcanics including Alley units lie under conductive Tertiary–Recent sedimentary cover and remain relatively untested.
Gentor’s VMS expertise was moved to Turkey in 2012

This was a direct result of Gentor’s inability to finalise deals on larger development properties in the region and Omani Government restrictions on tenement approvals ahead of a new Mining Act.

The Turkey Story is for next time!
Thank you.