WINDIMURRA VANADIUM DEPOSIT, MURCHISON REGION, WA

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LOCATION

The Windimurra Vanadium deposit is 80 km ESE of Mt Magnet at 28º18'S 118º32'E; Youanmi 1:250 000 map sheet SH509-04.

DISCOVERY HISTORY

The deposit was discovered in 1961 by Mangore Australia Ltd and subsequent detailed exploration was by Hawkstone Minerals Ltd in 1973. Hawkstone used mapping, drilling, magnetometer surveys and bench scale magnetic separation. Precious Metals Australia (PMA) began exploration in 1989 (Habeteselassie et al., 1996), reviewing previous exploration and analyzing trench and RC and diamond drilled materials. Prominent topography (the lateritic Hawkstone Ridge, visible from the air), a positive gravity anomaly, a strong regional magnetic anomaly (Figure 1) and a surface expression of abundant magnetite float identify this deposit.

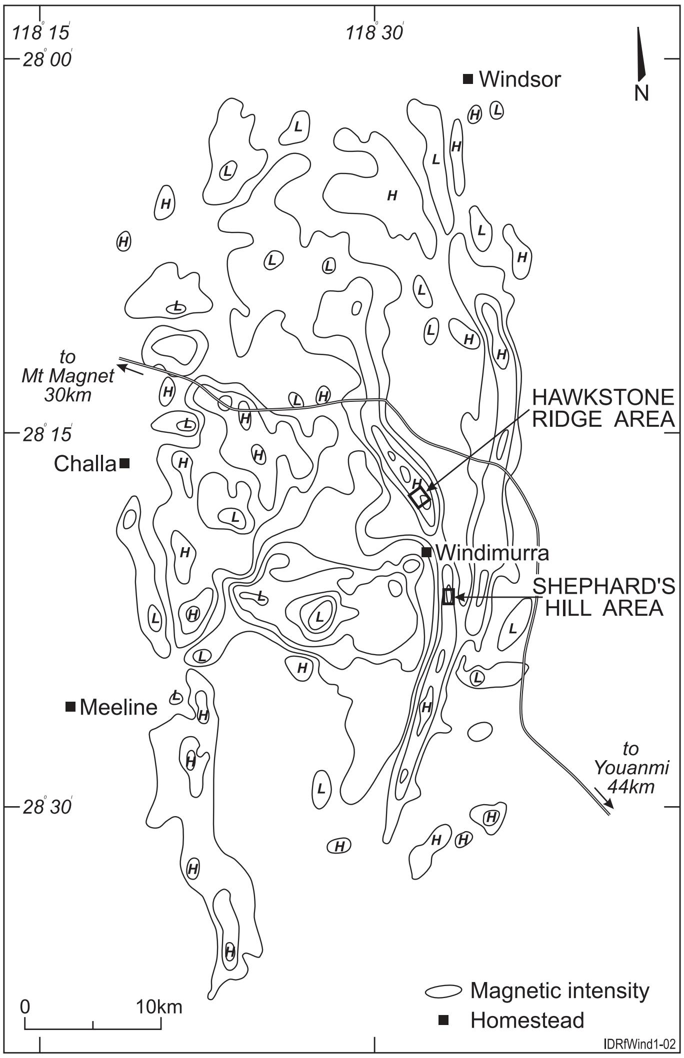

Figure 1. Magnetic interpretation map after Bureau of Mineral Resources aerial magnetic survey. The Windimurra Vanadium Deposit is a strong linear feature.

PHYSICAL ENVIRONMENT

The region is semi-arid with an average rainfall of 280 mm per year and high evaporation. There is little to no surface water. The soil ranges from red loam to siliceous hardpan (Alan Tingay & Associates, 1998). Land use is for grazing, especially sheep, cattle and goats. The area consists of low-lying plains covered with mulga (*Acacia* spp), *Grevillea* spp., and a native herbaceous layer, there are also smaller amounts of annuals and perennial grasses (Tingay & Associates, 1998). *Grevillea inconspicua* occurs on Hawkstone Ridge and on other gabbroic outcrops and does not occur elsewhere in the area, although the more common *Grevillea stenabotrya* is found in local clay flats.

GEOLOGICAL SETTING

The Shephards Discordant Zone (SDZ) hosts the Windimurra Vanadium Deposit. The SDZ is part of the Windimurra Complex, a differentiated and moderately fractionated Archaean layered gabbroic intrusion, situated in the Murchison granite greenstone terrane of the NW Yilgarn Craton. It is separated from the younger granite-greenstone sequences by major shear zones, the Wymandoo Shear on the E and the Mullyabraya Shear to the W. Vanadiferous, titaniferous magnetite cumulate (VTM) layers and lenses, up to 10 m thick, occur in the upper portions of the complex, and minor chromite cumulates (up to several tens of mm thick) occur near the base. This is similar to the Bushveld Complex and other large layered mafic-ultramafic intrusions (Withall, 2001).

The SDZ, containing magnetitite and magnetite gabbros, is sill-like, strikes over 45 km and is 500-600 m thick. At surface, it is up to 1 km wide and the central portion has abundant magnetite float. A Sm-Nd two-point whole-rock isochron suggests an age for the Windimurra Complex at 3.05±0.25 Ga; the surrounding granitoids and the oldest set of dykes intruding the complex have Rb-Sr whole-rock isochron ages of 2.6 Ga and 2.7 Ga respectively (Ahmat, 1986).

The Windimurra Vanadium Deposit is defined by high V concentrations within the SDZ rather than any particular physical feature. It is 80-100 m thick and dips 35-45^{o} to the W. Only the regolith part of the deposit is mined.

REGOLITH

The vanadiferous magnetite gabbros are weathered to 40-50 m. Fresh gabbro passes through 5 m of saprock, 30-40 m of saprolite and 3-10 m of mottled clay to a lateritic caprock up to 5 m thick that has largely been eroded, except in the immediate vicinity of Hawkstone Ridge. The base of complete oxidation or redox boundary is approximately 30 m below surface (Withall, 2001).

The main minerals in the weathered profile include clays (kaolinite and vermiculite), chlorite, hematite, limonite, ilmenite and goethite (Habteselassie et al, 1996). Plagioclase has weathered to kaolinite, mafic minerals to kaolinite, hematite and goethite, and chlorite has altered to randomly distributed chlorite and vermiculite. The abundance of kaolinite increases with increased weathering from the saprock to saprolite, particularly above the redox boundary. The magnetite gabbros are more susceptible to weathering than the magnetitites. The main effect of weathering on magnetite is oxidation to hematite via martite. Ilmenite remains relatively unaffected, apart from a textural change from trellis-like lamellae to granular, rounded blebs.

Magnetite cumulates occur as blocky, jointed outcrops. Hematite and martite occur on grain boundaries and along fractures; minor kaolinite occurs along fractures. Magnetite occurs in the saprock as cores in hematite. The proportion of hematite depends on the original amount of magnetite, and increases with increased weathering. Fibrous and spotty goethite has weathered from magnetite and other iron-bearing minerals in the magnetite gabbros and only occurs along fractures and grain boundaries (Habteselassie et al., 1996).

Weathering begins along bedrock fractures, with progressive oxidation of magnetite to hematite, resulting in loss of magnetic susceptibility. The rocks become very fractured, sulphides are destroyed, goethite forms along fractures, and there is possible reorganization within the ilmenite.

MINERALIZATION

Mineralization is within magnetite gabbro and leucogabbro in a continuous layered sequence about 80 m thick. Locally, the relative proportions of plagioclase, augite and magnetite vary considerably and

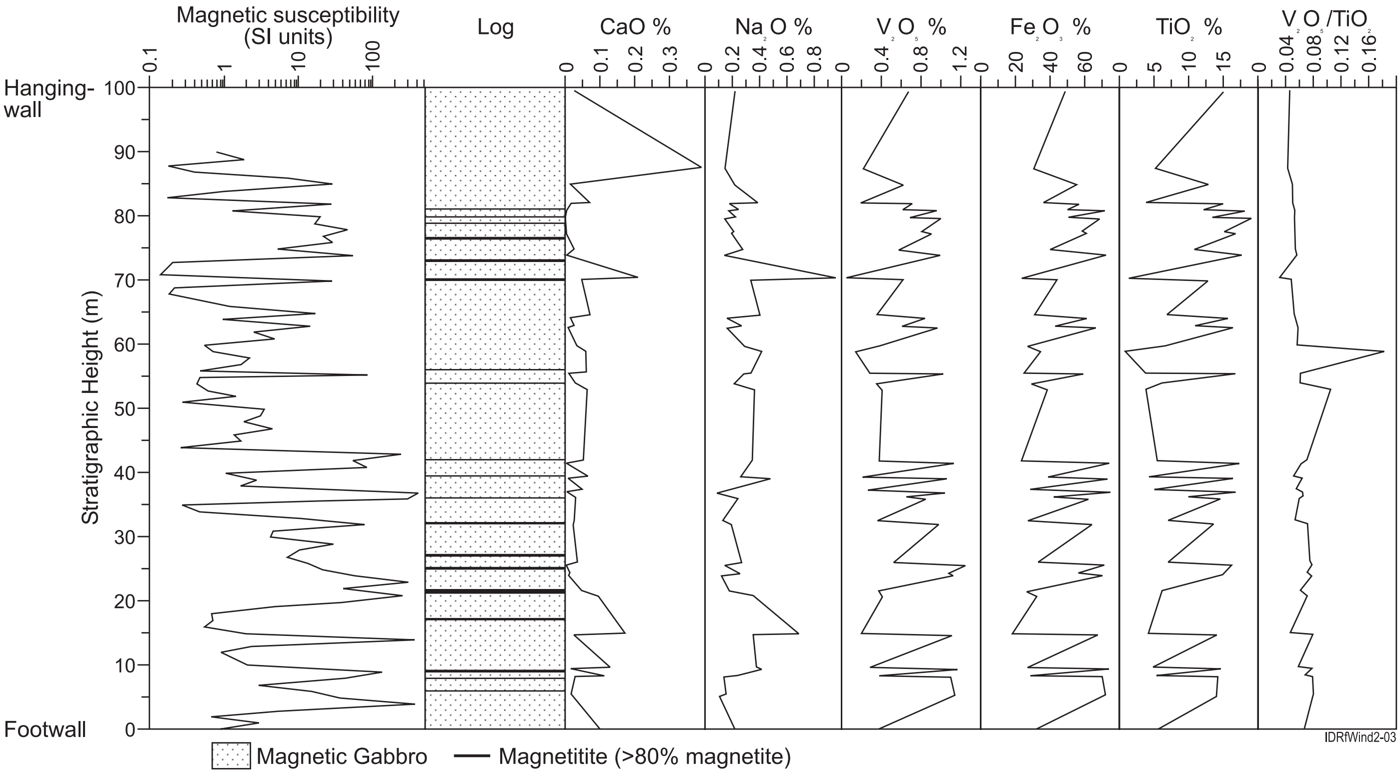

Figure 2. Simplified geology, magnetic susceptibility and element distributions in the main ore zone.

the compositions range from anorthosite (plagioclase >90%) to magnetitite (magnetite >90%). The sequence consists of individual layers with a sharp base of magnetite cumulate (magnetitite) grading upward. The sharp base is believed to be due to abrupt fluctuations in oxygen fugacity and magma composition during fractionation. Magnetite also occurs as disseminated blebs reaching 8 mm in the gabbro (Withall, 2001).

The basal contact of each layer consists of a chlorite-rich layer 20-200 mm thick and is overlain by cumulate vanadiferous titano-magnetite (VTM) containing up to 90% opaque ore minerals. Cumulate plagioclase becomes progressively more abundant above and the VTM content decreases, grading upwards into leucogabbro or anorthosite.

Vanadium replaces some of the Fe^{3+} in the titano-magnetite which has a mean content of 1.2% V (ranging from 0.8-1.4%). Most V occurs within the magnetite of the titano-magnetite, or in martite in the weathered titano-martite. The weathered cumulus magnetite grains are granular, highly fractured, mostly interstitial and disseminated in magnetite gabbro.

Habeteselassie (1994) found that V in the magnetite decreases slightly with height within the intrusion, and Ti increases (Figure 2). The variation is dependent on the proportion of magnetite. The V:Ti ratio decreases with height in the intrusion, but there is no clear change between magnetitite and magnetite gabbro.

The gangue minerals are plagioclase (now weathered to clay), olivine and clinopyroxene. With the possible exception of clinopyroxene, the gangue does not contain appreciable vanadium. False anomalies are rare in this type of deposit as V is insoluble in water and has dispersed less than one metre during weathering. The deposit is open at depth but it is not economically viable to mine unweathered rock.

REGOLITH EXPRESSION

Float carrying titano-magnetite and magnetite and low outcrop were sampled along ten E-W traverses totalling 2140 m across the SDZ, to broadly assess the V and Ti grade in the VTM over a strike of 10 km of the SDZ. Analyses for V and Ti were by XRD on pressed powder samples. As with other, similar igneous intrusions, the V/Ti ratio decreases up the sequence.

The regolith expression of this deposit is most obvious in the geomorphological features. The resistant magnetite in the deposit has formed a prominent lateritic ridge, Hawkstone Ridge, on which grows the rare tree species *Grevillea inconspicua*.

Vanadium is relatively insoluble under most weathering conditions. Only small amounts of vanadium were lost during the weathering of the Windimurra deposit, and these were trapped locally in Fe oxides and other Fe-bearing species.

Iron disperses slightly in the lateritic environment and is abundant as hematite and goethite. Therefore it is not a practical indicator element. However, a magnetite deposit can be readily detected by aeromagnetic surveys and from abundant float.

The groundwaters at Windimurra are neutral (pH 6-8) and fresh to mildly brackish. They differ significantly from the surrounding borefield groundwaters from a shallow calcrete/ferricrete aquifer, and a deeper hyper-saline palaeochannel aquifer used for mineral processing.

Vanadium is relatively immobile during weathering of the SDZ, therefore its movement is constrained to distances between 50 mm and 1 m (Habeteselassie et al, 1996). Fractured rock groundwater has V at or below detection.

ACKNOWLEDGEMENTS

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REFERENCES

Ahmat, A.L., 1986. Petrology, Structure, Regional Geology and Age of the Gabbroic Windimurra Complex, Western Australia. PhD Thesis, University of Western Australia, 279 pp (unpublished).

Habeteselassie, M.M, 1993. Vanadium Distribution in the Shephards Discordant Zone, Windimurra Complex, Western Australia. MSc Thesis, University of WA (unpublished), 89 pp.

Habeteselassie, N.M., Mathison, C.I., and Gilkes, R.J., 1996. Vanadium in Magnetite Gabbros and its Behavour during Lateritic Weathering, Windimurra Complex, Western Australia. Australian Journal Earth Sciences, 43, 555-566.

Alan Tingay and Associates, 1998. Windimurra Vanadium Project Environmental Management Plan, Report no. 98/78, for Vanadium Australia Pty Limited part 1 11-15 (unpublished).

Withall, J., 2001. Windimurra vanadium mine. Archean granite-greenstones of the central Yilgarn Craton, Western Australia – a field guide. Western Australian Geological Society, Record 2001/14, 76pp.

SAMPLE MEDIA – SUMMARY TABLE

Sample Medium	Indicator Elements	Analytical Method	Detection Limits (ppm)	Background (ppm)	Threshold (ppm)	Max Anomaly (ppm)	Dispersion Distance (m)
Fresh Rock	V Ti Fe	XRF, AT/OES, XRD	2 5 0.01 %	103 n/a n/a	0.1% n/a n/a	1.7% 29% 62%	<1 0 0
Top of Basement	V Ti Fe	XRF, AT/OES, XRD	2 5 0.01 %	103 n/a n/a	0.1% n/a n/a	1.7% 29% 62%	<1 v. large variable
Colluvium-basement interface	V Ti Fe	XRF, AT/OES, XRD	2 5 0.01 %	103 n/a n/a	0.1% n/a n/a	1.7% 29% 62%	<1 variable variable