

THE MARLBOROUGH NICKEL LATERITE DEPOSITS

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INTRODUCTION

The Marlborough Nickel deposits are a series of discrete nickel enrichments over a 30-50 km² area, approximately 100 km NW of Rockhampton Central Queensland, Australia (149°53'30"E, 23°00'30"S) on the boundary of the St Lawrence and Daringa 1:250,000 sheets. They have formed on the ultramafic rocks of the Marlborough Block.

The enrichment was discovered in 1962 by the Geological Survey of Queensland (GSQ). Throughout the 1960's and 1970's BHP and INAL drilled over 2000 reverse-circulation and air core holes. Queensland Nickel Pty Ltd acquired the exploration leases in 1986 and developed the Brolga deposit in the southern end of the region. Full-scale mining of the Brolga deposit began in 1993 and ceased 2.5 years later in 1995. Preston Resources acquired the Marlborough portion of the Nickel deposits from Central Queensland Nickel in 1997 and began an extensive resource proving operation. In 1998 the mine feasibility was completed. The current proved reserve is 52 million tonnes at 0.88% nickel and 0.06% cobalt with an estimated resource of 210 million tonnes of ore grading 1.02% nickel and 0.06% cobalt (Preston Resources 2000).

The Marlborough Block is a sliver (approx 3 km thick) of serpentinitised harzburgite ophiolite that dominates the landscape of the Marlborough district, forming a series of raised ridgelines with the surrounding granites and volcanics as flat low valleys (Bruce *et al.* 1998, Korsch *et al.* 1997). The rock is now covered by a thick weathering profile containing economic enrichments of Ni, Co and chrysoprase. Chrysoprase is a semiprecious quartz rich gemstone being mined by Gumigil Pty Ltd. for jewelry and other items. The groundwaters that flow out of the serpentinite hills are supersaturated with magnesium (Mg²⁺) neutralised with OH⁻ and HCO₃⁻ and are thought to be responsible for the formation of the extensive nodular magnesite deposits (Kunwarara and Triple Four) that are present in the valleys to the east. The Kunwarara magnesite deposit is currently being mined by the Australian Magnesia Corporation (AMC) for blast furnace briquettes and magnesium metal. All three mineralisations are formed from the weathering of the ultramafics.

REGOLITH ARCHITECTURE

A generalised robust regolith architecture of an *in situ* weathering profile has been developed (Figure 1, Table 1). It is based on the weathering boundaries identified by drill logging, mineralogy and geochemistry:

Surficial (SUR) - Ferruginous rubble, soil, siliceous boxwork boulders, gravel and scree. Commonly found as a thin covering on the regolith profile. According to the Australian Soils Classification (Isbell 1996), soils of the area are dominantly Ferrosols and Kandosols.

Sediment (SED) - Rounded quartz pebbles and ferruginous nodules. Primarily found within a surficial ferricrete/silcrete profile that outcrops as an elongate (10-20 m wide and up to 500 m long) sinuous capping along the tops of ridgelines and hills. Geochemically the sediments are low in Ni and Mg and high in Zr, Fe and silica. Mineralogically the sediments are high in quartz and kaolinite.

Ferruginous Laterite (LAT) - Commonly found at the surface or below sediments along ridgelines and slopes, the ferruginous unit is a thin (1-10m) horizon composed primarily of hematite, goethite and siliceous (chalcedony) residuum. Geochemically the laterite unit is low in Ni, Mg and Co and high in Fe and Si.

Siliceous Unit (SIL) - Layered, light brown-to-brown silica (up to 87 wt. %). The siliceous unit may occur at any level in the regolith and commonly occurs in association with other regolith units such as saprolite veins and clay bands interlayered with the silcrete. This unit usually has low Mg, whilst being enriched in Fe and Si. Nickel and Co concentrations vary throughout the unit depending upon the quantity of clay and/or saprolite that is present.

Clay (CLY) - Clay is present in several forms throughout the entire regolith profile. XRD analysis reveals that the clays are dominantly smectitic, however, chlorite is also common. Geochemistry of the clays is variable and dependant on the clay type. The clays commonly carry ore grade Ni and Co, variable Mg values and may in some cases correlate with Al enrichment.

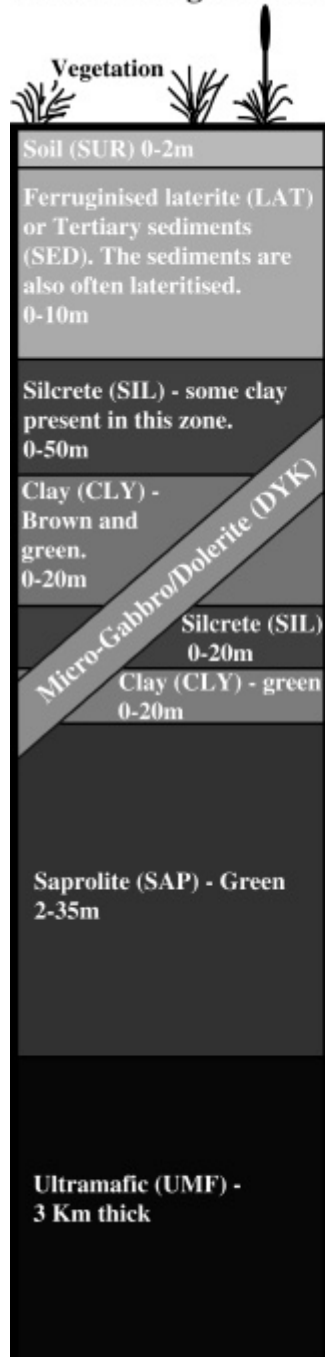
Saprolite (SAP) - The saprolite is predominantly composed of 5 cm to 50 cm blocks with fibrous needle-like or layered crystal pseudomorphs of weathered serpentinite, chlorite and talc. They have a separation of light and dark green minerals, some black dendrites along block boundaries and Fe staining of some chips. Geochemically, the saprolite has significant Mg and Ni values and is low in Fe. It often represents an Mg

discontinuity.

Dyke (DYK) - Dykes consist of dolerite, micro-gabbro and dunite. Dykes vary in width from 30 cm to 5 m. They are low in Ni and Co and moderately enriched in Fe and Mg. A highly weathered dyke is characterised by yellowish-white smectite.

Ultramafic (UMF) - Hard dark green-black serpentinised harzburgite (oceanic mantle peridotite). Serpentine, pyroxene and olivine have been identified through XRD analysis. Geochemically it is typically lower in Ni and Co than the saprolite although Mg levels remain high.

Idealized Regolith Profile



Geochemical Zones

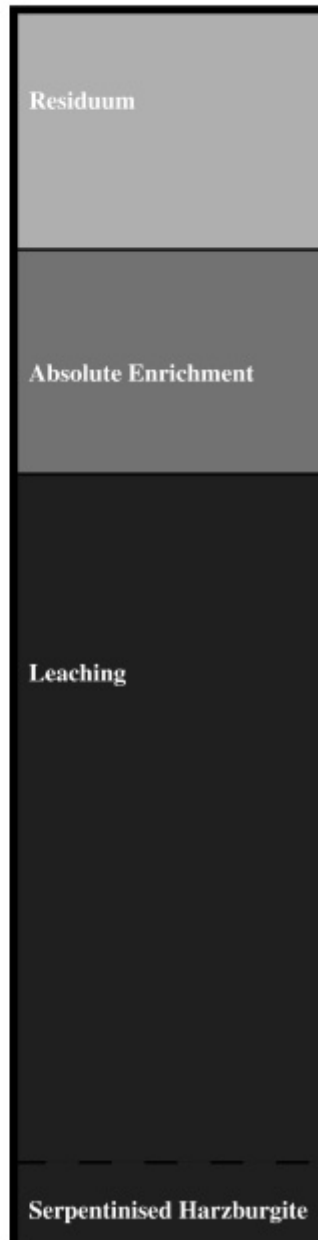


Figure 1: Idealised regolith profile and generalised geochemical trends in the regolith of the Marlborough Ophiolite.

Note:

- All zones described may be present in a profile, however some profiles have only saprolite and ultramafics.
- Blocks of less weathered material may be present higher in the profile than they should be. These blocks are probably less jointed areas that have resisted weathering to become a core stone.

EVOLUTION

Nickel distribution in the weathering profile appears to be controlled by three distinctive geochemical processes that form separate horizons: leaching; absolute enrichment; and residuum. The residuum horizon is where most elements, excepting Fe, Al and sometimes Si, are mobile. Nickel and Co levels in this horizon are usually uneconomic and decrease up-profile with the top of the residuum horizon having as little as 0.1%

Ni. The Ni in this horizon is commonly oxide and clay hosted. The absolute accumulation horizon is a portion of the regolith where Ni, Mn and Co appear to be enriched by absolute accumulation. The Si and any remaining Mg, along with Ni, Co, Cr and other trace elements, are dissolved from the overlying regolith and move downward in meteoric fluids and ground water to a level above the saprolite. Here Mg and Si released from the weathering ultramafic precipitate, primarily as Mg or Fe silicate clays, saponite, nontronite talc and quartz. Ni and Co substitute for Mg in silicates and hence this clay unit becomes a zone of absolute enrichment of nickel, typically containing 1-4% Ni. Alternatively, Brand *et al.* (1998) argue that the Ni precipitation at a particular section in the regolith may be caused by a porosity boundary or a pH-Eh shift. Manganese accumulations in this horizon indicate that a pH-Eh change may contribute to its development. The leaching horizon is where more mobile elements such as Mg are leached from the profile and there is a residual accumulation of immobile elements. Material leached from this horizon is often completely removed from the sequence. The upper half of the horizon often has economic grades of Ni and Co and the Ni in this horizon is primarily silicate hosted.

Table 1: Geochemical variation throughout the weathering profile.

Units	Enriched	Depleted	Variable
Sheet wash/soil (SUR)	Fe, Al		All elements
Sediments (SED)	Si, Zr, Ti, K, Al, Sr, Nb, Sn, Th	Ni, Fe, Mn, Cr, Mg, Co, Zn, W, Hf, Tl	
Laterite (LAT)	Fe, P, Al, Ti, Zr	Ni, Mg, Mn, Cr, Zn Co	
Clay (CLY)	Ni, Mg, Fe, Al, Co	Si	Mg, Mn
Siliceous (SIL)	Si, Fe	Mg, Al	Ni, Mn
Saprolite (SAP)	Mg, Ni, Ca	Fe, Si, Cr	Mn
Magnesite (MAG)	Mg, Ca, Cs	Fe, Si, Al, Co, Sc, Se, K, Cr, Ni	
Ultramafic (UMF)	Mg, Ni, Ca, S	Ni, Fe, Si, Cr, Mn, Al	Co
Dyke (DYK)	Ti, K, Al, Ca, Na, Cu, Zr, Ba, Ce, Nd, Fe	Ni, Si, Cr	Mn, Mg

The Marlborough Nickel laterite deposit appears to have all three mineralisation styles outlined by Brand *et al.* (1998) with several different mineral hosts identifiable in the regolith. They broadly correlate with regolith and geochemical horizons in the weathering profile. The mineralisation styles may vary across the prospect as well as vertically:

- Silicate hosted Ni: Serpentinite, garnierite, talc, chrysoprase & sepiolite. This style of mineralisation is found in the saprolite;
- Clay hosted Ni: Nontronite, saponite & other smectites. This style of mineralisation is found in the clay horizons; and,
- Oxide hosted Ni: Goethite & manganese oxides. Located in the base of the laterite unit. This mineralisation style is rare at Marlborough.

CHYSOPRASE

Chrysoprase is a green cryptocrystalline variety of quartz that contains 1-3% Ni. It is found throughout the regolith at Marlborough and is commonly associated with clear quartz and magnesite veins (Figure 2). Recent research indicates that a Ni-Talc phase, willemseite or pimelite $[(Ni_{2.45}Mg_{0.55}) Si_{3.95}O_{10}(OH)_{1.8}]$, is responsible for the green colour. Nickel-free chalcedony also appears throughout the high-grade chrysoprase. It appears to have formed alongside the nickeliferous chalcedony. Thin-section analysis indicates that the chrysoprase has a fabric similar to silcrete.

MAGNESITE

Magnesium-rich groundwater flowing out from the nickel laterite is thought to be the source of the magnesite that has formed in the valleys to the east of the serpentinite hills. The magnesite has no surface exposure because it is covered by a thick layer (1-5 m) of humus-rich black clay. Underneath the black soil plains lies a fluvial sequence which hosts the magnesite. The magnesite is present as irregularly sized nodules (from 1 mm to 50 cm diameter) and magnesite mud lenses.



Figure 2: Gumigil Chrysoprase Mine. The mine has cut approximately 75m into the regolith of the Marlborough Ophiolite.

CONCLUSION

The Marlborough Ophiolite dominates the regional regolith development with weathering profiles up to 100 m in thickness. It is this extensive chemical weathering, through atmospheric exposure of the ophiolite that has led to the development of three significant secondary mineralisations of economic scale. The nickel-laterite hosts a chrysoprase enrichment and is the source of magnesium for the extensive valley magnesite deposits. The mineralogical, geochemical and aqueous data from the weathered Marlborough Ophiolite demonstrate a genetic link between these mineralisations.

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