Horizonte Minerals Plc

NI 43-101 Technical Report on the Vermelho Project, Para State, Brazil

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1 SUMMARY

1.1 Introduction

This National Instrument 43-101 (NI 43-101) Technical Report describes the Vermelho Nickel Cobalt Project (“the Project”), an advanced mineral exploration area located in the region of Carajás, in the State of Pará, Brazil. The acquisition of the Vermelho Nickel Cobalt Project was announced by Horizonte Minerals Plc (HZM) on 19 December 2017, disclosing an agreement with Vale S.A. (formerly CVRD), the owner, to acquire 100% of the Project.

1.2 Property description and ownership

The Project area is characterised by relatively flat terrain, with two hills forming the V1 and V2 deposits. The hydrographical basin is formed by the Araras and the Verde Rivers, both of which are tributaries of the Parauapebas River.

The original vegetation is the equatorial latifoliated forest, with transitions to a tropical forest, dominated by low and medium size plants, and locally with very tall trees. However, much of the area has been deforested, and is currently used for agriculture purposes.

The Vermelho licence is located near Canaã dos Carajás in the Carajás Mining District and 45 km south of the municipal district of Parauapebas. Originally an Exploration Licence, the Vermelho licence is now described by DNPM Process 808.055/1974 and covers 2,000 hectares including the V1 and V2 nickel-cobalt laterite deposits. The title was transferred from Vale S.A. to Vale Metais Basicos S.A. in 2015.

The mineral rights phase is in between the first stage (Exploration) and the second stage (Mining) – i.e. in the period where a mining licence application (or “Requerimento de Lavra”) is submitted to and decided by the “Departmento Nacional de Produção Mineral” (DNPM). Currently, the Mineral Rights process is pending a decision by the DNPM regarding the revised “Plano de Aproveitamento Econômico da Jazida” (economic development plan or “PAE”) submitted by Vale on August 2016.

Access to the area is by plane from Brasilia, to Marabá (Pará), then by road from Marabá along 227 km of paved road to Canaã dos Carajás. Alternatively, access is possible by plane from Belem (Pará) to Canaã dos Carajás. The licence area is navigable in a 4x4 vehicle along drill access tracks which may now be overgrown or eroded.

1.3 Geology and mineralisation

Two hills named V1 and V2 (after Vermelho 1 and Vermelho 2) are aligned on a northeast-southwest trend, overlying ultramafic bodies. A third ultramafic body, named V3, also located in the same trend, lies on flat terrain, southwest of V2. The ultramafic bodies have had an extensive history of tropical weathering, which has produced a thick profile of nickel-enriched lateritic saprolite at V1 and V2.

The V1 and V2 deposits form flat lying topographical highs. The V2 hill is located approximately 2 km southwest of V1. The V1 hill has a deformed convex-concave shape (convex to northeast), and extends for approximately 2.4 km east-west, ranging from 700 m to 1.6 km north-south. The V2 hill has an east-west elongation, and extends for approximately 1.9 km east-west, ranging from 600 m to 900 m north-south. The V1 deposit has an average thickness of 53 m and a maximum thickness of 146 m, whereas the V2 deposit has an average thickness of 56 m and a maximum thickness of 115 m.

The ultramafic bodies are erosional relicts of the upper sheet of a three-layer intrusion, represented, from bottom to top, by a mafic zone (gabbros, gabbro-norites and leuconorites), a pyroxenite zone (orthopyroxenites and chromitites, with circa 50 m thickness) and a peridotite zone (serpentinised dunites and harzburgites, with circa 150 m thickness). The northeast-southwest oriented, 10 km long and 2 km wide, layered intrusion has intruded a package of gneisses and migmatites belonging to the Xingu Complex. Late sub-vertical diabase dykes intersect the three layers in different directions. Various chromitite levels have been identified at the southern sides of both V1 and V2 within the pyroxenite zone.

The mineralisation at Vermelho is contained within intensely weathered serpentinites, weathered to saprolites. These saprolites are characterised by extensive silicification, generally in the form of veins, boxworks and massive zones of chalcedonic silica. Five main material types can be identified in the lateritic profile (from bottom to top):

- High Magnesium (Garnieritic) Saprolite, is characterised by the predominance of serpentinite and relict structures, and MgO above 10%; the Ni grades usually exceed 1.5%, sometimes reaching 10% (15 m average thickness).
- Siliceous Saprolite, or Low Magnesium Saprolite, with SiO_2 grades ranging from 35% to 65%, and boxwork structures are usually packed with Fe oxides and hydroxides; the Ni grades range from 0.6% to 1.5% (20 m average thickness).
- Massive Silica, formed of thick, very resistant massive silica crusts, with SiO_2 grades usually above 65%, sometimes reaching 90%; the Ni grades rarely exceed 0.25% (30 m average thickness).
- Ferruginous Saprolite, is composed of finely grained and porous Fe oxides and hydroxides (goethite, limonite, hematite), and forming discontinuous and irregular lenses within the siliceous saprolite or the massive silica; the Fe_2O_3 grade commonly exceeds 80%, and the SiO_2 grade is lower than 35%; the Ni grades range between 0.6% and 1.5% (15 m average thickness).
- Overburden, formed of fine ferruginous soil, organic residues, and ferruginous concretions, commonly with rounded shapes (1 m average thickness).

Two main mineralisation types are recognised: silicate at the base and oxide at the top of the weathering profile. The mineralogical composition of the silicate zone, with 1.8% NiO in average, consists largely of serpentine, chlorite, and spinels, with quartz and goethite in minor amounts. Serpentine and chlorite are the main nickel-bearing minerals, Ni being about equally distributed between the two phases (2–3% NiO). There is no significant development of an enriched transition mineralisation type between the oxide and silicate horizons.

The oxide material, with 1.2% NiO on average, is composed predominantly of goethite, and contains chlorite, spinels and silica. In this case, the nickel is highly concentrated in chlorite (average 12% NiO), whereas in goethite, the NiO content ranges between 0.9% and 1.7%. As a result, the presence of chlorite, even in minor quantities, is important in elevating the grade of the oxide ore. Locally, higher grades of mineralisation can also be due to the presence of nickeliferous smectites.

Barren zones within the lateritic profile are represented by serpentinite blocks, strongly silicified bands, mafic or pyroxenitic dykes, and ferruginous concretions (common at the top of the section). A transitional saprolitic zone occurs at the base of the mineralised zone, with Ni grades usually ranging from 0.25% and 0.50%.

1.4 Status of exploration, development and operations

The Vermelho area was explored in various stages by CVRD from 1974 to 2004 involving approximately 152,000 m of combined drilling and pitting. The drilling grid density was substantially enhanced in 2002 to 2004, and most of the resources were upgraded to the Measured category as defined in JORC (2004). Pilot plant metallurgical studies were conducted in Australia focused on the High-Pressure Acid Leach (HPAL) processing method. A Prefeasibility Study (PFS) was prepared in 2003, and a Feasibility Study (FS) was completed in August 2004 by GRD-Minproc (2005). This study confirmed the positive economic outcomes obtained in previous studies and showed production capacity of 46,000 tonnes per annum (t/a) of metallic nickel, and 2,500 t/a of metallic cobalt. Vale (formerly CVRD) elected to place the Vermelho project on hold after delivery of the FS.

No field activities have occurred since 2004.

1.5 Mineral Resource estimates

During February 2018, the author reviewed the historical mineral resource estimates (MREs) (Section 6.2) and concluded that the FFS_25_2_m MRE that was audited by Snowden in 2005, is appropriate for adoption as a current MRE and concluded that the reporting conforms to the requirements of the JORC Code (2012 Edition).

At a cut-off grade of 0.90% Ni Equivalent (where NiEq = Ni % + 6 x Co%), a total of 161.4 million tonnes (Mt) at a grade of 1.34% NiEq is defined as a Measured Mineral Resource and a total of 6.4 Mt at a grade of 1.29% NiEq is defined as an Indicated Mineral Resource. This gives a combined tonnage of 167.8 Mt at a grade of 1.34% NiEq for Measured and Indicated Mineral Resources using a cut-off grade of 0.90% NiEq. A further 2.8 Mt at a grade of 1.23% NiEq is defined as an Inferred Mineral Resource at a cut-off grade of 0.90% NiEq. The Mineral Resource is summarised in Table 1.1.

Table 1.1 V1 + V2 – combined classified Mineral Resource report for Vermelho above 0.9% NiEq cut-off

Classification	Tonnage (Mt)	NiEq %	Ni %	Ni metal (kt)	Co %	Co metal (kt)	Fe_2O_3 %	SiO_2 %	MgO %
Measured	161.4	1.34	1.01	1,629	0.06	90	31.5	42.6	9.95
Indicated	6.4	1.29	0.93	59	0.06	4	27.5	50.3	6.85
Measured + Indicated	**167.8**	**1.34**	**1.01**	**1,688**	**0.06**	**94**	**31.3**	**42.9**	**9.83**
Inferred	2.8	1.23	0.94	27	0.05	1	25.9	41.8	13.5

1.6 Historical Mineral Reserve estimates

In 2005, Snowden Mining Industry Consultants reported a historical Mineral Reserve of 187 Mt at 0.93% Ni comprising 179.7 Mt at 0.93% Ni as Proved Mineral Reserve and 7.4 Mt at 0.83% Ni as Probable Mineral Reserve, in accordance with JORC (2004) guidelines. The Snowden mining study was part of the Vermelho FS of GRD-Minproc (2005).

A Qualified Person has not done sufficient work to classify any of the historical estimates as current Mineral Reserves.

1.7 Conclusions and recommendations

The Vermelho licence acquired by HZM is within the Carajás Mining District, an active mineral exploration and mining region with advanced infrastructure and services to support development of Vermelho. The previous operator had completed a FS to produce nickel and cobalt from open pit mining of the V1 and V2 deposits and processing via the HPAL method.

HZM is currently finalising a FS on its Araguaia nickel-cobalt deposits located approximately 85–150 km from Vermelho and is proposing open pit mining from numerous deposits and processing via the Rotary Kiln Electric Furnace (RKEF) method. HZM is familiar with operating in the region and is well placed to consider what synergies exist in the development of the Araguaia and Vermelho projects.

MREs are deemed "current" and are reported in conformance with JORC Code (2012) and CIM guidelines.

The author recommends the following:

- Processing options (RKEF or HPAL) for Vermelho require consideration by HZM. If based on this review, RKEF is the preferred processing route, then additional testwork is required. If existing samples are inadequate, then additional drilling will be required.
- Based on a current MRE and process options review, HZM should complete a Preliminary Economic Assessment (PEA) to determine the potential viability of the Project.

2 INTRODUCTION

This Technical Report has been prepared by Snowden for HZM, in compliance with the disclosure requirements of the Canadian National Instrument 43-101 (NI 43-101). The trigger for preparation of this report is the 6 May 2018 press release of HZM, disclosing MREs for the Vermelho Nickel-Cobalt Project.

Unless otherwise stated, information and data contained in this report or used in its preparation has been provided by HZM having access to the data-room of CVRD who completed a FS in 2005 (GRD-Minproc, 2005).

The Qualified Person for preparation of the report is Andrew F. Ross of Snowden who visited the project site from 9 to 12 December 2003 when drilling by CVRD was in progress. The Qualified Person has not made a current site visit and is advised by HZM that no meaningful activities were conducted at site since the completion of the FS in 2005.

3 RELIANCE ON OTHER EXPERTS

The author has relied upon the legal and environmental information provided by the following employees of HZM for inclusion in Section 4 (Property Description and Location):

- Mr Steven Heim, on 7 January 2018, provided an overview of mining legislation (Section 4.2) and tenement details (Section 4.3)
- Ms Katie Millar, on 3 January 2018, provided a status summary of environmental and social impact and other assessment permits (Sections 4.5 and 4.6).

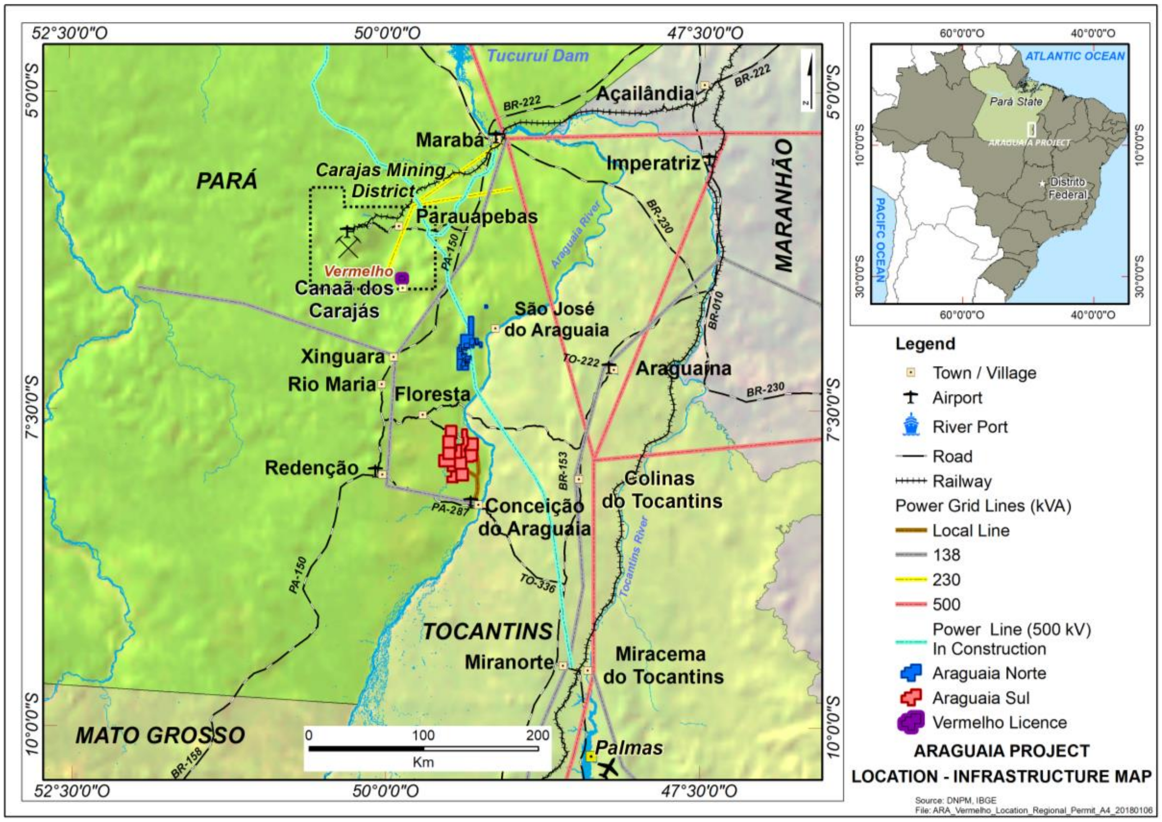
In addition, Mr Bernardo Freitas of Freitas-Ferraz, the principal lawyer on the Vermelho acquisition for HZM, advised that the mineral rights phase is in between the first stage (Exploration) and the second stage (Mining) (Section 4.3).

4 PROPERTY DESCRIPTION AND LOCATION

4.1 Location

The Vermelho licence is located near Canaã dos Carajás in the Carajás Mining District and 45 km south of the municipal district of Parauapebas in the Pará state, northern Brazil (Figure 4.1). Vermelho is located approximately 85 km from the northern part of HZM's Araguaia Project (Araguaia Norte).

Figure 4.1 Location map



Source: HZM

4.2 Mining legislation overview

The main sources of mining legislation in Brazil are the Federal Constitution and the Mining Code (Decree-law no. 227 of 28 February 1967). The Mining Code defines and classifies deposits and mines, sets requirements and conditions for obtaining authorisations, concessions, licences and permits, the rights and duties of holders of exploration licences and mining concessions. There are two main legal regimes under the Mining Code regulating exploration and mining, i.e. the "authorisation" for exploration and the "concession" for mining.

Exploration, which is defined by the Mining Code as the work required to locate and define a deposit and determination of the economic feasibility thereof, can be carried out through an authorisation from the Federal Government. The exploration authorisation is granted through a licence issued by the Director General of the "Departmento Nacional de Produção Mineral", or DNPM as it is commonly referred to. DNPM is the federal agency in charge of implementing the country's exploration and mining, fostering the mining industry, granting and managing exploration and mining titles and monitoring the activities of exploration and mining companies.

Exploration licences may be for areas up to 10,000 hectares and be granted for a period of up to three years depending on the substance being sought. Nickel qualifies for up to the maximum area and three years. The term (three years) can be renewed once, at the discretion of the DNPM, upon its review of an interim Partial Exploration Report ("Relatório Parcial de Pesquisa" (RPP) from the licence holder regarding exploration conducted to date which justifies further exploration. Prior to the termination of the exploration licence, be it the initial three-year period or in the case of renewal its second three-year period the holder must submit a "Relatório Final Único De Pesquisa" (RFP), the Final Exploration Report, on the results of the work to DNPM. DNPM may then decide to:

- Approve the report, when it shows the existence of a resource which can be both technically and financially developed;
- Dismiss the report, when the exploration work undertaken was insufficient or due to technical deficiencies in the report;
- File the report, when it has been proved that there was no deposit which may be both technically and/or financially developed; or
- Postpone a decision on the report in the event the existence of a resource has been demonstrated, but for technical and/or financial reasons development of the property is not feasible at the time.

The decision to postpone a decision on the Final Exploration Report is referred to as "Sobrestamento". With this decision DNPM will fix a period in which the interested party will be required to submit a new technical-financial FS of the deposit. This is normally a three-year period (decree-portaria 21/97). The penalty for not meeting the deadline will be the archiving of the RFP and liberation of the area. If the new study does not demonstrate technical-financial feasibility, DNPM may grant the interested party an extension to the time limits or open a tender process for the licence if they believe there are third parties who could feasibly mine the deposit. If the new study demonstrates technical-economic feasibility, the RFP will be approved, and the holder of the licence will have one year to apply for a mining concession. An extension of one year can be requested in applying for the mining concession.

If the licence holder does not apply for the mining concession within the period mentioned above, the mineral rights over the property will lapse and the area becomes available for tender offers for 60 days, during which period any interested parties, including the previous licence holder, may submit their offers for an exploration licence or mining concession. The DNPM will review the offers and will select the bid that, in its view, presents the most favourable conditions to meet the interests of the mineral sector. If no offers are submitted within the 60-day period, the area will then be considered as available for future applications for exploration licences under the priority system described above.

The application for a Mining Concession must be accompanied by the following information:

- I – The company's certificate of registration from the Board of Trade;
- II – Identification of mineral substances to be mined, with a copy of the exploration permit and the approval of the exploration final report (RFP);
- III – Name and description of the area intended for development, clearly and accurately reporting all river valleys or streams identified on maps or charts of known authenticity and exactitude; all railways and highways or any natural or topographical features of unmistakable determination; boundary lines with neighbouring Exploration Consents and Exploitation Consents if any; and the identification of the District, Municipality, Circuit, and State; as well as the name and residential address of the owners or possessors of the land;
- IV – A graphic depiction of the intended area, circumscribed by a geometric figure formed by straight lines with a true north-south and east-west orientation, with two of their vertices, or in exceptional cases, one, anchored to a fixed, unmistakable point of the land, with the vectors defined by their lengths and true bearings, and showing the properties covered, indicating the names of the respective holders of rights to the surface of the soil, in addition to the site plan;

- V – Easements that apply to the mine;
- VI – Economic development plan of the deposit, with a description of the beneficiation plant;
- VII – Proof of the availability of funds or the existence of financial commitments necessary for the execution of the economic development plan and mining operations.

The economic development plan of the deposit known as the "Plano de Aproveitamento Econômico da Jazida" (PAE) consists of:

- I – A descriptive report;
- II – Pertinent designs or preliminary plans:
  - the mining method to be adopted, referring to the initially forecasted production scale and its projection;
  - the lighting, ventilation, transportation, signalling and work safety plans in the case of underground mining;
  - the surface transportation, beneficiation, and stockpiling of the ore;
  - the power installations, water supply, and air conditioning;
  - the hygiene of the mine and respective work;
  - the housing facilities and their habitability for all who live in the mining area;
  - the installations for the supply and protection of the origin, storage, distribution, and use of water for Class VIII deposits.

The design of the installations and equipment referred to in the economic development plan shall be consistent with the production justified in the descriptive report and include a forecast for future expansions.

The Mining Concession will be denied if the development is considered by the Government to be prejudicial to the public welfare or compromises interests that transcend the use of the industrial exploitation. In the latter case, the explorer shall have the right to receive indemnification from the Government for expenses spent on the exploration work, once the exploration final report has been approved.

The holder of a mining concession must inter alia: (i) commence development within 180 days from the granting of the concession, subject to obtaining all required environmental licences and authorisations; (ii) refrain from suspending development and mining operations for more than six months without the prior approval of the DNPM; (iii) mine according to the mining plan approved by the DNPM; (iv) compensate the land owner for occupation of the property; (v) pay a royalty to the landowner; (vi) pay a royalty to be distributed among the local, state and federal governments; (vii) obtain all required environmental licences and authorisations; (viii) restore the areas degraded by mining and processing operations and infrastructure; (ix) report annually to the DNPM on activities, production and sales.

Mining concessions may be transferred (in whole or in part) to legal entities incorporated in Brazil, if the transferee demonstrates technical and financial capability to the DNPM. The transfer is subject to the approval of and registration by the DNPM. Furthermore, mining concessions can also be encumbered, e.g. because of a judicial order or as a security. The mining concession may be relinquished by its holder at any time. In such event, the holder will, at the discretion of DNPM, be able to remove its property from the mine location provided that no damage is caused to the mine.

In general, mining projects must undergo a three-stage environmental licensing process. Generally, the State environmental authority oversees licensing a mining project for projects contained within one State, as opposed to the Federal environmental authority (IBAMA) whom are responsible for licensing mining projects across state borders. The Federal environmental authority will be in charge whenever mining activities will be undertaken in, or cause an impact on, areas deemed as federal, such as national environmental conservation units, as well as in cases where mining activities will be executed in two or more States. The compliance with all applicable environmental laws includes, but is not limited to, the possession by mining companies of all permits and other governmental authorisations required under applicable environmental laws, and compliance with the terms and conditions thereof, including the authorisations granted to impound water and exploit forest resources.

A Preliminary Licence (“LP”) must be obtained at the planning stage of the mining project. A Social and Environment Impact Assessment (“EIA RIMA”) and a plan for the restoration of degraded areas must be prepared at this stage. Public hearings are usually called to present the EIA RIMA to the communities and authorities. Following the public hearing, the State Environmental Agency (“SEMAS”) may or may not approve the issue the LP. The LP usually imposes conditions that must be complied with by the mining company. By granting the LP, the environmental authority acknowledges that the project is environmentally acceptable. At this stage, the environmental authority will also set the amount of the environmental compensation, which is a minimum of 0.5% of the projected development investment.

The second stage of the environmental licensing process is the Installation Licence (“LI”) stage. During this stage the mining company must produce an Environmental Control Plan (“PCA”), among other documents and submit it to the environmental authorities. Once the PCA is approved, the LI is granted, usually under certain conditions. The mining company may start construction of the mine, plant and infrastructure. A mining concession can only be granted by the Minister of Mines once the mining company has obtained the LI.

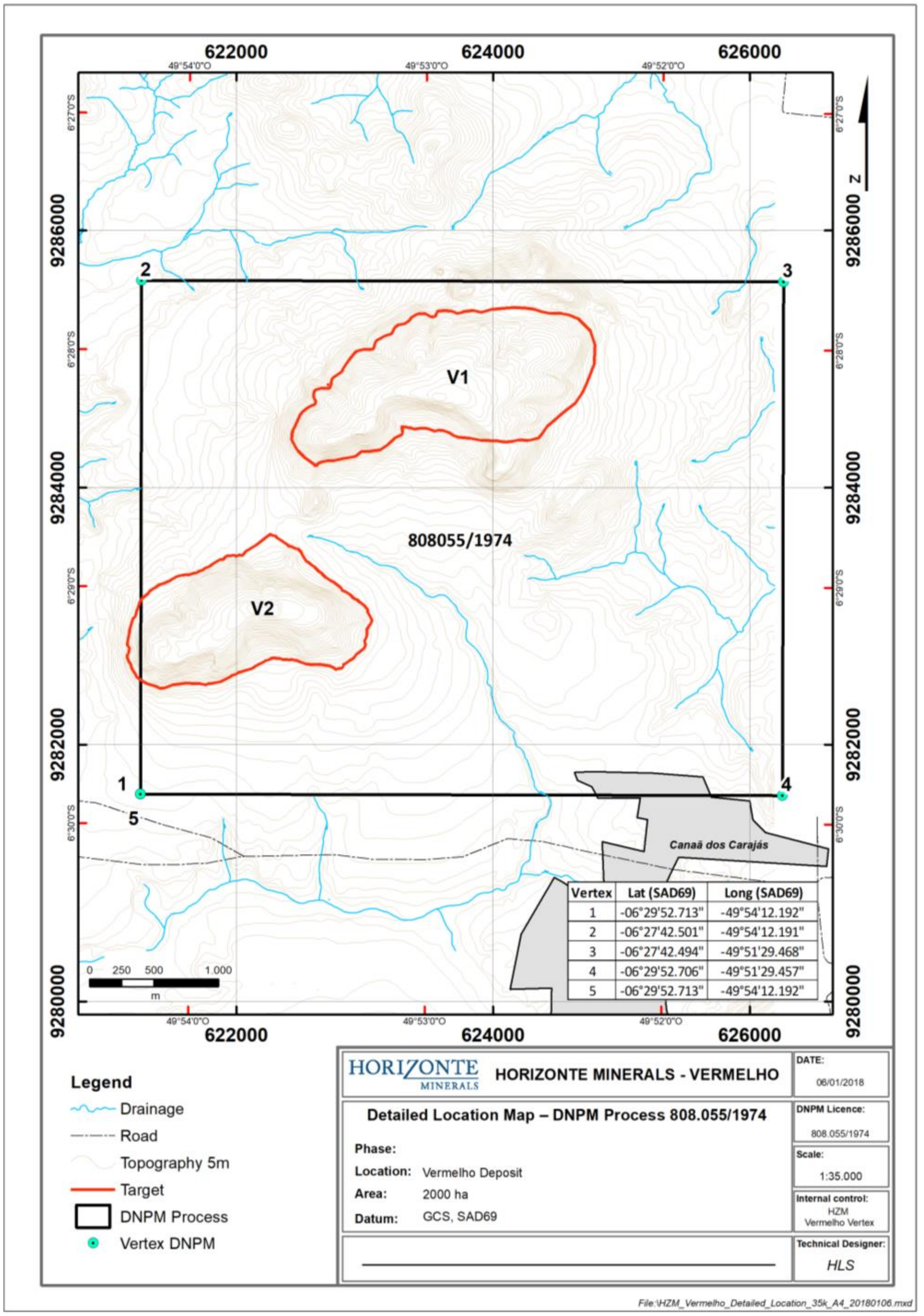
The last stage of the environmental licensing process is the one related to the Operation Licence (“LO”). The LO is granted once the environmental authorities are satisfied that the development and construction were completed in accordance with all the conditions of the LI and that the PCA is correctly implemented. The LO authorises a mining company to mine, process and sell (as well as other ancillary activities that may be described in the licence), from an environmental viewpoint. It is possible to renew the LO if the request is presented 120 days (or another period set by specific regulations) before the expiry date of the last permit. In that case, the LO is automatically extended until the environmental agency discloses its final decision about the request.

4.3 Vermelho licence

On 28 June 1974, CVRD (Vale) filed a request for an exploration licence which initiated DNPM Process 808.055/1974. Exploration Licence 1111 was published on 3 April 1978. At the end of the initial three-year exploration period, CVRD requested an extension which was renewed under the new licence number 1727, published on 12 June 1981. The Vermelho licence is described by DNPM Process 808.055/1974 and covers 2,000 hectares including the V1 and V2 nickel-cobalt laterite deposits (Figure 4.2). The title was transferred from Vale S.A. to Vale Metais Basicos S.A. in 2015.

Mr Bernardo Freitas of Freitas-Ferraz, the principal lawyer on the Vermelho acquisition for HZM, advised that the mineral rights phase is in between the first stage (Exploration) and the second stage (Mining) – i.e. in the period where a mining licence application (or “Requerimento de Lavra”) is submitted to and decided by the “Departmento Nacional de Produção Mineral” (DNPM). Currently, the Mineral Rights process is pending a decision by the DNPM regarding the revised “Plano de Aproveitamento Econômico da Jazida” (economic development plan or “PAE”) submitted by Vale on August 2016.

Figure 4.2 Licence surveyed vertices



Source: HZM

4.4 Issuer's interest

On 19 December 2017, HZM announced that it had reached an asset purchase agreement with Vale S.A. (Vale) to acquire 100% of the Vermelho Nickel-Cobalt Project. A total acquisition cost of US$8.0 million includes an initial cash payment of US$150,000 upon signing, and US$1,850,000 due on the second anniversary with the balance payable on sale of first commercial product.

In addition to the purchase price, HZM has granted a 1% Net Smelter Royalty (NSR) to Vale on any nickel produced during the first 10 years of commercial production up to a maximum of 15,00 t/a, which then reduces to a 0.5% NSR thereafter.

4.5 Environmental liabilities

The community of Canaã dos Carajás located on the southern boundary of Vermelho has seen significant development resulting from mining projects in recent years. The population increased approximately 30% from 26,700 in 2010 to approximately 35,000 in 2016.

The Vermelho Nickel-Cobalt Project does not include any publicly registered legal reserves or federal/state forests.

The main economic activities for the population include mining (copper and iron) and cattle farming.

A Full Environmental and Social Impact Assessment (EIA RIMA) was conducted and the Preliminary Licence (LP) subsequently granted for the Vermelho Project, demonstrating the government's approval of the environmental and social viability for the proposed HPAL project to produce 46,000 t/a nickel in cathode, 2,800 t/a cobalt and 500 t/a of copper (by-product) in the Canaã dos Carajás region.

4.6 Permits

HZM has summarised these as follows:

- Full Environmental and Social Impact Assessment (EIA RIMA) completed by CEMA consultants
- Preliminary Licence (LP) for Vermelho was granted to Vale in 2006, demonstrating government concurrence with social and environmental viability of project proposal
- Vale submitted a request for the Installation Licence (LI) in May 2007
- Vale decided not to progress the Vermelho Project, and the environmental licence process was discontinued with SEMAS as a result.

The current Project status is summarised as:

- The previous EIA RIMA, LP and all environmental licences relating to Vermelho mine and process plant contain background studies that will be useful to guide new social and environmental studies in the region.
- Once the concept design for the project is determined by the technical team within HZM, a new social and environmental impact assessment (EIA RIMA) will be conducted with the objective of obtaining an LP, and later LI to construct the Vermelho Project in line with HZM's proposed Vermelho Project characteristics.
- The company will require engagement with community groups in the region, as well as authorities, such as, but not limited to:
  - SEMAS – Para State Environmental Licensing agency
  - INCRA – Brazilian Land Authority
  - ITERPA – Para State Land Authority
  - IPHAN – Brazilian Institute of Historic and Artistic Heritage.

5 ACCESSIBILITY, CLIMATE, LOCAL RESOURCES, INFRASTRUCTURE AND PHYSIOGRAPHY

5.1 Topography, elevation and vegetation

As described in AMEC (2006), the project area is characterised by relatively flat terrain, with two hills forming the V1 and V2 deposits (Figure 5.1). The hydrographical basin is formed by the Araras and the Verde rivers, both of which are tributaries of the Parauapebas River.

The original vegetation is the equatorial latifoliated forest, with transitions to a tropical forest, dominated by low and medium size plants, and locally with very tall trees, including the cedar (*Cedera odera*), ipê roxo (*Tabebuia barbata*), angelim (*Hymenolobium petraeum*), maçaranduba (*Manikalra luberi*). Other common species include the cipós and various species of palm trees. However, much of the area has been deforested, and is currently used for agriculture purposes.

Figure 5.1 Topography and vegetation

Source: AMEC, 2006

5.2 Access

Access to the area is by plane from Brasilia, to Marabá (Pará), then by road from Marabá (by highway BA-155 and PA-275), along 227 km of paved road to Canaã dos Carajás. Alternatively, access is possible by plane from Belem (Pará) to Canaã dos Carajás. The licence area is navigable in a 4x4 vehicle along drill access tracks which may now be overgrown or eroded.

5.3 Proximity to population centre and transport

As described in AMEC (2006), the nickel laterite deposits are 6 km northeast from Canaã dos Carajás which was founded during the 1980s. The 2004 census recorded a district population of 13,000, mostly occupied with agriculture, cattle farming, and related services. The population increased approximately 30% from 26,700 in 2010 to approximately 35,000 in 2016.

Mineral discoveries in the region (copper at Sossego, nickel at Canaã dos Carajás) boosted the interest in the area. Local living and working conditions are improved due to major investments from CVRD.

The regional transport is good; railroads and highways connect the towns and cities of the state. Regularly scheduled air services are available in Carajás and Marabá, a main urban centre in this region, approximately 180 km from Carajás by highway. Most flights connect to Brasilia and to Belém, the capital of Pará. Parauapebas and Marabá are connected by the EFC railway to São Luís and by the PA-275 and PA-150 highways to Belém.

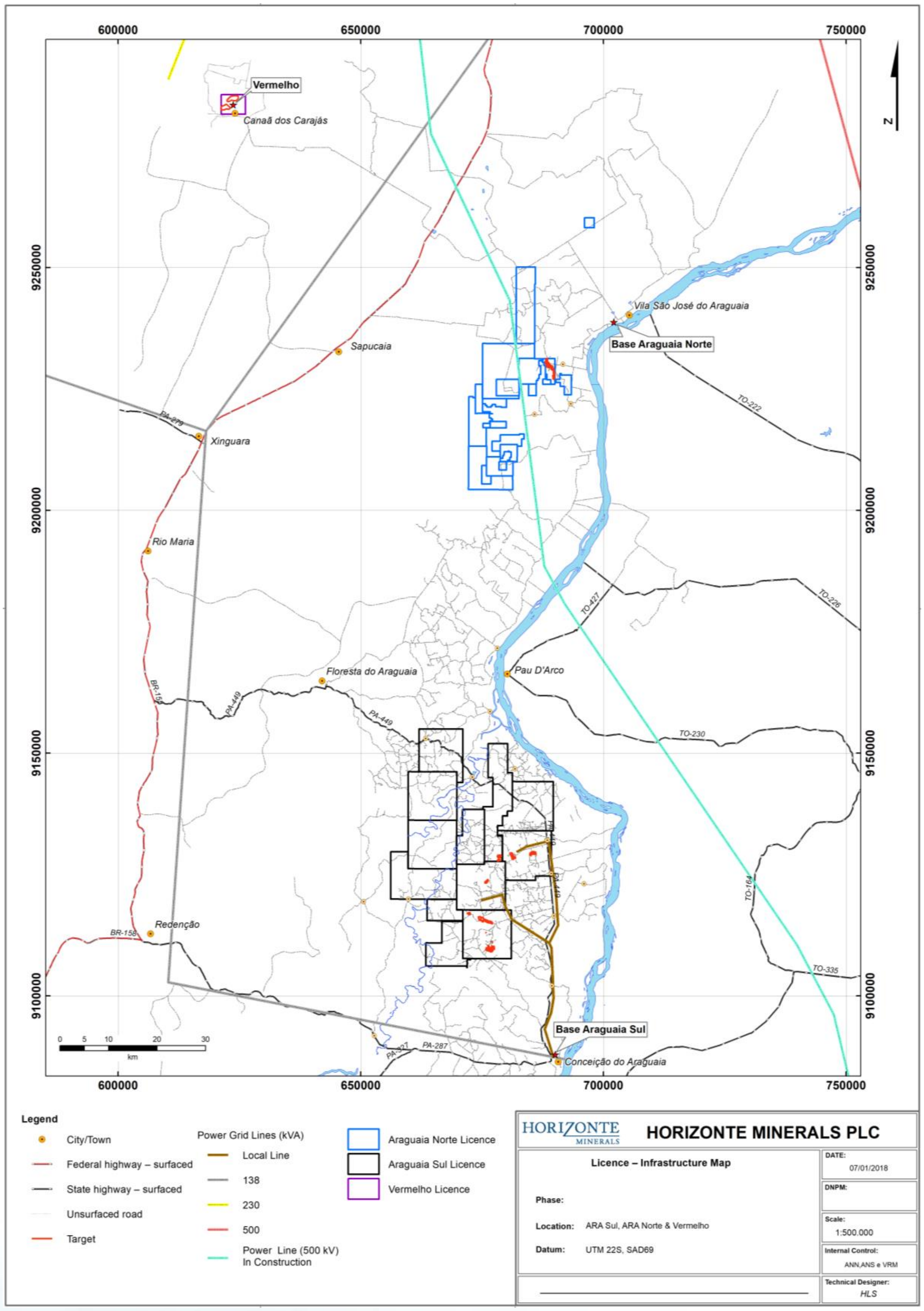
5.4 Climate and length of operating season

As described in AMEC (2006), the Vermelho property is in the Amazonas sedimentary basin. The climate is characterised by a hot and humid tropical climate, with two distinct seasons. A rainy season occurs from November through April, and a dry season from May through October. During the 30-year period from 1968 to 1998, the annual rainfall averaged 1,930 mm. On average, the heaviest rainfall is generally in March. Temperatures range from a low of 15°C to a high of 35°C. The operating season is yearly.

5.5 Infrastructure

Infrastructure is shown in Figure 5.2. As described in AMEC (2006), the Carajas district is an established mining region with well-developed infrastructure in place, including rail, roads and hydro-electric power.

Figure 5.2 Infrastructure



Source: HZM

6 HISTORY

6.1 Previous exploration and development work

As described in AMEC (2006), the Vermelho area was explored in various stages by DOCEGEO, the exploration company of CVRD. From 1974 to 1976, the presence of ultramafic rocks south of Serra dos Carajás were identified through the interpretation of radar data and photo-geological surveys, and subsequently followed by ground exploration, soil sampling, and limited drilling and excavation of shallow pits.

Further exploration was conducted in 1980 to 1982 and again from 1988 to 1991, comprising the digging of shallow pits, which allowed a better assessment of the nickel potential. More detailed exploration campaigns were conducted from 1993 to 1994 and 1997 to 1998, including drilling, shallow pits, and detailed sampling. By 1997, the exploration and metallurgical work indicated that a hydrometallurgical process route (HPAL) could be feasible. After this period, the total historical resource was estimated by CVRD at 32.9 Mt of garnieritic material averaging 1.7% Ni, and 190.9 Mt of lateritic material that graded 0.93% Ni and 0.08% Co. The drilling grid density was substantially enhanced, and most of the resources were upgraded to the Measured category. Pilot plant metallurgical studies were conducted in Australia. A PFS was prepared in 2003, and a FS was completed in August 2004 by GRD-Minproc (2005). This study confirmed the positive economic outcomes obtained in previous studies and showed production capacity of 46,000 t/a of metallic nickel, and 2,500 t/a of metallic cobalt. Vale (formerly CVRD) elected to place Vermelho on hold after delivery of the FS.

Approximately 152,000 m of combined drilling and pitting was completed by CVRD (Table 6.1).

Table 6.1 Summary of CVRD exploration

Description	V1		V2		Project area		Total	
	Unit	Drilling (m)	Unit	Drilling (m)	Unit	Drilling (m)	Unit	Drilling (m)
Pit excavation	251	3,903	231	3,585			482	7,487
Large-diameter drilling	86	3,582	152	7,333			238	10,915
Diamond drilling	39	2,931	24	1,806			63	4,736
Rotary percussion	1,289	72,875	867	50,768	65	1,370	2,221	125,013
Exploration pits					11	60	11	60
Mixed geotechnical drilling					20	788	20	788
Percussive geotechnical drilling					75	783	75	783
Auger drilling	15	8	13	8	296	265	324	280
Rotary geotechnical drilling	9	945	9	906			18	1,851
Totals	**1,689**	**84,243**	**1,296**	**64,405**	**467**	**3,265**	**3,452**	**151,913**

Source: Extracted from CVRD, 2004

6.2 Historical Mineral Resource and Mineral Reserve estimates

6.2.1 Historical Mineral Resource estimates

Following review by the author in February 2018, the sequence of MRE studies appears to have been:

Table 6.2 Sequence of MREs

Model name	Generated by	Year	Block size	Software	Audited by
PFS_25_2m	CVRD	2003	25 x 25 x 2 m	Gemcom	Snowden
Updated PFS_25_2m	CVRD	2004	25 x 25 x 2 m	Gemcom	Snowden
FFS_25_2m	CVRD	2004	25 x 25 x 2 m	Gemcom	Snowden
RFS_12.5_3m	CVRD	2005	12.5 x 12.5 x 3 m	Gemcom	AMEC
CVRD-SRK_12.5_3m	CVRD-SRK	2007	12.5 x 12.5 x 3 m	Gemcom	Not done
Snowden_25_1m	Snowden	2008	25 x 25 x 1 m	Datamine	Incomplete

6.2.2 PFS_25_2m MRE and block models

In August 2003, CVRD requested Snowden to undertake a mining study and optimisation as part of the PFS for the Vermelho Nickel Project. Preparatory to this mining study Christine Standing and Andrew Ross of Snowden conducted a brief review of the resource models and then provided on-going resource review and advice to CVRD. Following the review of the PFS resource model Andrew Ross, of Snowden, visited the Property from 9 to 12 December 2003 to observe field procedures during an infill phase of drilling that was underway at that time. This included the transport of core and RC samples from the drill rig to the core logging shed and sample farm respectively, sample storage, processing and security and the measurement of density.

The block models were generated using Gemcom v4 software. The block size was 25 m (X) x 25 m (Y) x 2 m (elevation).

6.2.3 Updated PFS_25_2m MRE and block models

In January 2004, CVRD requested Snowden to review the grade continuity for Ni, SiO_2 and MgO within the Baixo MgO, Alto MgO and SapFe domains for the areas of closed spaced drilling at the V1 and V2 deposits. Subsequent to this, Snowden reviewed the continuity of the beneficiated nickel grade in the areas of closed spaced drilling.

Following the implementation of Snowden's recommendations from the PFS resource review that capped data should be re-analysed and that additional domaining should be undertaken to separate the two Ni populations within the Alto MgO domain, the PFS resource models for the Alto MgO domain were updated by CVRD. Snowden was requested to conduct a brief review of updated resource models for V1 and V2 in February 2004.

The block models were generated using Gemcom v4 software. The block size was 25 m (X) x 25 m (Y) x 2 m (elevation). Table 6.3 provides a tabulation of this historical MRE.

Globally, there was little change in the updated PFS resource compared to the original PFS resources and an interim mining study was not undertaken on the updated PFS models. It was decided to update the entire models following infill drilling to an Final Feasibility study (FFS) level and to implement the mining studies based on the FFS models.

Table 6.3 Updated PFS_25_2m historical Mineral Resource estimate at 0.40% nickel cut-off

Resource category	Tonnage (Mt)	Contained Ni metal (kt)	Contained Co metal (kt)	Ni (%)	Co (%)	MgO (%)	SiO_2 (%)
Measured	250.9	2,105	110.6	0.84	0.04	8.28	-
Indicated	12.7	92	5.7	0.73	0.04	10.98	-
Measured + Indicated	**263.5**	**2,198**	**116.3**	**0.83**	**0.04**	**8.41**	**-**
Inferred	10.6	68	2.9	0.64	0.03	21.86	-

Source: Extracted from CVRD, 2004

6.2.4 FFS_25_2m MRE and block models

The resource models were updated for the FFS by CVRD from July to September 2004, and preparatory to the mining component of the FFS, Snowden was requested to review the updated FFS resource models and this was reported in January 2005. No further review was undertaken for the drilling operations and field procedures at V1 and V2.

The study was designed to incorporate a detailed understanding of the processes used to develop the FFS resource models, from the geological interpretation through to the hand-over of the model to the mining team. To achieve this Christine Standing, Principal Resource Geologist for Snowden, visited the Project site from 2 to 5 August 2004 and met with CVRD personnel responsible for the capture of the assay and geological data and the development of the geological interpretation. She then visited CVRD's office in Belo Horizonte from 6 to 12 August 2004 and met with the CVRD resource evaluation team who were responsible for the database management, quality assurance and quality control (QAQC), digital capture of the geological interpretation, statistical and geostatistical analysis of the data and generation of the resource models. Review of the V2 model was carried out at CVRD's office and then, following revisions to the model, a final review of the V2 model (dated 19 August 2004) was undertaken in Snowden's Perth office. Celeste Queiroz visited Snowden's Perth office for review of the V1 model (dated September 2004) which was undertaken from 20 September to 1 October 2004. As part of the resource review, CVRD requested a comparison between the PFS and FFS models.

Preliminary results from comparisons of the finalised FFS model and the PFS model (updated in November 2003) for the V2 deposit were presented to CVRD. As the updated PFS model was not used for mining studies, this comparison was subsequently revised to compare the FFS with the original PFS model that was reviewed by Snowden from August to October 2003.

Documentation of the resource models by CVRD was not complete at the time of the resource reviews. The Gemcom project files were provided for V1 (GCDBV1) and V2 (GCDBV2) along with the project files used for grade estimation in unfolded space (GCDBD1 and GCDBD2 for V1 and V2 respectively). The GCDBV1 and GCDBV2 project files contain the grade models developed for V1 and V2 for each rock type and the final integrated model (both diluted and undiluted) with ore and waste percentage models. Grade models were developed by CVRD for Ni, Co, MgO, Al_2O_3, Fe_2O_3, MnO, SiO_2, Cr, Cu and Zn and density models were developed for the ore and waste components of the resource.

In addition to the Gemcom project files, CVRD provided hard and/or digital copies of the following data:

- Tables and graphs from the statistical analysis of the assay and density data
- Graphs generated from the contact analysis
- Spreadsheets, with graphs, of the data from the QAQC study
- Model validation graphs, comparing input grade and block grade by incremental easting, northing and elevation for all estimated variables (except Zn for V2)

- A PowerPoint presentation summarising the exploration history, geological interpretation, statistical analysis, contact analysis, density determination, resource estimation methodology and resource reporting for V1 and V2
- Tabulated kriging parameters for V1
- Reports on the variography study undertaken for V1 and V2.

After Snowden’s review, an anomaly in the silica estimates was identified and rectified in March 2005.

For scheduling purposes, the FFS25_2 m was re-blocked to a 3 m bench height and was therefore referred to as the FFS25_3m model.

6.2.5 Block size studies – March 2005

As part of the investigation into the appropriate block size for scheduling requested by CVRD, Snowden completed studies into:

- The comparison of the resource model grade-tonnage curves for 12.5 m x 12.5 m x 2 m panels to 25 m x 25 m x 2 m panels
- Estimation accuracy determination through regression slope and kriging efficiency analyses of the two models.

At V1, the drilling was predominantly based on a 50 m x 50 m spacing, with infill around the edges of the deposit to a 25 m x 25 m spacing. At V2, the eastern part of the deposit was drilled based on a 25 m x 25 m spacing and the western part was drilled based on a 50 m x 50 m spacing.

Snowden understood that CVRD’s primary motivation for testing a smaller panel size for grade scheduling purposes was to quantify whether the smaller panel would result in the ability to preferentially select higher grade material based on the current information. The Snowden results for the comparative grade-tonnage curves for the two panels size show that greater selectivity is not achieved.

The estimation accuracy work showed, however, that the smaller panel size had a very similar, and in the key domains marginally superior, estimation accuracy and as such could be used for scheduling purposes. However, Snowden cautioned that while the average drill spacing in the V2 deposit is much closer than the average spacing in V1 and as such, the smaller panel would only be recommended for the V2 deposit.

6.2.6 RFS_12.5_3m MRE and block models

In March 2005, the DIST (Technical Analysis Team) of CVRD requested that the MRE be re-generated into block sizes of 12.5 m (X) x 12.5 m (Y) x 3 m (elevation). The estimates were made by CVRD using Gemcom v4 software and are known as “ReAval 2005”. AMEC was engaged to independently audit the CVRD estimates and their findings were presented in December 2005.

AMEC concluded:

- The geological model was consistently built according to lithology, weathering, and ore groups.
- Unfolding technique was properly used for variography and grade estimation.
- Statistical analysis presented satisfactory results to support ore groups’ definition; however, variography could be enhanced since overall models are not satisfactory.
- Original samples, in average 1 m long, were used instead of composites.
- Contact analysis study was performed to indicate the use of hard or soft boundaries for variography and grade estimation.

- AMEC did not receive documentation regarding capping analysis and therefore could not comment on the results of such study but identified that capping was used for resource estimation.
- Several density determination methods were used according to material type mainly and data availability.
- Grade estimation validation routines were satisfactory; however AMEC checks indicated grade underestimation in some areas. In summary, AMEC concluded that grade estimation quality is not ideal, but should not interfere in the global estimated resources.
- AMEC agreed that metallurgical hole samples should not be used for resource estimation.
- Resources classification is adequate for actual drilling spacing.
- AMEC accepts resources reported by CVRD for both V1 and V2 deposits as 210.6 Mt at 0.757% Ni in the Measured category and 11.9 Mt at 0.728% Ni in the Indicated category using a 0.4% Ni cut-off.

AMEC recommended the following recommendations should be performed, understood as part of Continuous Improvement by the author:

- Fix problems found for solid “SAPFE_CP” at V1 deposit due to errors found.
- Define and use composites for a better control of sample support. Compositing could help enhance variography as well.
- Evaluate V1 and V2 variography, and one suggestion was to use pair-wise variograms instead of correlograms, since some zonal anisotropy could be noticed from the experimental variograms.
- Combinations of some units should also be re-evaluated in order to help in better detecting grade continuity and variogram structures.
- For future short-term models, AMEC recommended re-evaluating ore groups and estimation parameters in order to enhance the grade estimation quality.
- Although resource classification is supported by an acceptable drilling spacing, AMEC suggested using a drilling spacing study that will consider kriging variance from simulated different drilling spacings according to production rates (yearly, and quarterly), to support resources classification rather than only using distances defined by variography variances.

Earlier in March 2005, Snowden understood that CVRD’s primary motivation for testing a smaller block size for grade scheduling purposes was to quantify whether the smaller block would result in the ability to preferentially select higher grade material based on the current information. The results for the comparative grade-tonnage curves for the two block sizes showed that greater selectivity is not achieved.

The estimation accuracy work showed, however, that the smaller block size has a very similar, and in the key domains marginally superior, estimation accuracy and as such could be used for scheduling purposes. However, Snowden cautioned that, as the average drill spacing in the V2 deposit is much closer than the average spacing in V1, the smaller block would only be recommended for the V2 deposit.

Snowden considered that the 25 m x 25 m x 2 m block size used for the FFS was appropriate, given that ~64% of the resource is from V1, which has been predominantly drilled on 50 m x 50 m spacing, except around the edges where the deposit is thinner. Reducing the block size to 12.5 m x 12.5 m x 3 m for the RFS did not improve the selectivity; however, it did not reduce the estimation accuracy within the pit.

The results of Uniform Conditioning and the simulation re-blocking estimates by Snowden confirmed that a block size of 12.5 m x 12.5 m x 2 m or 10 m x 10 m x 2 m did offer greater selectivity, but to achieve that greater selectivity the drill spacing of information used to estimate the block must be closer than that was available. As such, Snowden considered that direct estimation into blocks of this size using the relatively wide spaced information was sub-optimal.

AMEC was silent on the choice of block size.

6.2.7 CVRD-SRK_12.5_3m MRE and block models

To address the recommendations made by AMEC during the review process, SRK Consulting (SRK) was commissioned to assist CVRD in updating the resource model in 2006, with a completion date in early 2007. While updating the model, SRK revised the geological interpretations, adjusted to match the new topography provided for the V2 area; addressed the recommended review of the MgO grades, and revised the density and moisture datasets used for estimation.

A comparison between the CVRD RFS 12.5_3m and CVRD-SRK 12.5_3m models showed that they were materially different due to changes in the variography, use of grade capping, and types of samples used for density estimation (Table 6.4).

The most notable recommendations came from the AMEC audit of the RFS_12.5_3m MRE completed in May 2006 and an Inco Technical Services Limited (a Vale company) audit completed in May 2007 of the CVRD-SRK 12.5_3m MRE. These audits looked at one or both resource models depending on when the audit was performed. Some the of the key recommendations included: combine and simplify some of the geological domains, investigate the impact of different data sources for density and grades, compositing of sample lengths, remodel domains without using interpolation algorithms, and accounting for more factors during resource classification. If a new resource model was required, the identified deficiencies would need to be addressed during resource model development.

Table 6.4 CVRD-SRK_12.5_3m historical MRE at 0.40% nickel cut-off

Resource category	Tonnage (Mt)	Contained Ni metal (kt)	Contained Co metal (kt)	Ni (%)	Co (%)	MgO (%)	SiO_2 (%)
Measured	246.8	2,171	116.7	0.88	0.05	8.75	46.07
Indicated	11.3	95	4.8	0.84	0.04	11.20	44.85
Measured + Indicated	**258.1**	**2,266**	**121.5**	**0.88**	**0.05**	**8.86**	**46.02**
Inferred	14.03	113	4.5	0.80	0.03	19.28	40.65

Source: Extracted from SRK, 2007

6.2.8 Snowden 25_1m MRE

In 2008, Snowden was engaged by MOP (subsidiary of Vale) to develop a resource model in consultation with ITSL. The geological and estimation domains were updated and simplified.

While the full study was not completed due to cessation of Vale activities on the project, much of the basic estimation work was completed.

The major departures from the previous MRE block models were:

- Changes to the geological and estimation domains.
- Estimation of service variables instead of assayed elements and oxide constituents. The service variables accounted for the beneficiation process and changes to density over the deposit volumes. Snowden had some concerns in the use of service variables for estimation but were directed to use them.
- Use of Datamine software including Datamine unfold strings and method.
- The block size was 25 m (X) x 25 m (Y) x 1 m (elevation).

6.2.9 Recommendation for adoption of historic MRE

After review of relevant MRE documentation and check reporting of block models, the author recommends that the FFS_25_2m (Section 6.2.4) model is adopted as the current MRE, for the following reasons:

- These estimates were audited by Snowden and the author and formed the basis of the FFS in 2005.
- Subsequent MREs were either based on a block size of 12.5 m (X) x 12.5 m (Y) x 3 m (elevation) (Sections 6.2.6 and 6.2.7), or (in the case of Section 6.2.8) remain incomplete. The author does not agree that the smaller block size is applicable given that the majority drill spacing is 50 m x 50 m. This is in agreement with the block size used for estimation at HZM's Araguaia deposits where the majority drill spacing is 50 m x 50 m.
- While there have been changes in geological interpretation since the FFS_25_2m MRE, the author does not believe these changes are material in the context of the intended use of the MRE in a PEA.

In the event a PEA is positive, the author recommends that the Vermelho MRE block models are aligned with the Datamine resource estimation processes applied to HZM's Araguaia deposits. For example, Datamine unfolding and estimation processes are considered superior to Gemcom in that:

- Improved audit trail and verification
- Use of sub-cell models instead of percent models
- More efficient method of unfolding
- Industry strength software and support.

It is expected that much of the work performed in Datamine for the Snowden 25_1m MRE can be recovered and used in updating of the Vermelho MRE.

Section 14 provides details and results of the estimation process.

6.3 Historical Mineral Reserves

Snowden (2005) reports a historical Mineral Reserve of 187 Mt at 0.93% Ni comprising 179.7 Mt at 0.93% Ni as Proved Mineral Reserve and 7.4 Mt at 0.83% Ni as Probable Mineral Reserve, in accordance with JORC (2004) guidelines. The Snowden mining study was part of the Vermelho FS of GRD-Minproc (2005).

A Qualified Person has not done sufficient work to classify any of the historical estimates as current Mineral Reserves.

6.4 2005 Feasibility Study

The FS for Vermelho was undertaken by CVRD Base Metals Projects Department from October 2003 to March 2005. The main activities undertaken are outlined below:

- Geological exploration campaign, reaching a cumulative 152,000 m of drilling
- Resource estimation, with independent audit
- Hydrological, hydrogeological and meteorological assessment
- Geotechnical investigations and interpretation
- Landowners' assessment
- Preparation and submission of PAE (Economic Development Plan) and EIA (Environmental Assessment Study) to Brazilian Authorities

- Process testwork, including demonstration pilot plant and bench-scale testwork
- Market studies and visits to potential intermediate customers
- Engineering study, including process plant and infrastructure design
- Financial analysis.

7 GEOLOGICAL SETTING AND MINERALISATION

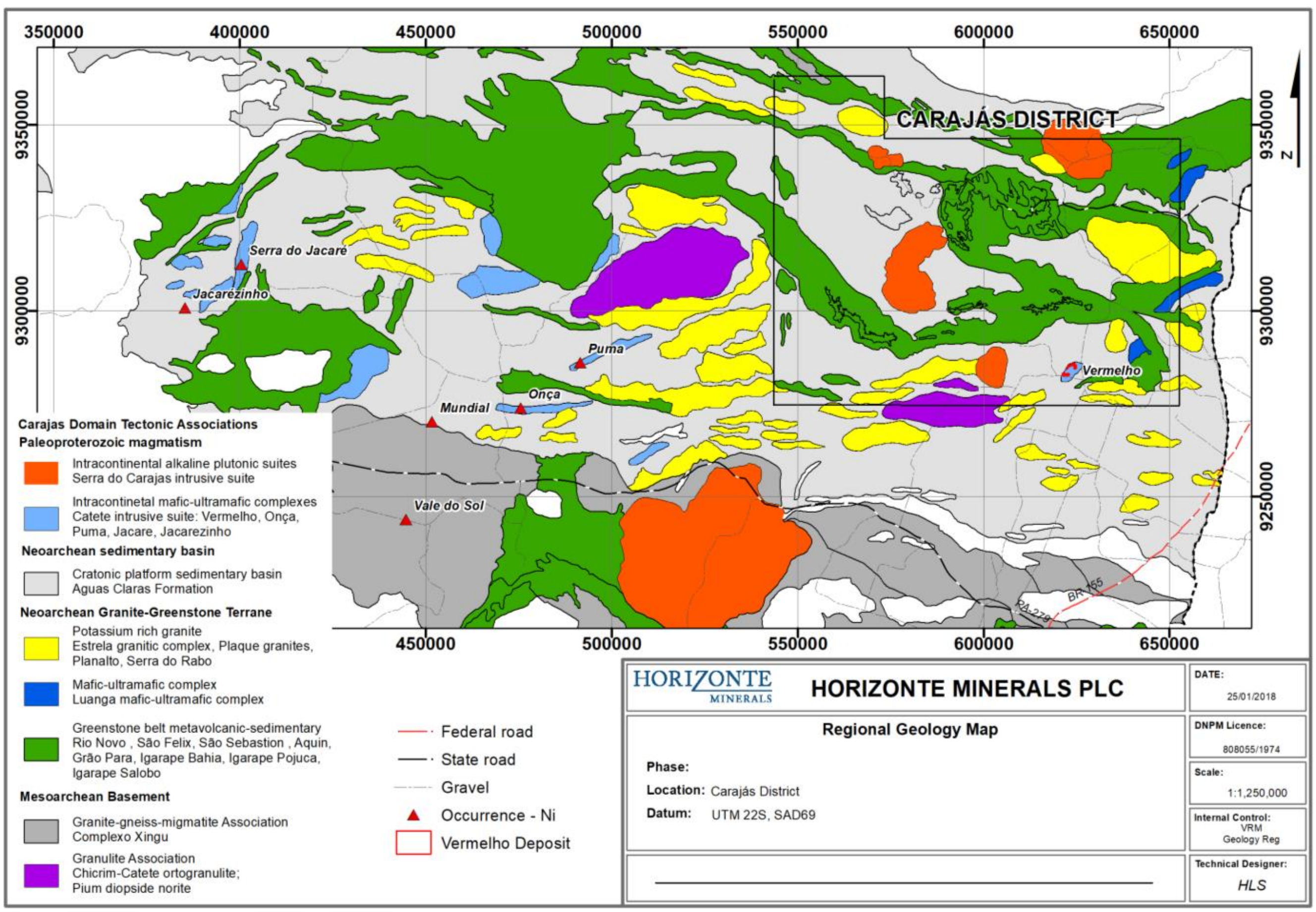
The following is extracted from AMEC (2006), reviewed and amended by the author for inclusion in this Technical Report.

7.1 Regional geology

The Vermelho Nickel-Cobalt Project is in the south-eastern portion of the Carajás Mineral Province. The deposits have formed because of supergene weathering and leaching of mafic and ultramafic rocks of the Vermelho layered intrusion, which belongs to the Cateté Intrusive Suite (CIS). This anorogenic mafic and ultramafic suite intrudes the Archaean Xingu Complex, composed of gneisses, amphibolites, migmatites, and granulites.

The anorogenic bodies have not been deformed or metamorphosed. Their intrusion, related to distensional Palaeoproterozoic events, has been dated at 2.4 Ga. Other well-known intrusive bodies belonging to the CIS, distributed from east to west in the southern portion of the Carajás Mineral Province, are Serra da Onça, Serra do Puma, Igarapé Carapanã, Serra do Jacaré, Serra do Jacarezinho, Fazenda Maginco, and Ourilândia (Figure 7.1).

Figure 7.1 Regional geological setting



Source: HZM

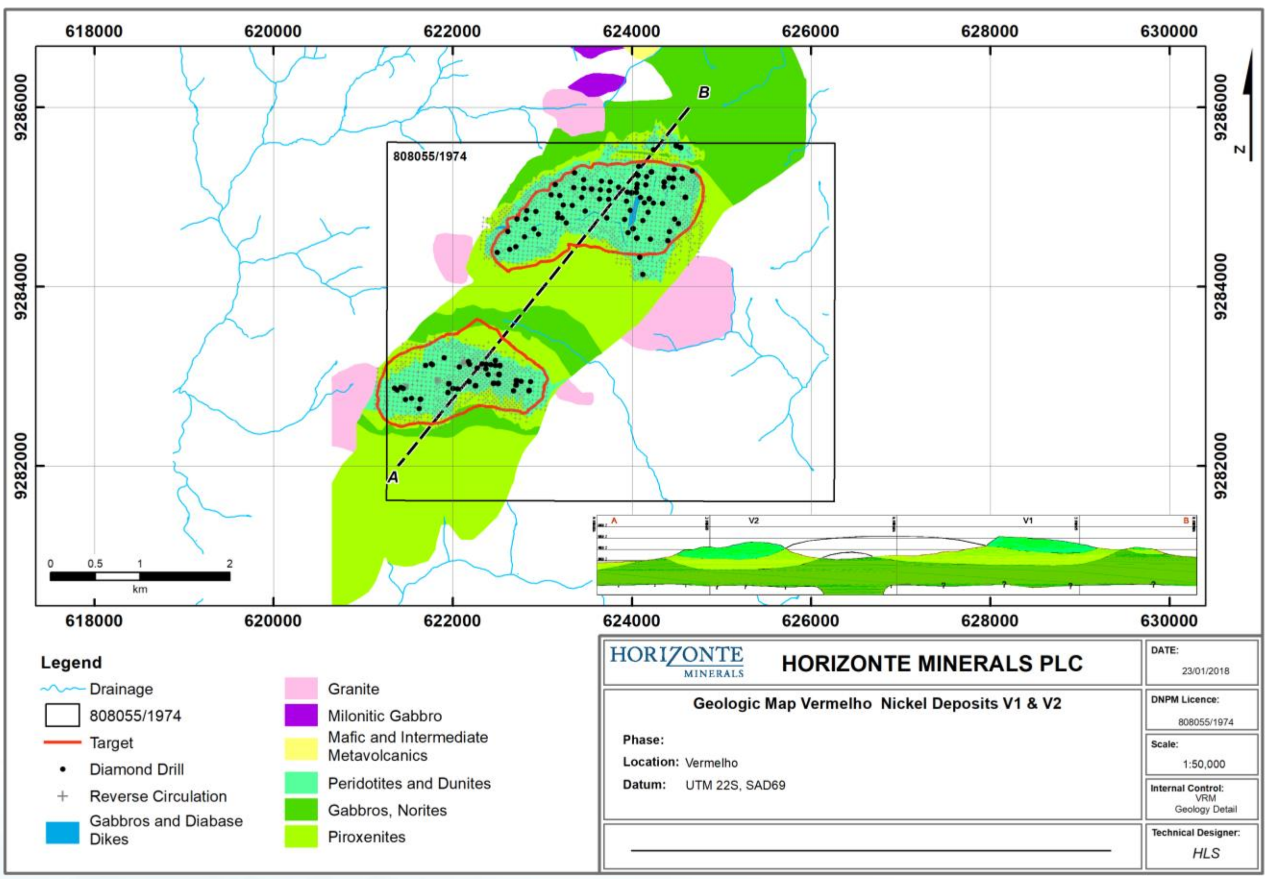
7.2 Deposit geology

The Vermelho nickel deposits consist of two hills named V1 and V2 (after Vermelho 1 and Vermelho 2), aligned on a northeast-southwest trend, overlying ultramafic bodies. A third ultramafic body, named V3, also located in the same trend, lies on flat terrain, southwest of V2. The ultramafic bodies have had an extensive history of tropical weathering, which has produced a thick profile of nickel-enriched lateritic saprolite at V1 and V2.

The V1 and V2 deposits form flat lying topographical highs (refer to Figure 5.1). The V2 hill is located approximately 2 km southwest of V1 (Figure 7.2). The V1 hill has a deformed convex-concave shape (convex to northeast), and extends for approximately 2.4 km east-west, ranging from 700 m to 1.6 km north-south. The V2 hill has an east-west elongation, and extends for approximately 1.9 km east-west, ranging from 600 m to 900 m north-south. The V1 deposit has an average thickness of 53 m and a maximum thickness of 146 m, whereas the V2 deposit has an average thickness of 56 m and a maximum thickness of 115 m.

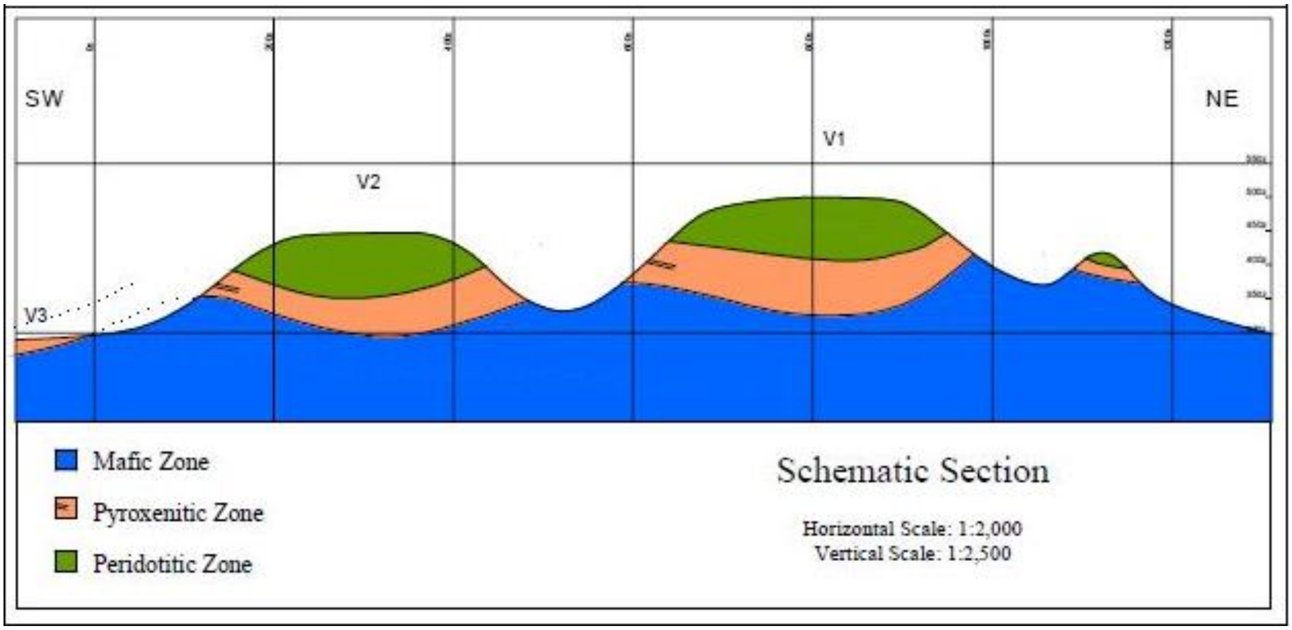
The ultramafic bodies are erosional relicts of the upper sheet of a three-layer intrusion (Figure 7.3), represented, from bottom to top, by a mafic zone (gabbros, gabbro-norites and leuconorites), a pyroxenite zone (orthopyroxenites and chromitites, with circa 50 m thickness) and a peridotite zone (serpentinised dunites and harzburgites, with circa 150 m thickness). The northeast-southwest-oriented, 10 km long and 2 km wide, layered intrusion has intruded a package of gneisses and migmatites belonging to the Xingu Complex (Figure 7.4). Late sub-vertical diabase dykes intersect the three layers in different directions. Various chromitite levels have been identified at the southern sides of both V1 and V2 within the pyroxenite zone.

Figure 7.2 Geological map of the Vermelho nickel deposits, V1 and V2 and the adjacent areas



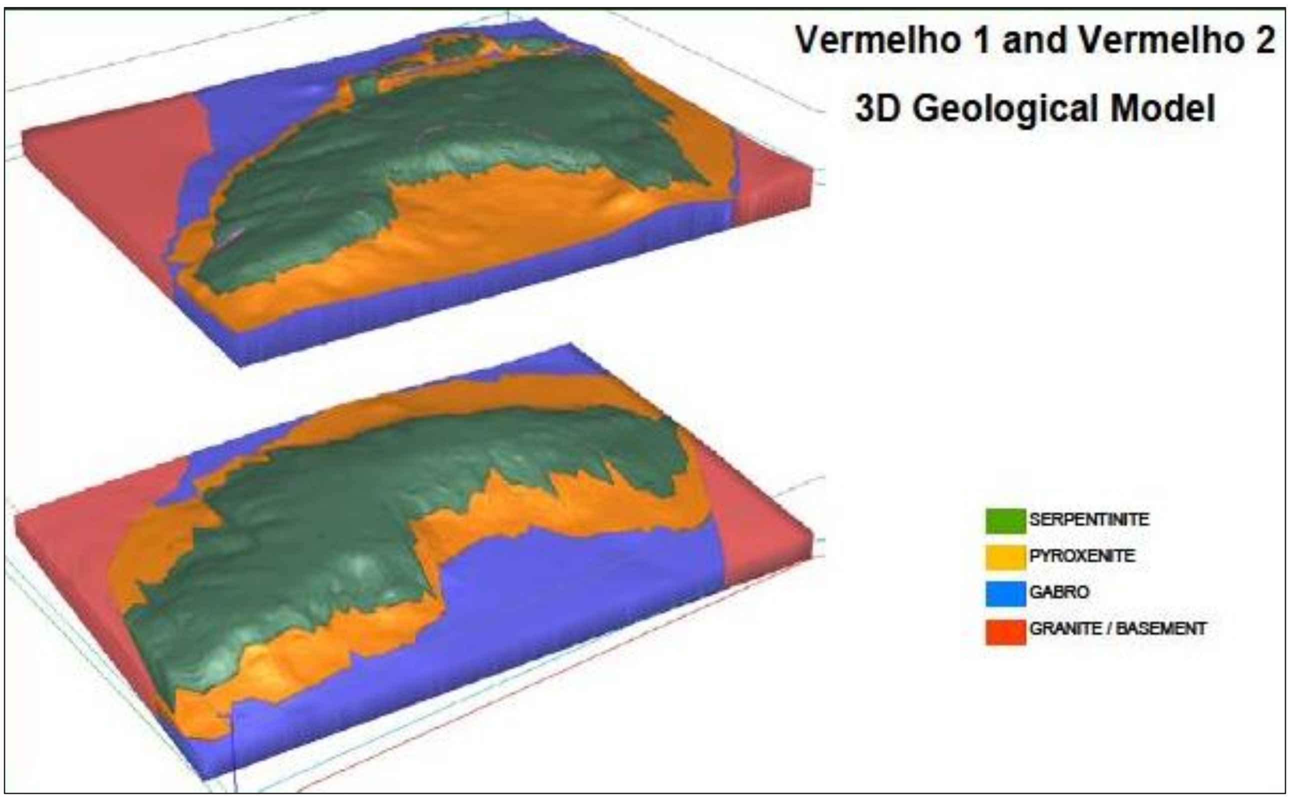
Source: HZM

Figure 7.3 Layered structure of the Vermelho intrusion



Source: AMEC, 2006

Figure 7.4 Vermelho 3D geological model

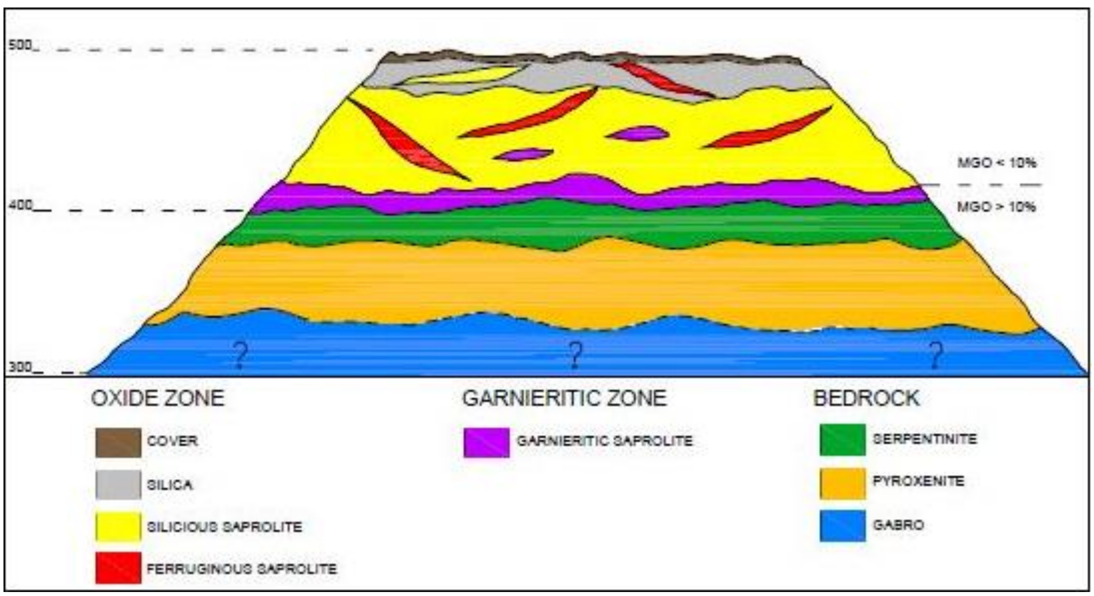


Source: AMEC, 2006

The mineralisation at Vermelho is contained within intensely weathered serpentinites, weathered to saprolites. These saprolites are characterised by extensive silicification, generally in the form of veins, boxworks and massive zones of chalcedonic silica. A typical section through the lateritic profile at Vermelho is presented in Figure 7.5. Five main material types can be identified in the lateritic profile (from bottom to top):

- High Magnesium (Garnieritic) Saprolite, coded SAP in the Vermelho drillhole database, is characterised by the predominance of serpentinite and relict structures, and MgO above 10%; the Ni grades usually exceed 1.5%, sometimes reaching 10% (15 m average thickness).
- Siliceous Saprolite, or Low Magnesium Saprolite, coded SAPSIL, with SiO_2 grades ranging from 35% to 65%, and boxwork structures are usually packed with Fe oxides and hydroxides; the Ni grades range from 0.6% to 1.5% (20 m average thickness).
- Massive Silica, coded SILICA, formed of thick, very resistant massive silica crusts, with SiO_2 grades usually above 65%, sometimes reaching 90%; the Ni grades rarely exceed 0.25% (30 m average thickness).
- Ferruginous Saprolite, coded SAPFE, is composed of finely grained and porous Fe oxides and hydroxides (goethite, limonite, hematite), and forming discontinuous and irregular lenses within the siliceous saprolite or the massive silica; the Fe_2O_3 grade commonly exceeds 80%, and the SiO_2 grade is lower than 35%; the Ni grades range between 0.6% and 1.5% (15 m average thickness).
- Overburden, coded COB, formed of fine ferruginous soil, organic residues, and ferruginous concretions, commonly with rounded shapes (1 m average thickness).

Figure 7.5 Mineralisation



Source: AMEC, 2006

Contacts between these zones are commonly transitional. Other materials can be present in different proportions and positions in the lateritic profile: weathered and semi-weathered serpentinites (coded SERPINT and SERPSI, respectively), fresh serpentinites (coded SERP), pyroxenitic and gabbroic saprolites (coded SAPIROX and SAPGAB, respectively), and fresh gabbros and pyroxenites (coded GAB and PIROX, respectively).

7.3 Mineralisation

In the lateritic nickel deposits of Vermelho, two main mineralisation types can be recognised: silicate at the base and oxide at the top of the weathering profile. The mineralogical composition of the silicate zone, with 1.8% NiO in average, consists largely of serpentine, chlorite, and spinels, with quartz and goethite in minor amounts. Serpentine and chlorite are the main nickel-bearing minerals, nickel being about equally distributed between the two phases (2–3% NiO). There is no significant development of an enriched transition mineralisation type between the oxide and silicate horizons.

The oxide material, with 1.2% NiO on average, is composed predominantly of goethite, and also contains chlorite, spinels and silica. In this case, the nickel is highly concentrated in chlorite (average 12% NiO), whereas in goethite NiO content ranges between 0.9% and 1.7%. As a result, the presence of chlorite, even in minor quantities, is important in elevating the grade of the oxide ore. Locally, higher grades of mineralisation can also be due to the presence of nickeliferous smectites.

Barren zones within the lateritic profile are represented by serpentinite blocks, strongly silicified bands, mafic or pyroxenitic dykes, and ferruginous concretions (common at the top of the section). A transitional saprolitic zone occurs at the base of the mineralised zone, with Ni grades usually ranging from 0.25% and 0.5%.

The Vermelho laterites are mineralogically similar to the limonitic laterites of Western Australia and, like the Australian ores, are amenable to pressure acid leaching. A possible treatment route of the higher grade saprolite ores is the RKEF process as envisaged for HZM's Araguaia deposits.

7.4 Geological interpretation and modelling

For geological modeling, CVRD used a combination of wireframe solids and surfaces based on drillhole logging and assays. For solid modelling, the classical method of manual interpretation of the lithological contacts by sections was undertaken; the method considers an orthogonal projection to the section plan to include drillhole information that does not sit exactly in the section plan. This projection is halfway to the previous and next section. For surface modeling, interpolated grids, with cells of 12.5 m x 12.5 m were generated based on existing drillhole intersections.

At Vermelho, vertical sections are spaced every 25 m with an east-west direction. Horizontal sections, also used for interpretation, are distributed every 10 m.

At total of 1,517 holes were used for V1 modelling, and 1,022 holes at V2.

Using both sets of sections, the model units were clustered into the following groups: geologic, weathering, chemical, and ore.

For surface modelling, criteria were developed to pick up the drillhole intersections that would define the limits. Table 7.1 presents the criteria used for modeling each surface.

Table 7.1 Surface modeling criteria

Surface	Criteria
COB	Cover description starting at the bore opening; COB definitions below rock were not considered, below or coinciding with a topographic surface
Al_2O_3	First peak with Al_2O_3 >2%, below or coinciding with the cover zone
MgO	Zone with continuous values, greater than 10% of MgO, below or coinciding with the Al_2O_3 limit
NiO^5	Zone with nickel grade greater than 0.5%, located below or coinciding with the MgO limit
NiO^{25}	Zone with nickel grade greater than 0.25%, located below or coinciding with the NiO^5 limit
Bedrock	Limited starting with the Serpsi descriptions, where it did not contradict the bore description, Serp, gab and pirox below or coinciding with the MgO limit

Source: AMEC 2006

Where intersections in between surfaces occurred, an automated method of generating a minimum in between them was used. This method identifies crossings and fixes the lower surface to match with the upper one. After surfaces were created and fixed, solids representing each unit were created by joining top and bottom surfaces.

AMEC considers the methodology used of good practice and reviewed several sections for V1 and V2, found no problems. Only the ferruginous saprolite solids that were interpreted manually should have a more consistent extrapolation shaping.

8 DEPOSIT TYPES

The target mineralisation at the Vermelho Nickel-Cobalt Project's V1 and V2 deposits are characteristic of typical nickel laterite deposits formed in a seasonally wet tropical climate, on weathered and partially serpentinised ultramafic rocks. Features of nickel laterites include:

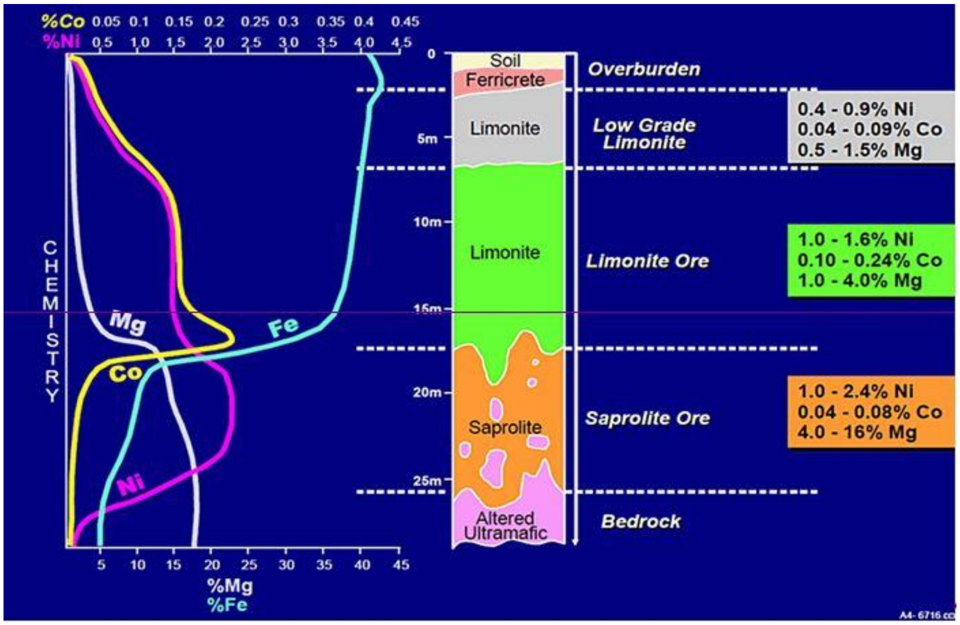
- The nickel is derived from altered olivine, pyroxene and serpentine that constitute the bulk of tectonically emplaced ultramafic oceanic crust and upper mantle rocks.
- Lateritisation of serpentinised peridotite bodies occurred during the Tertiary period and the residual products have been preserved as laterite profiles over plateaus/amphitheatres, elevated terraces and ridges/spurs.
- The process of formation starts with hydration, oxidation, and hydrolysis, within the zone of oxidation, of the minerals comprising the ultramafic protore.
- The warm/hot climate and the circulation of meteoric water (the pH being neutral to acid and the Eh being neutral to oxidant) are essential to this process. Silicates are in part dissolved, and the soluble substances are carried out of the system.
- This process results in the concentration of nickel in the regolith in hydrated silicate minerals and hydrated iron oxides; nickel and cobalt also concentrate in manganese oxides. The regolith hosting nickel laterite deposits is typically 10–50 m thick, but can exceed 100 m.
- Concentration of the nickel by leaching from the limonite zone and enrichment in the underlying saprolite zones is also common. Leaching of magnesium +/- silicon causes nickel and iron to become relatively concentrated in the limonite zone. Nickel is released by re-crystallisation and dehydration of iron oxy-hydrides and is slowly leached downwards through the profile, both vertically and laterally, re-precipitating at the base with silicon and magnesium to form an absolute concentration within the saprolite (Figure 8.1).
- The degree of the nickel concentration and the detailed type of regolith profile developed is determined by several factors including climate, geomorphology, drainage, lithology composition, and structures in the parent rock, acting over time.
- A typical laterite profile contains two distinct horizons, (limonite (oxide) and saprolite (silicate). The transition between these two horizons can be thick, however in the Vermelho case the transition horizon is thin.

Exploration criteria is summarised from Brand *et al* (1996) as follows:

- Geological massifs with olivine-rich lithologies and their metamorphic derivatives, large enough to host nickel laterite deposits that will support low-cost, high-tonnage, open-cut mining operations, must initially be identified.
- Airborne magnetic surveys, regional mapping and known occurrences of lateritic nickel are useful to identify likely targets.
- Later, detailed geological and geophysical surveys may be needed to delineate olivine-rich lithologies and faulting that may represent sites for shallow, high-grade manganese-cobalt-nickel and garnierite mineralisation.
- Regolith landform mapping and reconnaissance drilling can be used to determine the nature and distribution of the regolith (i.e. whether in-situ, concealed or stripped) and those zones that host nickel enrichments.
- Regional drilling and possibly soil sampling of in-situ regolith can be used to identify nickel halos (>0.5% Ni) and target the most prospective parts of a weathered ultramafic sequence.

- Follow-up drilling to delineate nickel-enriched zones will, in association with geochemistry and mineralogy, provide valuable information on the geological and metallurgical characteristics of any nickel laterite. For metallurgical purposes, it is useful to maintain a consistent element suite when analysing drill samples (Ni, Co, Mn, Cr, Mg, Fe, Si, Al and ignition loss).

Figure 8.1 Chemical trends in schematic nickel laterite profile



Source: MALA Ground Penetrating Radar

9 EXPLORATION

It should be noted that HZM has not conducted any exploration work on the Vermelho licence. All exploration work on the licence was completed prior to HZM announcing the acquisition of the Project in December 2017.

Prior exploration work in the region has been conducted by DOCEGEO (a subsidiary of CVRD) and contractors.

The following is extracted from AMEC (2006), reviewed and amended by the author for inclusion in this Technical Report.

9.1 Surveys

L&I Geologia e Topografia Ltda (later named Geotec Geologia e Topografia Ltda) was the local contractor in charge of the topographical services. A local coordinate system was initially used for referencing, but in 2002 the local system was converted to UTM. The first topographic map was at 1:10,000 scale, with contour lines every 10 m (locally every 5 m). The SAD69 datum was used.

A regular grid with 275° azimuth was surveyed at V1, and later continued into V2 with the same orientation. In V1, CVRD cut 4.5 km base lines and control polygonal lines, as well as 70 km of perpendicular lines placed 50 m apart from each other. In V2, there were 4 km base lines and control polygonal lines, as well as 76 km of perpendicular lines placed 50 m apart from each other. The lines had wooden pickets every 20 m, and cement monuments every 400 m.

The whole survey was conducted with total station equipment. The polygonal accuracy is as follows: $\Delta x \leq 0.3$ m; $\Delta y \leq 0.3$ m; and $\Delta z \leq 0.8$ m.

Exploration has been mainly by drilling and pitting. Drilling is described in Section 10.

10 DRILLING

It should be noted that HZM has not conducted any drilling work on the Vermelho licence. All drilling work on the licence was completed prior to HZM announcing the acquisition of the Project in December 2017.

The following is extracted from Snowden (2005), AMEC (2006) and GRD-Minproc (2005), reviewed and amended by the author for inclusion in this Technical Report.

10.1 Drilling and pitting summary

CVRD has conducted both core and reverse circulation (RC) drilling at V1 and V2 since 1974. However, no details were provided to AMEC for the drilling methodologies utilised before 2002.

The PFS resource estimate was based largely upon a 50 m x 50 m square drilling pattern. Infill drilling was undertaken to a 25 m x 25 m grid over much of V2 and around the edges of V1. This drilling was largely designed to convert areas that had been classified as Inferred in the PFS to Measured or Indicated. Four small areas (three from V2 and one from V1) of close spaced drilling (to a 12.5 m x 12.5 m pattern) was undertaken to provide detailed geological information and to determine the short-range variability of the grade components for resource modelling.

RC drilling between 2002 and 2004 at the V1 and V2 deposits was performed by Geosedna, on 100 m x 100 m and 50 m x 50 m grids (sometimes with a hole in the centre of the 50 m x 50 m cell), and locally on a 12.5 m x 12.5 m grid. Geosedna used three Prospector W750 rigs, with 4-¼”' and 5-1/8” (108 mm and 130 mm respectively) diameters (Table 10.1). The maximum hole lengths were 175 m in V1 and 115 m in V2, and the average hole lengths were 56.4 m in V1 and 58.0 m in V2. The average recovery at both areas was 80%.

Table 10.1 Drillholes by deposit

Deposit	Year	Type	No. of holes	Meterage (m)	Average (m)	Diameter	Grid
V1	1976–1998	RC	15	1,172	-	5-1/8”	Partial data
		DDH	4	305	-	HQ	Partial data
	2000–2001	RC	113	7,490	-	5-1/8”	100 m x 100 m
		DDH	2	160	-	HQ	-
	2002–2003	RC	490	31,356	-	4-¼”	50 m x 50 m
		DDH	38	1,961	-	ZW	-
	2003–2004	RC	651	31,553	-	4-¼”	50 m x 50 m; 12.5 m x 12.5 m
		DDH	22	1,956	-	HQ	-
		DDH	48	1,622	-	ZW	-
	Subtotal		**1,383**	**77,575**	**56.1**		
V2	2002–2003	RC	229	15,265	-	4-¼”	100 m x 100 m
		DDH	16	786	-	ZW	-
	2003–2004	RC	620	34,034	-	4-¼”	50 m x 50 m
		DDH	12	1,080	-	HQ	-
	Subtotal		**877**	**51,165**	**58.3**	**-**	**-**
TOTAL			**2,260**	**128,740**	**57.0**		

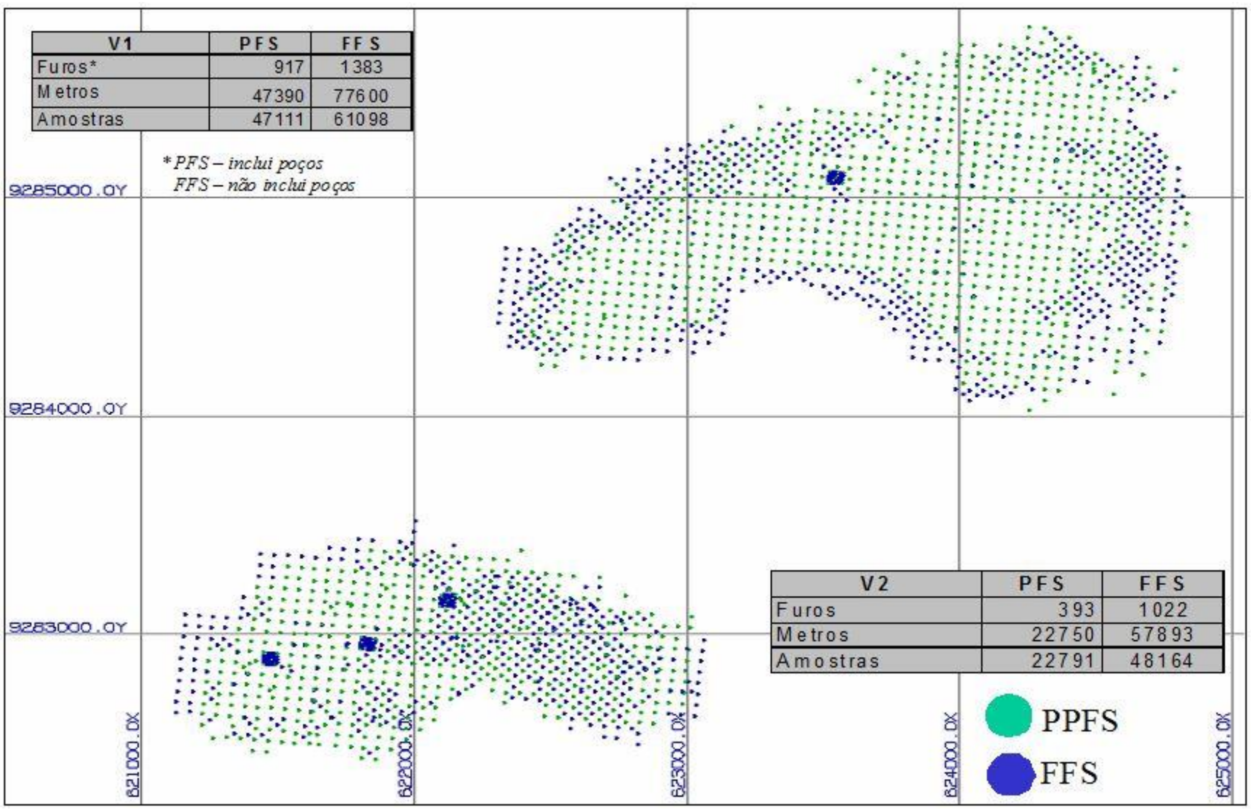
Notes: 4-1/4” = 108 mm; 5-1/8” = 130 mm; HQ = 63.5 mm; ZW = 202.5 mm; RC = reverse circulation; DDH = diamond drilling
Source: AMEC, 2006

CVRD also conducted diamond core drilling in the Vermelho deposits. Geosol, a local contractor, used three Maqsonda rigs to drill 40 drillholes with HQ (or 96.1 mm) diameter and at variable inclinations from 60° to 90° (Table 10.1). The vertical diamond holes always twinned previously drilled RC holes, and the inclined holes were oriented to intercept shear zones or dykes. Maximum hole lengths were 146.0 m in V1 and 115.6 m in V2, and the average hole lengths were 86.5 m in V1 and 90.0 m in V2. Average core recoveries were 91% and 95%, respectively.

Geosol drilled 102 large diameter holes (ZW, or 150 mm) with Maqsonda rigs (Table 10.1). These holes also twinned RC holes, and the recovered material was used for metallurgical studies. The maximum hole lengths were 85.0 m in V1 and 93.1 m in V2, and the average hole lengths were 41.7 m in V1 and 48.3 m in V2.

All holes were marked with large wooden posts and aluminium labels, including the drillhole number and the UTM coordinates, and some holes were also marked with cement blocks with similar identifications. Figure 8.1 shows the distribution of the drillhole grids.

Figure 10.1 Location of drillholes and pits for the PFS and FFS



Note: Holes (Furos); Metres (Metros); Samples (Amostras)
Source: GRD-Minproc, 2005

Shallow pits were dug to provide geological information in two campaigns, an early program from 1996 to 1998 that was restricted to V1, and a later program, in 2003 to 2004 that covered both deposits. Pitting details are shown in Table 10.2.

Table 10.2 Pitting by deposit

Deposit	Year	No. of shafts	Meterage (m)	Dimensions
V1	1976–1998	114	1,792	1 m x 1 m
	2003–2004	20	318	1 m x 1 m
	Subtotal	**134**	**2,111**	
V2	2003–2004	9	6,548	1 m x 1 m
	Subtotal	**9**	**6,548**	
TOTAL		**143**	**8,659**	

Source: AMEC, 2006

10.2 Logging and sampling

The RC samples were taken at 1 m intervals by collecting the entire discharge from the bottom of the cyclone. This material was immediately weighed and bagged in thick plastic bags. The samples were subsequently placed on aluminium trays, dried on a charcoal oven, and re-bagged. Drilling weight recovery was estimated by comparing the actual sample weight with the theoretical sample weight based on the interval drilled, the hole size and the material dry density. The samples were later quartered, initially through the cone-and-quartering method, and later using a Jones splitter, to obtain 2–3 kg samples which were again split in two portions: one to be submitted to the preparation facility (for pulverisation) and one to be kept as for future reference.

From the reference samples, a small portion was separated and placed on a description board (one per drillhole), consisting of 1.5 m x 0.1 m rectangular pieces of wood, where the cuttings were glued forming 2 cm wide bands, one per 1 m drilled (Figure 10.2). These description tables served for future fast reference regarding lithology, etc. A second portion of the backup sample was stored in wood boxes divided in cells (Figure 10.3).

Figure 10.2 Description board

Source: AMEC, 2006

Figure 10.3 RC cuttings stored in wood boxes

Source: AMEC, 2006

Sample lithology was described using the RC cuttings. In total, the project geologists differentiated 13 lithologies, which are listed in Table 10.3 (including the corresponding codes).

Table 10.3 Lithological codes used at Vermelho

Lithology	Code
Cover	COB
Ferruginous Saprolite	SAPFE
Siliceous Saprolite	SAPSIL
Silica	SILICA
Magnesium Saprolite	SAP
Weathered Serpentinite	SERPINT
Semi-weathered Serpentinite	SERPSI
Fresh Serpentinite	SERP
Pyroxenite Saprolite	SAPIROX
Pyroxenite	PIROX
Gabbroic Saprolite	SAPGAB
Gabbro	GAB
Granite	GRANITO

Source: AMEC, 2006

Diamond drill core was stored in wood boxes and transported to a facility at the camp, where they were logged and sampled. The logs were general and mainly described the rock type (as per Table 10.3) and colour, the presence of some characteristic minerals (such as garnierite, chromite, chlorite, plagioclase, manganese oxides) and in few cases, certain structural features. The distinction between mineralised and waste units was quite clear in drill core. All these attributes were hand-entered into the project database management system.

The choice of lithological units and the methods for core logging are suitable to separate mineralised and non-mineralised units, and are appropriate for this type of deposit.

After logging, the core was sampled as quarter-core samples, in some cases with a mechanical splitter and in others with a diamond saw. Sample intervals were marked off in nominal 1 m intervals. However, main geological contacts were honoured; maximum and minimum sample lengths were 2.6 m and 0.3 m, respectively.

The large diameter core was logged, photographed, and finally sampled with 3 cm wide x 3 cm deep x 1 m long channels taken along the core axis. The magnetic susceptibility was determined in the sample bags with a handheld Exploranum kappameter.

A summary of sampling at V1 and V2 is presented in Table 10.4.

Table 10.4 V1 and V2 sampling summary

Deposit	No. of samples	Length				Length in mineralisation			
		Total (m)	Maximum (m)	Minimum (m)	Average (m)	Total (m)	Maximum (m)	Minimum (m)	Average (m)
V1	78,718	79,686	2.5	0.3	1.0	58,245	2.6	0.3	1.0
V2	57,698	57,561	1.6	0.4	1.0	43,530	1.6	0.4	1.0
Total	**136,416**	**137,246**	**-**	**-**	**-**	**101,776**	**-**	**-**	**-**

Source: AMEC, 2006

The choice of sampling intervals and sampling methods are appropriate for this type of deposit where the transition in key ore types may occur over short downhole distances.

10.3 Statistical analysis of sample data by AMEC (2006)

AMEC verified the statistical analysis of available information, such as:

- Assays of samples of vertical channels in pits
- Assays of samples of diamond cores
- Assays of samples of RC of rotary percussion
- Assays of samples of large-diameter diamond cores
- Measurements of *in situ* density (a distinct drilling database).

Sample support is 1 m long at the several sources.

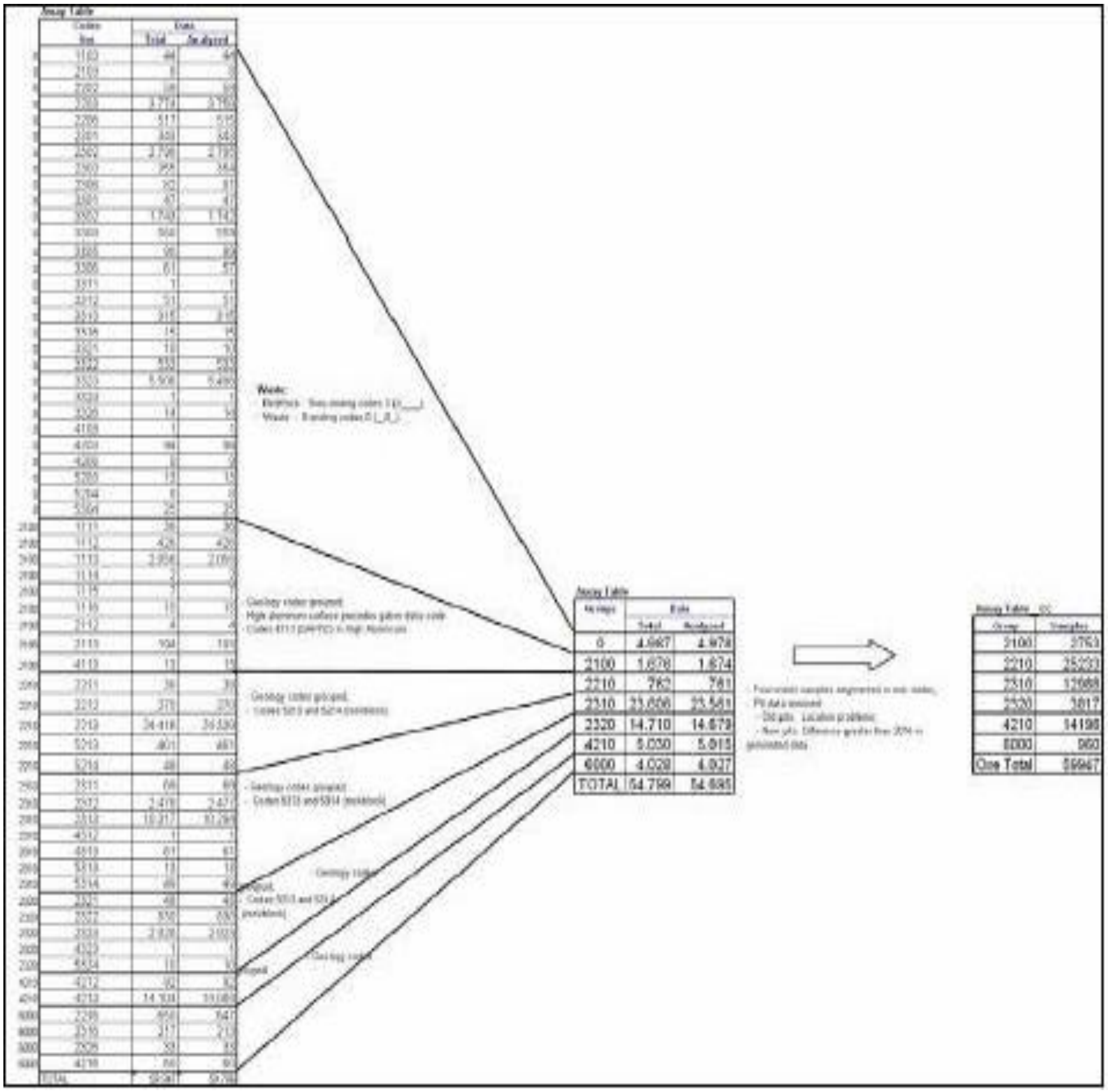
Due to the complexity of the geological model, units were grouped by ore type to facilitate the analysis. Figure 10.4 and Figure 10.5 show the grouping criteria for V1 and V2, respectively.

Pit channel samples presented high discrepancies compared to other sampling sources, and CVRD decided to ignore those samples when estimating resources. AMEC did not see problems in discarding such data, since enough information was available to obtain a good quality estimate.

AMEC considered that unit grouping was properly defined and executed to adequately represent the ore type variations at the deposit, and provided a good basis for using this information in resource estimation.

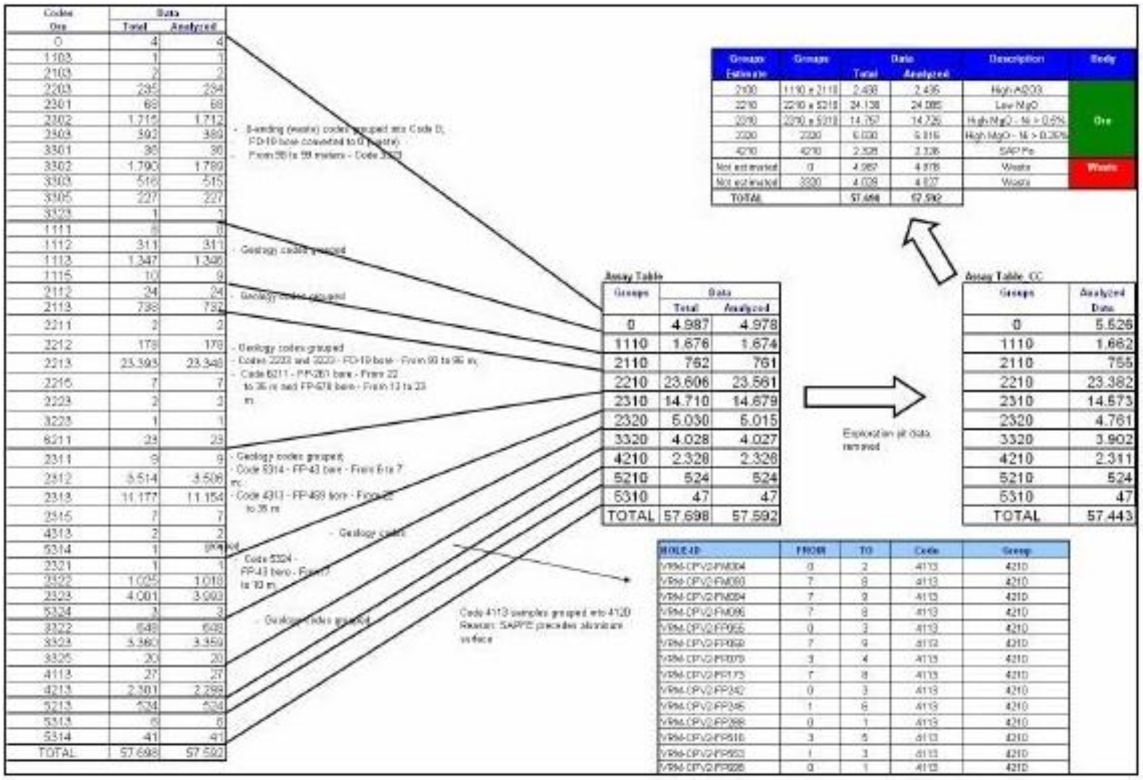
In general, low coefficients of variation were obtained, even considering the original 1 m sample lengths.

Figure 10.4 Unit grouping criteria for V1



Source: AMEC, 2006

Figure 10.5 Unit grouping criteria for V2



Source: AMEC, 2006

As described earlier, CVRD drilled core holes, RC holes or excavated pits to twin RC holes and pits. This analysis was restricted for to the nickel variable only and to data whose horizontal distance was less than 5 m and 1 m vertical distance.

As can be observed in Table 10.5 and Table 10.6, V2 presents very high differences between Diamond Drill x Pit Channels and RC x RC samples. Such differences are not found in V1 in the same magnitude. At V1, the highest discrepancy is found when comparing Diamond Drill x Metallurgical samples and could be due to the sampling method used for the metallurgical holes, since a very small amount of material was sampled.

Table 10.5 Comparison of twin sample pairs of different sampling types for V1

Pair	Average			Pair distance			Pairs	Pair	
	1	2	Diff. (%)	Average	Minimum	Maximum	Counting	(An>0.4 x An<0.5)	(%)
FM x FM	0.93	0.93	-0.09	3.12	0.61	4.32	2,550	524	20.55
FM x FD	0.78	1.51	-63.87	45.89	45.89	45.89	48	9	18.75
FM x PO (new)	0.72	0.80	-10.57	2.09	0.87	3.08	44	6	13.64
FD x PO (old)	2.14	1.72	21.91	17.62	14.12	20.55	30	0	0.00
FP x PO (new)	0.68	0.86	-23.45	2.14	1.41	3.64	306	54	17.65
FP x PO (old)	1.08	1.21	-11.62	1.48	0.11	5.41	278	51	18.35
FP x FM	0.93	0.96	-2.77	1.90	0.00	5.80	3,110	729	23.44
FP x FD	0.77	0.83	-7.60	2.83	0.47	5.88	1,199	391	32.61
FP x FP	0.60	0.51	15.47	2.19	1.48	2.81	129	44	34.11

Notes: Metallurgical bores (FM); Rotary bores (FD), Exploration pits (PO) – disposed of; Roto-percussive bores (FP). 1 There are no pairs with distances. 2 Old pit data disposed of due to location problems and to the data themselves. New due to high grade difference (>20%) to. 3 AN>0.5 x AN<05 – Represents pair counting when one analysis was greater than and the other less than 0.5% Ni. The percentage column is the sample percentage under those conditions, which much be regarded as a project risk.

Source: AMEC, 2006

Table 10.6 Comparison of twin sample pairs of different sampling types for V2

Pair	Average			Pair distance			Pairs	Pair	
	1	2	Diff. (%)	Average	Minimum	Maximum	Counting	(An>0.4 x An<0.5)	(%)
FM x FM	1.07	1.08	-1.15	3.03	1.73	4.50	9,248	2,571	27.80
FM x FD	1.31	1.41	-5.99	3.40	1.04	4.75	310	99	31.94
FD x PO	0.73	2.00	-93.17	2.07	2.05	2.11	19	3	15.79
FP x PO	0.70	0.99	-34.70	2.89	0.73	5.80	148	49	33.11
FP x FM	1.19	1.08	10.01	2.08	0.21	5.60	6,412	1,725	26.90
FP x FD	0.98	0.95	3.09	2.62	0.44	5.54	647	236	36.48
FP x FP	0.42	1.22	-97.97	9.28	9.28	9.28	79	44	55.70

Notes: Metallurgical bores (FM); Rotary bores (FD), Exploration pits (PO) – disposed of; Roto-percussive bores (FP). 1 There are no pairs with distances. 2 Old pit data disposed of due to location problems and to the data themselves. New due to high grade difference (>20%) to. 3 AN>0.5 x AN<05 – Represents pair counting when one analysis was greater than and the other less than 0.5% Ni. The percentage column is the sample percentage under those conditions, which much be regarded as a project risk.

Source: AMEC, 2006

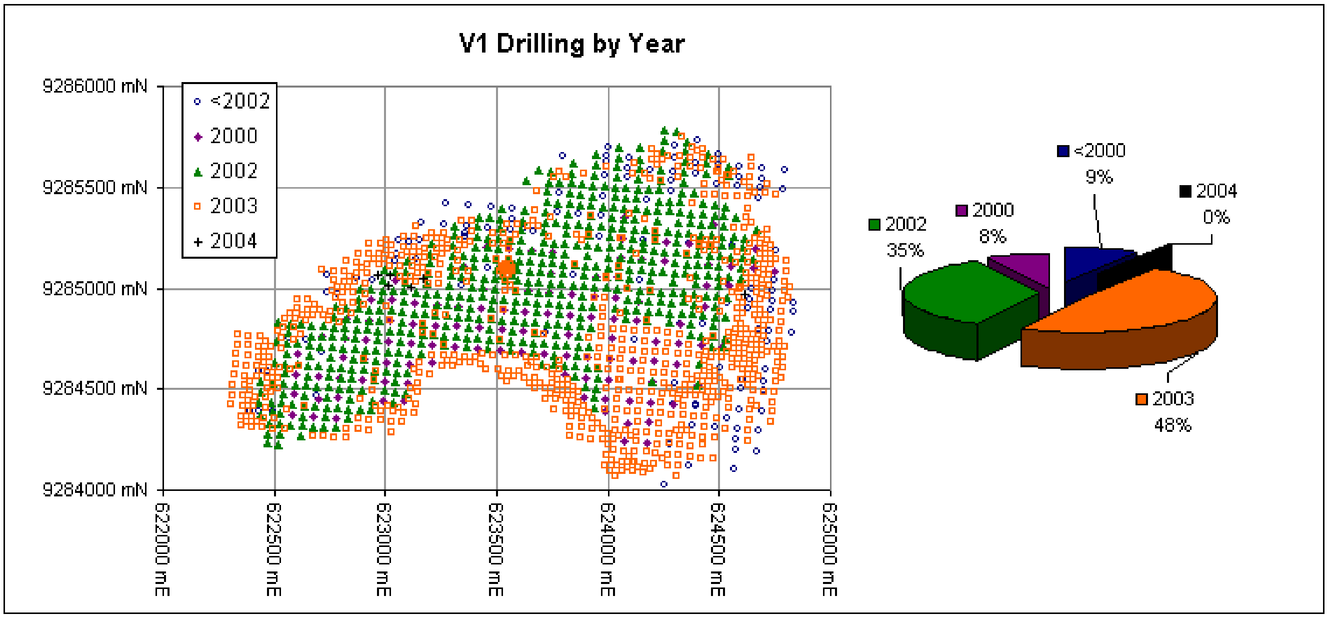
AMEC also compared some of the twin holes and the results were conclusive that no sampling bias occurs, but the comparison between metallurgical holes and others shows a clear bias, explained by the methodology used for sampling. AMEC agreed that metallurgical hole samples should not be used for resource estimation.

10.4 Comments on drilling by Snowden (2005)

10.4.1 Pre-2000 data

Golder Associates (Golder, 2004) reported that data collected prior to 2000 may be unreliable. Snowden interrogated the 2005 CVRD resource estimation databases (GCDBV1.mdb and GCDBV2.mdb) and determined that only the V1 deposit was affected by drilling prior to 2000 (Figure 10.6).

Figure 10.6 V1 collar locations coded by year of drilling



Source: Snowden, 2005

The pre-2000 drilling comprises approximately 9% of the V1 collar table with the holes predominantly located on the margins of the deposit. In all cases, the early drilling has been infilled by later programs. The more current and reliable data sufficiently surrounds the pre-2000 drilling to mitigate any risks posed by the more historical data in the resource model. Snowden therefore considered any risk associated with pre-2000 drilling to be globally negligible and locally minor.

10.4.2 Crossover sampling

Golder reported that samples collected using a crossover sampling bit had the potential to cause smearing of intercepts due to the potential transfer of material down the side of the drill string between the bit and the point at which the sample crosses over to the inner sampling tube of the RC drill string. Snowden could not determine from the available databases whether CVRD had recorded where a crossover bit had been used as opposed to a face sampling bit. Snowden was therefore unable to comment on the spatial extent to which potential downhole smearing occurs.

Snowden commented that although interpreted mineralised boundaries may be offset by downhole smearing, the mineralised thickness interpreted from the results is generally correct albeit offset vertically from the true position. Given that resource estimation of each local block grade is derived from many samples in the local search neighbourhood, Snowden considered any risk associated with cross over sampling to be locally minor and globally negligible.

10.4.3 Cone and quarter sampling

Golder reported that samples collected prior to 2003 were collected using a cone and quartering method which had the potential to introduce poor precision into the resulting subsamples. Snowden proposed that poor precision would be identified in the results of the duplicate field samples collected prior to 2003. Snowden's analysis of CVRD duplicate results showed an improvement in duplicate sample precision from May 2003 onwards which may coincide with the introduction of riffle splitting versus quartering. However, while the degree of improvement was significant, the degree of precision for samples prior to May 2003 appeared acceptable for resource estimation purposes.

11 SAMPLE PREPARATION, ANALYSES, AND SECURITY

It should be noted that HZM has not conducted any sample preparation, analyses and security undertakings on the Vermelho licence. All sample preparation and analyses on the licence was completed prior to HZM announcing the acquisition of the Project in December 2017.

The following is extracted from AMEC (2006) and Snowden (2005), reviewed and amended by the author for inclusion in this Technical Report.

11.1 Sample preparation

The sample preparation was initiated by ALS Chemex at the preparation facility at Parauapebas and was completed at the preparation facility at Luiziania. The general preparation procedure was as follows (crushing only applied to diamond drilling samples):

- Drying at 105°C
- Crushing to 95% passing ¼" (6.35 mm) in a jaw crusher (every 50 samples, mass control on one sample; every 20 samples, granulometry control on one sample)
- Homogenising with four passes and splitting using a Jones splitter with 12 mm openings, to obtain at least 1 kg sample to be submitted for pulverisation (the coarse reject was stored as backup)
- Pulverising with a ring-and-puck pulveriser to 95% passing 150 mesh (every 50 samples, mass control on one sample; every 20 samples, granulometry control on one sample)
- Splitting a 20 g aliquot for assay (the fine reject was stored as backup).

Sample preparation protocols conform to industry standard practices and are suitable for nickel laterite deposits. Checks of preparation specifications are commendable.

11.2 Assaying

All samples were assayed at ALS Chemex in Vancouver, Canada, using the ME-ICP81 method. The following components were assayed: Ni, Al_2O_3, Co, Cr, Cu, Fe_2O_3, MgO, MnO, SiO_2 and Zn. The ME-ICP81 method consists of the fusion of a 0.2 g sample aliquot with 2.6 g of sodium peroxide, digestion in 250 ml of 10% and analysis by AAS for Ni and by ICP-AES for the rest of the components. According to the laboratory, the analytical precision was better than 7.5%. The detection limits are listed in Table 11.1. The official hardcopy assay certificates were stored on site.

Assaying methods are standard for this type of deposit.

Table 11.1 Detection limits of the ME-ICP81 method

Element/oxide	Unit	Upper limit	Lower limit
Al_2O_3	%	30	0.01
Co	%	30	0.002
Cr	%	30	0.01
Cu	%	30	0.005
MgO	%	30	0.01
MnO	%	30	0.01
Ni	%	30	0.005
Zn	%	30	0.01
Fe_2O_3	%	80	0.1
SiO_2	%	100	0.01

Source: AMEC, 2006

11.3 Quality assurance and quality control findings by Snowden (2005)

11.3.1 Golder

A preliminary review of the quality assurance (QA) procedures, with respect to the resource data, was carried out by Golder in April 2003 (Golder, 2003). Golder reported that:

- Drillhole data collected prior to 2000 was somewhat unreliable due to loss of original samples, lack of quality control samples and poor survey control in some cases; however, CVRD has generally replaced the old data locations with a new grid of RC holes which have industry standard QA procedures in place.
- RC drilling and collection procedures for new holes were expected to produce good quality samples albeit with some risk of downhole smearing when crossover drill bits are used in soft ground conditions.
- Prior to 2003, samples were split by coning and quartering on a rubber mat which is a process that can introduce poor precision into the resultant subsamples. From 2003, samples were riffle split through a Jones riffle splitter and were pre-dried if necessary.
- Golder could not confirm that the bulk density measurements determined from drill core were dry density values.
- Survey control on drillhole collar locations was satisfactory.
- All RC samples collected during 2002 and 2003 were re-assayed for nickel grade because prior x-ray fluorescence (XRF) estimates had been shown to understate nickel concentration;
- No detailed description of the analytical methods was available for review.
- Quality control (QC) checks included field and laboratory assay duplicates, blank and standard reference samples, and checks on pulp particle sizes and masses.
- The basis of certified values for standard reference materials was poorly documented and the standards available at that time did not test high grade nickel and cobalt accuracy.
- High grade assays of magnesia, alumina and iron oxide have been truncated by upper detection limit values of the analytical method.
- 4,698 samples (not affected by truncation) have total oxide values below what Golder considered an acceptable limit of 85% by total mass where the mass discrepancy is explained by “loss on sample ignition” of hydroxyl, carbonate and sulphate compounds.

11.3.2 Snowden

Snowden visited the Vermelho deposit in December 2003 and completed a QA review of the drill sampling collection methods being utilised (Snowden, 2004). The key results of this review were:

- Resource definition drilling samples were collected in a consistent and secure manner, and processes were in place to ensure acceptable levels of primary sample recovery
- Subsampling methods followed a logical process of drying weighing and riffle splitting prior to laboratory despatch
- Standard, blank and duplicate samples were included in the sample despatches to the laboratory
- Bulk density values were determined from dried and waxed pit samples using a water displacement method
- A random check of logs from 12 holes found that the quality of CVRD geological logging was satisfactory and consistent with the physical samples of stored sample chips
- Sampling issues raised by a prior auditor (Golder) had been or were in the process of being addressed
- The interim electronic resource database that was in place at the time of audit required additional validation and some correction to above detection limit values for magnesia and alumina.

11.3.3 Agoratek

As part of the current review, CVRD provided Snowden with a copy of a report from Agoratek International (Agoratek) who was contracted by CVRD to independently review QAQC of the Vermelho database in September 2004. Agoratek reported that:

- Sample preparation was performed by ALS in Carajas.
- Assay of the sample pulps was completed by ALS in Vancouver with:
  - XRF determination of oxides on fused pellets
  - Acid digestion and ICP determination for metals (except for Ni).
- Acid digestion and AAS determination for Ni.
- Check assays were analysed at a second laboratory (GAMIK).
- CVRD project personnel verified the resource database in 2004 and Agoratek concluded that on completion of a two-stage review the data entry error rate for assay data was negligible and estimated to be <0.5%.
- Standard reference materials used by CVRD were not properly certified and Agoratek subsequently re-certified the standards.
- The corrected standard results indicated that several assay batches were suspected to be outside acceptable levels of accuracy and Agoratek recommended that CVRD assess the effect of discarding these results for resource estimation purposes.
- A 4.5% relative negative bias (grades understated) was identified for magnesia results from ALS and Agoratek recommended upwards scaling of magnesia results or estimates.
- A positive 19% relative bias (grade overstated) was identified for MnO.
- Blank materials were not certified; however, results indicate a contamination rate in the order of 1.5% of submitted barren materials.
- Submissions to umpire laboratory of GAMIK did not include standards with the check assays.
- Only the four main attributes of nickel cobalt, silica and magnesia were reviewed in detail.

- CVRD did not visit or acquire monthly reports from the primary assay laboratory.

11.4 Quality assurance and quality control findings by AMEC (2006)

CVRD used detailed procedures at Vermelho for every operation, from drilling and sampling to sample preparation and assaying, including recommendations to minimise errors. A QC procedure was implemented during the V1 and V2 exploration programs. The program included the following control operations and control samples:

- Mass control after crushing (2%) and pulverisation (5%)
- Sieve tests after crushing (2%) and pulverisation (5%)
- Coarse duplicates (3%): inserted after splitting the original sample, before the granulometric separation (blind to the laboratory)
- Pulp duplicates (5%): inserted after pulverisation (blind to the laboratory)
- Standard samples: three standards were inserted in the sample batches: a project standard (PJ, 2%), an international standard (PI) and a synthetic standard (PS)
- Check samples (5%): submitted for external analysis to a secondary laboratory (CVRD/Gamik).

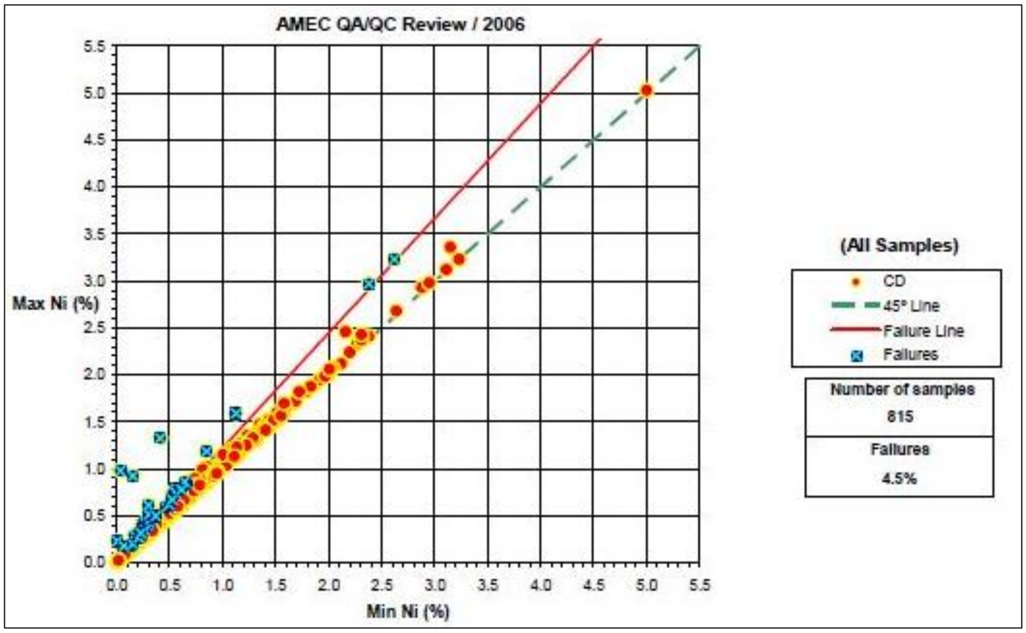
AMEC evaluated the Ni and Co coarse duplicate and pulp duplicate data for V1 and V2 (which were reported together), and concluded that the preparation quality was within acceptable ranges, as well as the analytical precision (maximum 10% failures; Table 11.2; Figure 11.1 to Figure 11.4).

Table 11.2 Duplicate summary

Sample type	Element	No. of samples	No. of failures	Failures (%)*
Coarse duplicates	Ni	830	37	4.5
	Co	830	14	1.7
Pulp duplicates	Ni	8,527	151	1.8
	Co	8,527	331	3.9

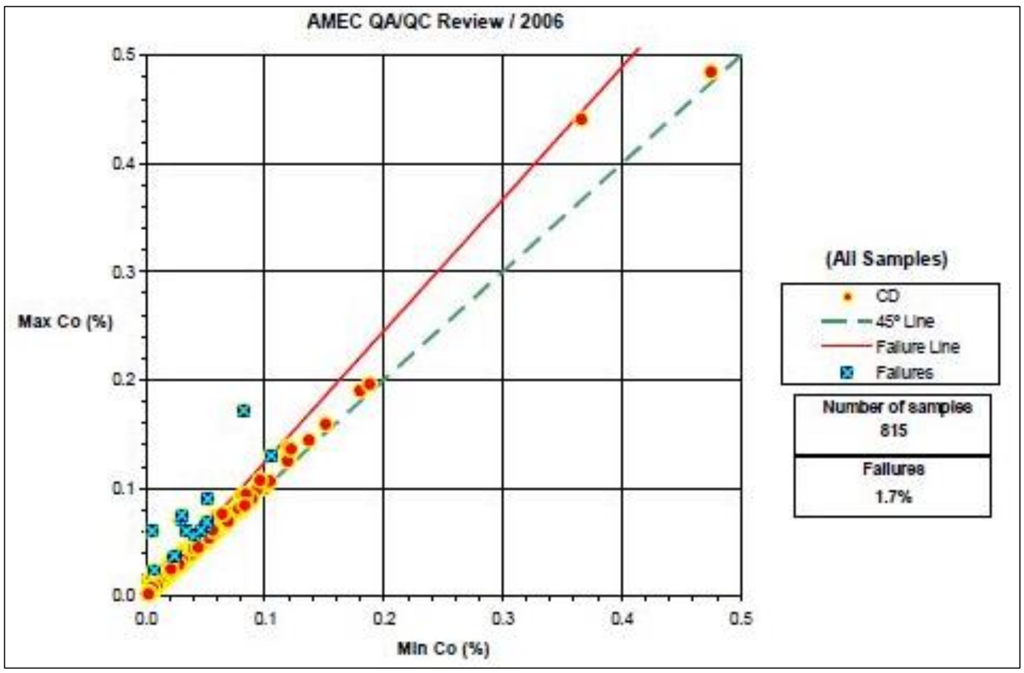
*Notes: * Maximum acceptable proportion of failures: 10%*
Source: AMEC, 2006

Figure 11.1 Ni in coarse duplicates



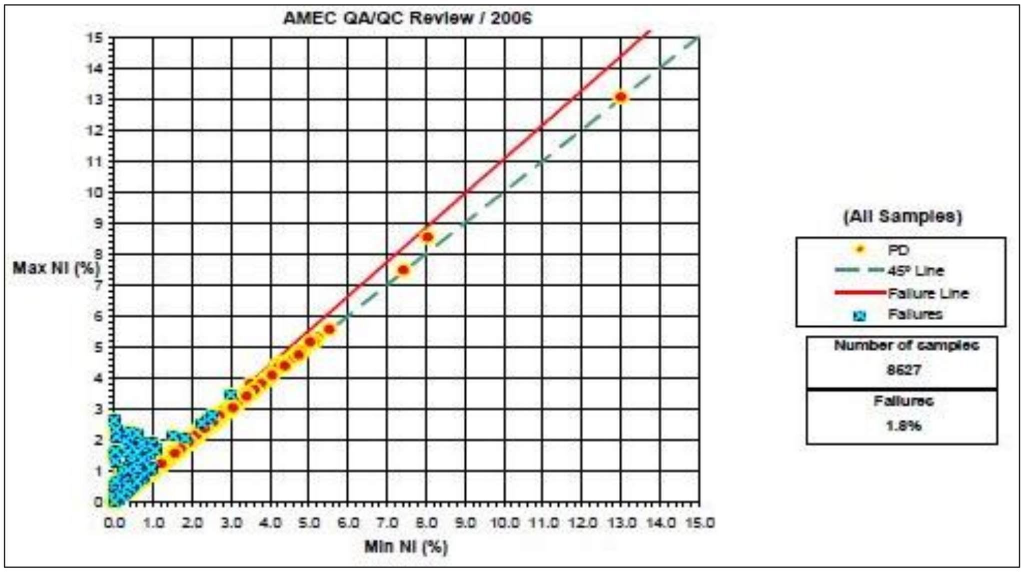
Source: AMEC, 2006

Figure 11.2 Co in coarse duplicates



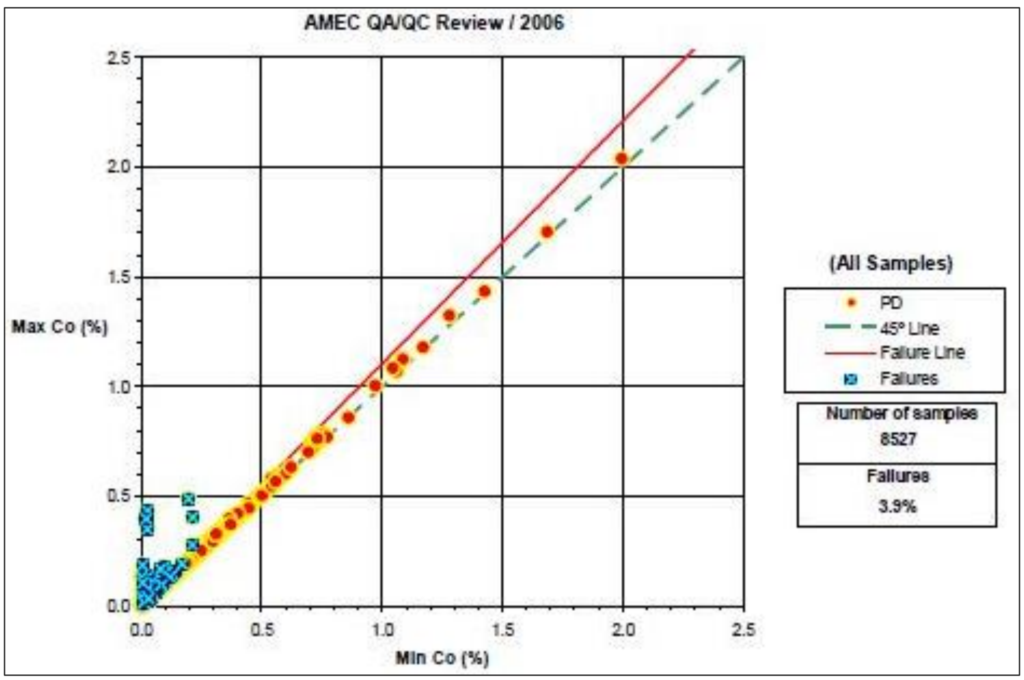
Source: AMEC, 2006

Figure 11.3 Ni in pulp duplicates



Source: AMEC, 2006

Figure 11.4 Co in pulp duplicates



Source: AMEC, 2006

Four project standards were used initially for assessing the analytical accuracy, but five additional standards were prepared and inserted later in the submission batches. The standards included in the first set were certified through a round robin with 15 international laboratories, which assayed each of the four standards 20 times. The standards included in the second set were certified through a round robin with 10 international laboratories, each of which produced four assays for each standard. The certified values for both sets are listed in Table 11.3 and Table 11.4 respectively.

Agoratek (2004) reviewed the standard assay data, and prepared accuracy plots (ALS Chemex Mean versus Recalculated Certified Values) for multiple standards. After excluding a certain number of outliers, Agoratek concluded that ALS Chemex did not show any significant relative biases for Ni, SiO_2 and Co, although a -4.5% relative bias was apparent for MgO (Figure 11.5).

Table 11.3 First set of standards used at Vermelho

Standard	Best value Ni (%)	Control limits Ni (%)	Best value Co (%)	Control limits Co (%)
VRM-1 (BT)	0.335	0.306–0.364	0.048	0.038–0.058
VRM-2 (BT)	0.615	0.574–0.656	0.024	0.017–0.031
VRM-3 (AT)	1.118	1.053–1.183	0.057	0.046–0.068
VRM-4 (MT)	0.909	0.858–0.960	0.106	0.091–0.121

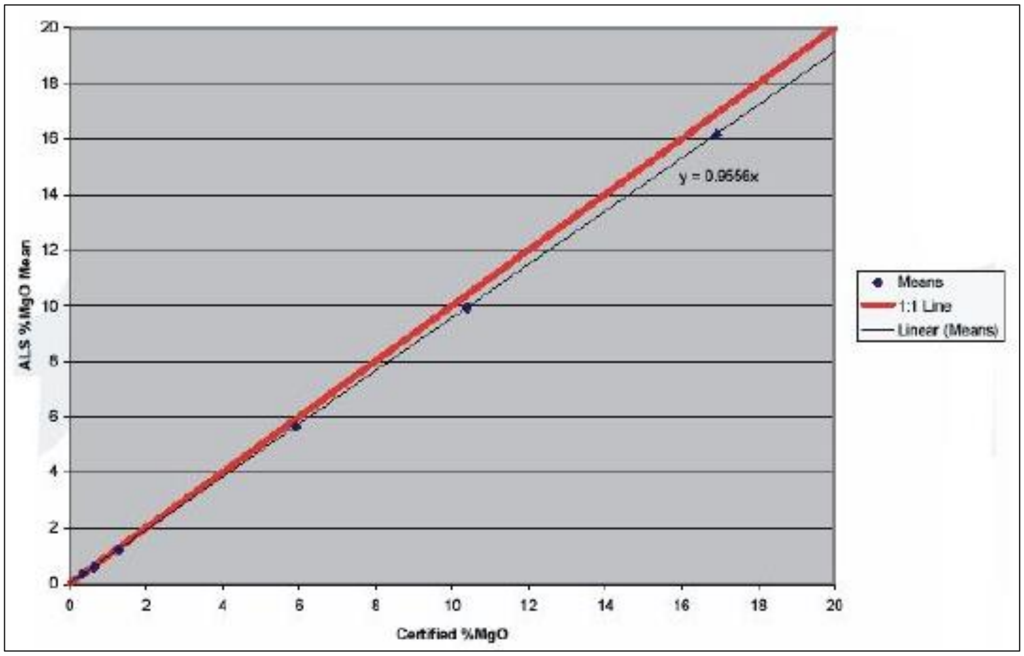
Source: AMEC, 2006

Table 11.4 Second set of standards used at Vermelho

Standard	Element	Mean (%)	RSD (%) (I)*	RSD (%) (II)**
FEBT	Ni	0.635	2.15	1.24
	SiO_2	4.052	4.56	4.3
	MgO	0.351	7.81	7.5
	Co	0.031	5.01	3.86
SIBT	Ni	0.550	2.34	1.91
	SiO_2	62.400	0.84	0.83
	MgO	1.302	2.46	2.4
	Co	0.039	3.93	1.67
PDF	Ni	1.013	2.31	2.01
	SiO_2	29.110	2.31	2.25
	MgO	10.401	1.26	1.23
	Co	0.058	4.59	3.71
AAAT	Ni	2.279	2.19	2.13
	SiO_2	43.950	2.24	2.15
	MgO	16.930	2.32	2.27
	Co	0.045	4.58	1.81
FEAT	Ni	1.205	2.7	2.24
	SiO_2	6.806	2.91	2.53
	MgO	0.652	3.51	3.19
	Co	0.225	4.48	2.69

*Notes: *Including the Standard Error of the Mean. **Excluding the Standard Error of the Mean.*
Source: AMEC, 2006

Figure 11.5 MgO average vs. nest value for multiple standards

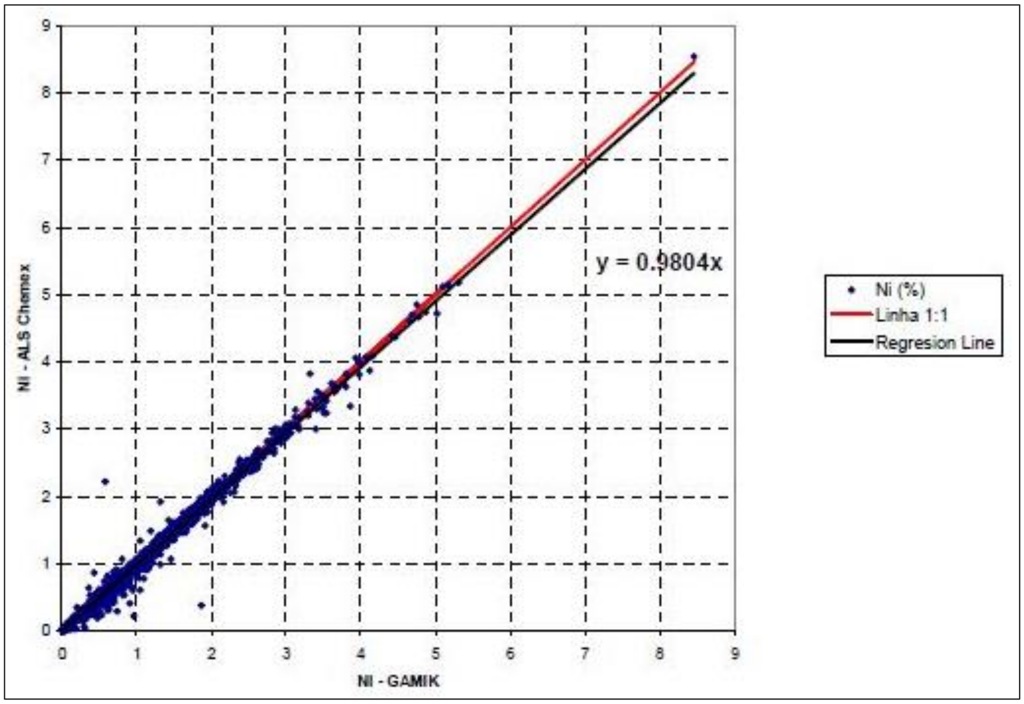


Source: AMEC, 2006

Agoratek (2004) also studied the results of 4,785 check assays performed at Gamik as a secondary laboratory. Their report confirmed the absence of a statistically significant biases for Ni (-2.0%; Figure 11.6) and SiO_2, the presence of a larger, although still acceptable MgO bias (-4.5%) relative bias of ALS Chemex as compared to Gamik, and the presence of a very Co large bias (-19%; Figure 11.7) and a large positive MnO bias (19.5%) of ALS Chemex as compared to Gamik, possibly related to reporting difficulties at Gamik, as well as other minor disturbances (Fe_2O_3, Cr). Agoratek (2004) recommended that the incompatibilities between standard results and check assay results be studied and solved if they would be deemed important for metallurgy.

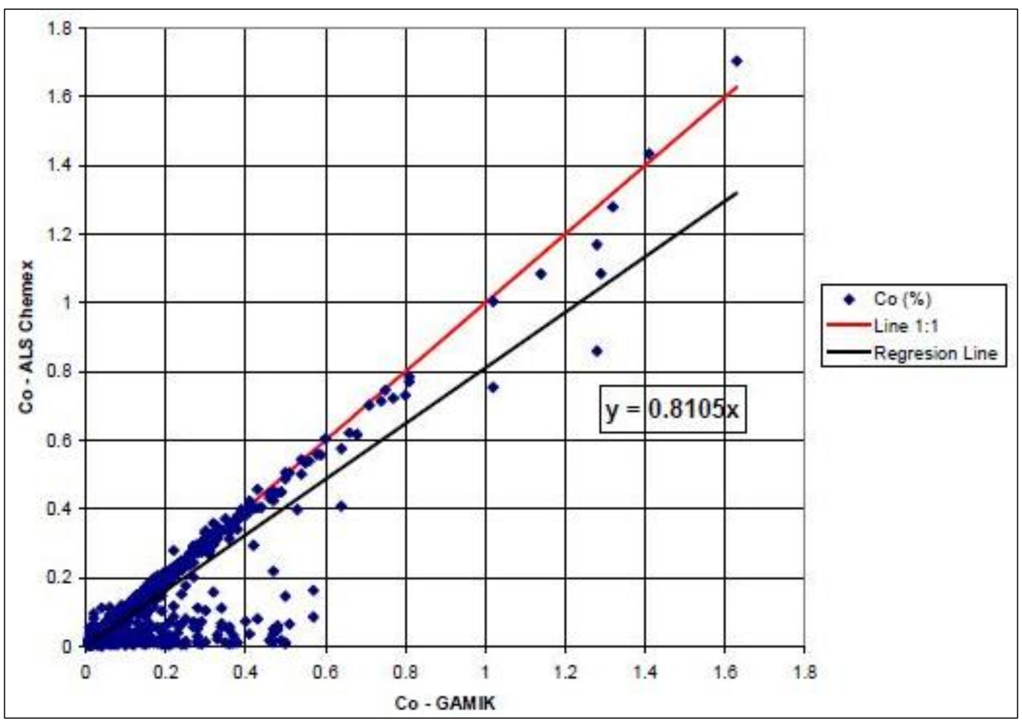
CVRD inserted a certain number of coarse blanks during sample preparation at Vermelho. However, the barren condition of those blanks does not seem to have been previously established which limits the use of such results to assess the possibility of contamination during sample preparation.

Figure 11.6 ALS Chemex vs. Gamik – Ni in check samples



Source: AMEC, 2006

Figure 11.7 ALS Chemex vs. Gamik – Co in check samples



Source: AMEC, 2006

11.5 Bulk density

As described by AMEC (2006), CVRD determined the bulk density at Vermelho through three different methods:

- Water Displacement Method on Drill Core: Bulk density was measured by the water displacement method in selected trimmed sections of intact and coherent core. Core selected for measurement of bulk density by this method was dried, weighed on air (*Wa*), covered with a thin layer of paraffin, and weighed again under water (*Ww*). The *D* density was calculated as follows:
  - $D (t/m^3) = W_a / (W_a - W_w)$
- Thin Wall Tube Method: A 15 cm diameter cylinder, with razor-sharp edges, was inserted in the ground (Figure 11.8), after which it was carefully extracted by excavating around the cylinder until it was uncovered. The material recovered within the cylinder was dried and weighed. The bulk density was calculated as the ratio between the dry weight and the inner volume of the cylinder.
- In Situ Tests: Bulk density was calculated as the ratio between the dry weight of the material extracted from a cube-shaped excavation at the bottom of a test pit and the volume of water required to fill the excavation previously lined with a thin, waterproof plastic sack.

Figure 11.8 Insertion of the thin wall tube

Source: AMEC, 2006

The three methods were compared for various lithological types, and no substantial differences were found in their results. This project has a large bulk density database, allowing local estimation of densities. The bulk density values were kriged during the preparation of the 2005 block model. A summary of the bulk density data is presented in Table 11.5.

During the RC drilling program, 4,800 samples for moisture determination were collected. The samples were bagged, sealed, and submitted to the laboratory, where they were weighed, dried and re-weighed. The natural moisture content was determined as follows:

- M (%) = (WW – DW) / WW

where WW is the wet weight and DW is the dry weight.

Density measurement methods and the number of measurements are suitable to estimate the tonnage of individual mineralised lithologies.

Table 11.5 Summary of bulk densities

Lithology	Code	No. of samples	Maximum (g/cm^3)	Minimum (g/cm^3)	Average (g/cm^3)	Median (g/cm^3)
V1						
Laterite	COB	15	2.297	1.278	1.555	1.447
Gabbro	GAB	5	2.941	2.177	2.499	2.45
Pyroxenite	PIROX	14	2.655	1.855	2.2	2.148
Magnesium Saprolite	SAP	105	2.751	0.807	1.702	1.746
Ferruginous Saprolite	SAPFE	252	2.518	0.779	1.39	1.385
Siliceous Saprolite	SAPSIL	215	2.317	0.665	1.405	1.339
Silica	SIL	61	2.487	1.171	1.809	1.764
Pyroxenitic Saprolite	SAPIROX	13	2.739	1.43	2.099	1.956
Gabbro Saprolite	SAPGAB	10	2.538	1.474	1.747	1.671
Serpentinite	SERP	15	2.584	2.339	2.416	2.409
Weathered Serpentinite	SERPINT	26	2.357	1.375	1.995	2.115
Semi-weathered Serpentinite	SERPSI	14	2.612	2.231	2.382	2.364
V2						
Laterite	COB	26	2.813	0.956	1.527	1.303
Pyroxenite	PIROX	3	2.537	2.396	2.482	2.514
Magnesium Saprolite	SAP	156	2.55	0.881	1.634	1.638
Ferruginous Saprolite	SAPFE	113	1.865	0.883	1.256	1.246
Siliceous Saprolite	SAPSIL	436	2.585	0.665	1.499	1.437
Silica	SIL	38	2.449	0.826	1.853	2.013
Pyroxenitic Saprolite	SAPIROX	11	2.11	0.903	1.432	1.363
Gabbro Saprolite	SAPGAB	3	1.475	1.144	1.335	1.385
Serpentinite	SERP	6	2.478	2.322	2.418	2.429
Weathered Serpentinite	SERPINT	14	2.477	1.32	2.079	2.121
Semi-weathered Serpentinite	SERPSI	3	2.376	2.305	2.354	2.376

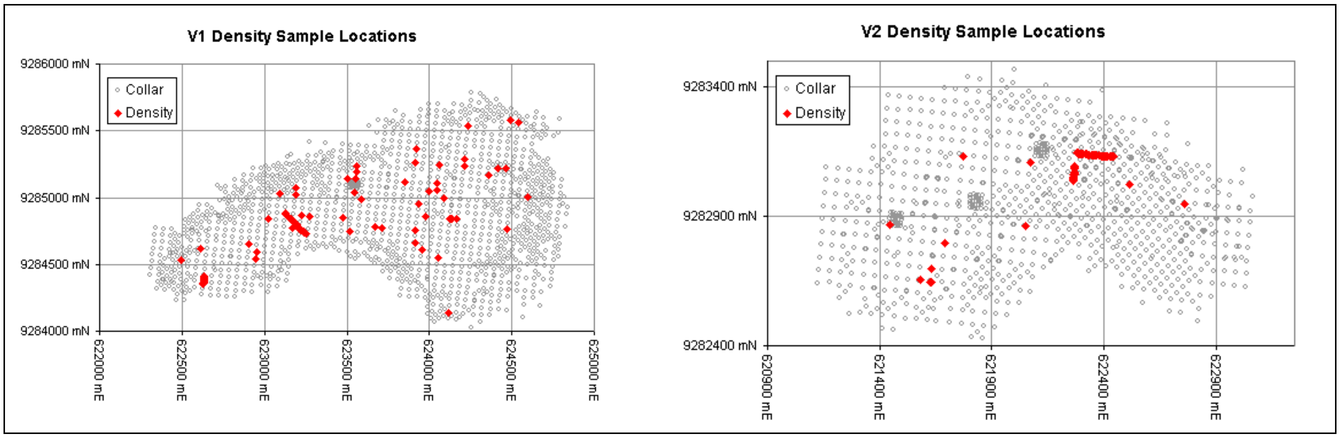
Source: AMEC, 2006

11.5.1 Comments on bulk density sampling (Snowden, 2005)

Golder was unsure as to whether bulk density samples were reported on a wet or dry basis. Snowden confirmed in a later audit that bulk density determinations were carried out on dried and waxed samples. Figure 11.9 below shows the spatial location of the available bulk density data which comprises 972 measurements in V1 and 987 measurements in V2.

The apparent clustering of samples was not considered by Snowden to represent a risk to correct density allocation since the bulk density in the model is assigned on a lithology code basis. Importantly, Snowden's experience is that determination of local bulk density in nickel laterite deposits is problematic due to the nature of variation of materials and that while the global estimation of density is reasonable, local estimation accuracy is subject to the correct estimation of material types within each model block.

Figure 11.9 Bulk density sample locations for V1 (left) and V2 (right)



Source: Snowden, 2005

11.6 Author's opinion on the adequacy of sample preparation, security, and analytical procedures

The author considers that major issues of quality assurance with respect to sampling protocols have been addressed in prior reviews. The site visits by Golder and the author have confirmed that the CVRD procedures put in place for collecting, subsampling, and despatching samples generally followed good industry standards.

Snowden's review in 2005 identified other QAQC issues identified in prior reviews that have not all been addressed in subsequent documentation. As such, the author concurs that Snowden has identified the key issues with respect to QAQC and formed an opinion as to the current status of each key issue as follows.

- The pre-2000 drilling may be unreliable; Snowden considers that this data represents only a small portion of the resource database and in most cases samples have been taken from new holes near these locations using more reliable methodologies.
- Crossover sampling bits may lead to sample smearing downhole; Snowden could not identify how much of the drilling data had been collected using a crossover sampling bit but considers that in this type of deposit that that any inaccuracy introduced by drillhole wall cavitation would be minor and that local estimates would be acceptable.
- Cone and quarter sampling pre-2003; Snowden's analysis of duplicate data has shown that the cone and quartering method used until mid-2003 has lower sampling precision than riffle splitting but the improvement in precision with riffle splitting is small. However, there is generally poorer precision associated with the samples associated with the central portions of the Vermelho deposits as a function of the focus of earlier drilling programmes in these areas.
- Reliability of bulk density values; Snowden considers that CVRD has collected sufficient bulk density values to allocated density on a rock code basis. However, Snowden notes that the pattern of sampling for density in V1 is concentrated at the margins on the deposit while in V2 the samples are more from the core of the deposit.
- No analytical procedure descriptions; Snowden reviewed descriptions of analytical procedures provided by CVRD and considers the methods to be of good industry standard.
- Quality of standard materials; An initial review raised concerns as to the quality of standard reference materials and a subsequent study involved re-certification of some standards. Snowden has confirmed these issues and attempted to interpret the available results as discussed further below (see Section 11.6.2).

- Assay truncation (particularly magnesia at 30%); The majority of truncated magnesia values have been re-assayed to determine high concentration values within resource envelope. Snowden considers that the risk associated with remaining capped values is small because most are outside the resource envelope or are locally constrained by more accurate data.

11.6.1 Sampling precision

Snowden reviewed the representation and precision of the duplicate data for nickel, cobalt, magnesia, silica and iron. It has found that:

- The field and laboratory duplicate representation is generally good with duplicates collected from nearly all holes in all phases of drilling.
- From April 2003 onwards, the field duplicate level of precision for nickel, silica and iron oxide is good with approximately 90% of the duplicate results having an absolute relative difference in the order of ±10% of the pair mean. However, precision of earlier drilling programs (pre-April 2003) is not as good with approximately 85% of the duplicate results having duplicate pair mean relative difference in the order of ±10% of the pair mean. For magnesia and cobalt, the duplicate precision is lower than that of the other attributes reviewed, with approximately 75–85% of duplicate assays having a pair mean relative difference of ±10%.
- The precision of laboratory repeats is very good with nearly 100% of duplicates for nickel, magnesia silica and iron oxide having a pair mean relative difference of ±10%, with only cobalt having marginally lower precision.

Accepting that the average of duplicate values is a more robust estimate of the grade at each sample location, the results for the duplicate data indicate that nickel, iron oxide and silica grades used on the resource estimate are generally within 10% of the mean in approximately 90% of the cases. For cobalt and magnesia, the confidence is lower, with approximately 85% the cases being within 10% of duplicate mean.

11.6.2 Assaying accuracy

Snowden found that the many of the standard reference materials assayed by CVRD during the course of resource definition drilling appear to have been incorrectly certified in terms of the certified variability of the data. Additionally, a number of outlier results indicate some sample submission errors and/or heterogeneous standard materials. By removing obvious outlier and an analysis of the mean grades and variability of the standards submitted, Snowden has estimated the levels of accuracy of assaying at the 95% confidence limit for the key attributes to be approximately:

- ±6% relative for nickel grade, with nickel being approximately 1% understated
- ±8% relative for cobalt grade, with cobalt grades being generally accurate
- ±15% relative for magnesia grade with magnesia grades being approximately 3% understated
- ±7% relative for silica, with silica grade generally accurate.

Note that these are somewhat subjective estimates due to issues associated with the quality of the standard reference material data; however, the estimates do give a guide to the level of confidence in individual input assays.

12 DATA VERIFICATION

12.1 Introduction

There have been several data verification studies performed on the primary Vermelho exploration data during its ownership by CVRD. The author visited the site in December 2003 and his amended report is included below, followed by other verification studies performed by independent experts.

12.2 Data verification by the Qualified Person in 2003

At the request of CVRD, Andrew F. Ross of Snowden visited the Vermelho Property on 9–12 December 2003. The purpose of the visit was to:

- Observe field procedures during an infill phase of drilling that was underway at the time of the site visit so that the author could endorse the CVRD classification scheme with respect to JORC and CIM guidelines
- Obtain the latest Gemcom database including re-assayed over limit MgO sample data for ongoing geological and statistical analysis, if requested
- Review the geological basis for partitioning the low-grade Ni grades from the SAP horizon.

The visit was made in the company of CVRD's Marcello Costa and included discussions with site geological staff Roberto Albuquerque, Divinio Fleury, Walter Riehl and Marcos Ferreira. Post-visit meetings were held with CVRD's Edson Ribeiro and Marcio Fonseca at Belo Horizonte on 13 December 2003 and Vanessa Torres and Ruy Rodriguez at Perth on 19 December 2003.

12.2.1 Drill program

Drilling operations at both V1 and V2 deposits were observed on several occasions during the site visit.

At V2 large diameter (approximately 8-inch) coring operations were observed at three sites: hole FM 105 was in progress of being extended from 50 m to a planned depth of 90 m; rig 121 was in the process of being moved; and the core barrel was being pulled on rig 119, hole FM 78 at 59 m. The author understands that nine rigs are involved in the large diameter core program to obtain samples for metallurgical testwork. The equipment is operated by contractor GEOSOL on a 2 x 12-hour shift basis for an average advance of 7 m per day.

RC drilling was in progress at V1. Contractor GEOSEDNA's Prospector rig was observed being refuelled at hole 1056 at a depth of 61 m on 9 December. On 11 December, the rig was drilling at a depth of 5 m at line LT725W 175N. Samples were bagged at 1 m intervals.

The accompanying photos (Figure 12.1) illustrate various aspects of the drill programs.

Figure 12.1 Photos from the drill programs

Large diameter coring operations –
pulling the core barrel at FM 78

Large diameter coring operations –
depth markers in core boxes

Infill RC operations –
equipment is old but drilling penetration rates are high

Infill RC operations –
Prospector W750 articulated rig at V1 LT725W

Large diameter coring operations –
safe storage of drill consumables and recycling

12.2.2 Chain of custody of samples from rigs to sample farm

The author observed the safe transport of core from the drill rig to the core logging shed adjacent to the Project Office building, and the safe transport of RC samples from the drill rig to the sample farm on several occasions. The ZAG geological technicians were responsible for safe transport of the samples.

12.2.3 Sample storage, processing and security

The author found that there was little left to chance in the security of core, and orderly processing of RC samples.

The large diameter core boxes were laid out for geological logging and sampling, and these activities were underway at the time of the site visit. After logging and sampling the boxes were stacked, awaiting the results of assays before despatch to Australia for metallurgical testwork. The core required compositing and then transfer to metal or plastic containers to meet quarantine approval.

RC samples were processed in a compound within walking distance of the Project Office. Samples were dried, weighed, and split using a modified riffle splitter recommended by D.F. Bongarcon of Agoratek. The author observed the handling and splitting of several samples and the procedures for decontamination and bagging. The ZAG technicians processed the samples in accordance with the procedures described by CVRD staff.

Representative material was cast onto wooden “rules” for geological logging and an additional sample was archived in plastic cups for reference. These are satisfactory ways for storing reference material and the library appeared to be secure and well organised.

Images from the sample preparation process are shown in Figure 12.2.

Figure 12.2 Photos of sample preparation

Bagged and labelled RC samples at drill pad, ready for transport to farm

RC sample weighing

Drying of RC samples

Preparation of “rules” for logging of RC chips

Storage of RC chips for reference – lid was removed from box

Logging and sampling of large diameter cores

12.2.4 Density measurements

A laboratory was established in the RC sample compound to handle density measurements of samples taken from the pits (pocos).

The technicians described the procedures for drying and wax coating of samples. The author observed the water replacement method in process and concluded that the procedures conformed to standard industry practice.

12.2.5 Sample preparation and assay

The quartered RC samples were transported to the nearby assay laboratory at Carajas. At the time of the site visit there were no samples from Vermelho being processed and the author did not review this aspect of the field operations.

12.2.6 Status of Golder’s recommendations

CVRD had previously engaged Golder to conduct a review of the geology and resource database in April 2003 and the resultant recommendations were considered by CVRD. The author discussed the status of Golder’s recommendations with CVRD staff.

12.2.7 Data provided by CVRD

CVRD supplied the author with the following data:

- The latest unvalidated Gemcom sample database as two versions, date stamped on 9 and 12 December 2003
- Original logs for 11 holes from line LT700W, deposit V2: V2-FP185; V2-FP-178; V2-FP-179; V2-FP-173; V2-FP-60; V2-FP-114; V2-FP-53; V2-FP-48; V2-FP-50; V2-FP-55; V2-FP-59
- 117 original assay electronic assay certificates, dated from 2002 and 2003
- Source files for duplicates (19), standards (10) and survey (10) results
- Drillhole location maps for V1 and V2 (scale 1:5,000)
- Drill section LT700W section.

12.2.8 Findings

Drill operations

The author observed that field operations were conducted in a safe and professional manner, that drill sites were clean, with samples securely boxed and labelled, or bagged and labelled appropriately in a consistent way.

The author understood that GEOSEDNA was required to re-drill a hole where recoveries fell below 60%. Recoveries were determined by CVRD’s geological contractors, ZAG, who undertook routine weighing of samples.

It was standard CVRD practice for ZAG personnel to monitor RC drill performance and to transfer samples to the sample preparation areas. However, there was no requirement for ZAG to continually remain at the drill site during sampling operations. The author recommended that, in future programs, consideration is given to continuous monitoring by a geotechnician to ensure that sample bagging remains error-free.

Resource database

Some validation checks of the interim database were made by the author and inconsistencies were noted where over limit MgO and Al_2O_3 assays had been merged incorrectly. These were mostly rectified by site personnel; however, there were still several records where the new over limit MgO assay values were inconsistent with the earlier values and sample identification switching was suspected.

Further validation of the resource database was recommended prior to commencement of the FS resource estimates after all the results had been obtained.

Geological logging

The author selected 12 RC drillholes from line LT700W at V2 for a review of the geological logging and database integrity.

CVRD was able to recover the reference material for all requested holes and the author then compared the geological logs and Gemcom lithocodes with the actual chips. The quality of logging and database entries were found to be satisfactory.

Geological surfaces

A low-grade nickel population was identified in the SAP horizon in Snowden's earlier review of the resource model. The merits of applying a 0.5% Ni basal boundary to screen out the lower grade population was considered; however, it appears that a substantial number of low grade samples occur as low grade pockets at higher levels in the horizon. The author recommended applying a 0.3–0.5% Ni boundary to screen out included fresh rock both at the base and at higher levels in the profile and then compare this with the bedrock interpretation as determined solely from geological logging.

The author recommended that the selection of surfaces is considered after all the results of the geological mapping are to hand. The geological domaining should then be developed in parallel with contact analysis to determine vertical and lateral grade trends.

Consideration should also be given to the introduction of a transition horizon between the SAPFE and SAP horizons where MgO grades appear to crossover from extremes of low to high grades.

12.3 Data verification by Snowden in 2004

Extracted from Snowden 2005 (Final Feasibility Study Resource Review)

12.3.1 Resource Model Review Process

C. Standing of Snowden reviewed the V2 resource model in CVRD's office at Belo Horizonte during 6 to 12 August 2004 and then reviewed the revised V2 model from 23 to 25 August 2004. The V1 model (dated September 2004) was reviewed In Snowden's Perth office from 20 September to 1 October 2004.

The major aspects of the review for the V2 and V1 resource models included:

- Reviewing the geological interpretation in cross-section and as 3D solids and surfaces
- Checking coding of input data against the wireframe models
- Checking coding of block models against the wireframe models
- Review of the statistical analysis of input data for domain verification and consideration of grade estimation methodology
- Review of the variogram analysis for verification of variogram and search parameters

- Checking the output files from the kriging runs
- Checking for uninformed blocks and that grades are within expected limits
- Checking the application of the Gemcom script files used for dilution, classification and merging of the component folders
- Visual validation of the grade, density and classification models;
- Checking the integration of the component grade and density data into the final diluted and undiluted resource models
- Examination of the validation trend plots of the grade models by easting, northing and elevation provided by CVRD.

QA/QC data and graphs for duplicate standards were briefly examined. These were not reviewed in detail as it was understood that Dr D. Francois-Bongarcon had undertaken a detailed review of all the QAQC data and was preparing a report that covers this aspect.

Following the initial review of the V2 model, a few issues were identified which were summarised in a power-point presentation that was given to the CVRD's resource team in Belo Horizonte with Snowden's understanding of the actions that were to be taken by CVRD. The majority of Snowden's recommendations and issues were addressed and the revised V2 resource model was provided to Snowden on 19 August 2004. Following a check that the major issues had been addressed, this model was exported for the mining study.

The recommendations that were not addressed by CVRD are as follows:

- Following statistical analysis, it was noted that some Fe (25 values) and MgO (96 values) grade data have been increased by capping of grades at the lower end of the Fe distribution. It was expected that this would be revised, however while this grade capping is not advisable, this is not regarded as significant as it affects less than 0.2% of the data.
- The search orientations for the SapFe domain were revised but the variogram parameters were not.
- The nugget effects for Co and MnO used for grade estimation were too low and should have been increased.

It is understood that these issues are minor and that, as the development of the V1 model was regarded as a priority, these issues were not addressed. Snowden believes that they will have had an insignificant impact on the resource model.

It was understood that 1 m data compositing would be implemented for V1. This was not done but this is not regarded as being significant as it affects less than 2% of the data.

During the review of the V1 model, the undiluted model was developed, and corrections were made to the Cu grade model and the waste density model by CVRD. The V1 model was then exported for the mining study. During this time, a Zn grade model was provided by CVRD for V2 that was exported and incorporated into the V2 mining study.

12.4 Data verification by AMEC in 2006

12.4.1 Database integrity review

CVRD implemented an in-house database management system at Vermelho. Logging and sampling data were manually entered into the database. The database system had built-in algorithms for checking overlapping or missing values. The remainder of hand-entered data was checked visually, using the original data sheets. The survey data were digitally entered from the survey equipment, with no backup hard copies. The assay data were digitally entered by the laboratory, but official, backup hard copies of assay certificates were retained and filed.

Drillhole collars

AMEC inspected the collars of 16 drillholes from V1 and 14 drillholes from V2 (1.2% and 1.6%, respectively, of the drillholes included in the database), and measured the coordinates with a Vista e-Trex GPS. Most collars were well conserved and identified, with marked long wood sticks. The measured coordinates were compared with the database coordinates, and the maximum planar difference found was 28.3 m, within the current GPS precision (Table 12.1 and Table 12.2).

Table 12.1 Review of V1 collar coordinates

Hole ID	Database coordinates		AMEC coordinates		Differences	
	X (m)	Y (m)	X (m)	Y (m)	X (m)	Y (m)
V1FD024	623,247.000	8,284,717.000	623,262.042	9,284,716.239	15.0	-0.8
V1FP117	622,996.000	9,284,740.000	623,014.047	9,284,735.795	18.0	-4.2
V1FP148	623,698.000	9,284,731.000	623,715.914	9,284,725.655	17.9	-5.3
V1FP171	623,605.000	9,284,847.000	623,626.049	9,284,834.127	21.0	-12.9
V1FP181	623,562.000	9,284,801.000	623,570.475	9,284,788.588	8.5	-12.4
V1FP250	623,291.000	9,284,806.000	623,272.407	9,284,814.508	-18.6	8.5
V1FP263	623,101.000	9,284,820.000	623,072.703	9,284,831.045	-28.3	11.0
V1FP279	623,058.000	9,284,782.000	623,069.499	9,284,784.505	11.5	2.5
V1FP389	623,759.000	9,284,738.000	623,765.789	9,284,722.573	6.8	-15.4
V1FP540	624,205.000	9,284,885.000	624,232.755	9,284,881.131	27.8	-3.9
V1FP650	624,111.000	9,284,798.000	624,122.873	9,284,791.138	11.9	-6.9
V1FP667	624,216.000	9,284,330.000	624,233.445	9,284,783.603	22.3	10.6
V1FP706	623,967.000	9,284,768.000	623,968.933	9,284,758.824	12.8	-8.0
V1PO240	622,892.000	9,284,657.000	622,904.758	9,284,649.004	12.8	-8.0
V1PO241	623,015.000	9,284,840.000	623,023.997	9,284,836,969	9.0	-3.0

Source: AMEC, 2006

Table 12.2 Review of V2 collar coordinates

Hole ID	Database coordinates		AMEC coordinates		Differences	
	X (m)	Y (m)	X (m)	Y (m)	X (m)	Y (m)
V2FD019	622,257.000	9,283,095.000	622,268.548	9,283,094.617	11.5	-0.4
V2FP108	621,537.000	9,282,662.000	621,527.983	9,282,657.086	-9.0	-4.9
V2FM064	622,736.000	9,282,810.000	622,747.226	9,282,802.205	11.2	-7.8
V2FM099	621,617.000	9,282,761.000	621,634.927	9,282,747.595	17.9	-13.4
V2FP125	621,415.000	9,282,673.000	621,473.649	9,282,610.940	12.8	-7.7
V2FP212	622,046.000	9,282,967.000	622,056.227	9,282,962.007	10.2	-5.0
V2FP265	621,464.000	9,282,609.000	621,473.649	9,282,610.940	9.6	1.9
V2FP271	621,567.000	9,282,658.000	621,578.284	9,282,653.147	11.3	-4.9
V2FP273	621,519.000	9,282,715.000	621,532.458	9,282,706.406	13.5	-8.6
V2FP331	621,574.000	9,282,853.000	621,595.280	9,282,851.717	21.3	-1.3
V2FP342	621,789.000	9,282,835.000	621,794.791	9,282,834.179	5.8	-0.8
V2FP487	622,997.000	9,282,939.000	623,005.684	9,282,930.887	8.7	-8.1
V2FP853	621,479.000	9,282,878.000	621,483.931	9,282,873.348	4.9	-4.7
V2FP860	621,451.000	9,282,915.000	621,462.615	9,282,913.209	11.6	-1.8

Source: AMEC, 2006

As part of the collar review, AMEC also plotted 204 drillhole collars from V1 and 105 drillholes from V2 (14.8% and 12.0%, respectively, of the drillholes included in the database) on the final version of the topographic maps, with 5 m contour lines, and compared the collar altitude with the location altitude for each hole, according to the contour lines represented in the topographic map. None of the holes presented significant differences in elevation, and all appeared to be correctly plotted.

Original logs vs. database entries

The original drillhole logs were properly filed on site and could be easily reviewed. The original logs included both coded and detailed handwritten descriptions of the lithology, as well as codes for primary and secondary minerals and information about structures.

AMEC checked three fields (From, To and Lithology) of the database against 50 original logs from V1 and 42 original logs from V2, corresponding to 3.6% and 4.8%, respectively, of the drillholes included in the database, to determine the entry error rates. AMEC also reviewed, by double data entry, the Ni assay data of 2,768 samples from V1 and 2,892 samples from V2.

Table 12.3 lists the entry errors found in the review. The partial and total entry error rates were acceptable, given the industry standard of less than one percent error for databases supporting resource estimates.

Table 12.3 Entry errors in the V1 and V2 database

Field	No. of entries	No. of errors	Error rate (%)
V1			
From–To	543	1	0.2
To	543	4	0.7
Lithology	543	4	0.7
Ni	2,768	2	0.1
V2			
From	287	0	0.0
To	287	3	1.0
Lithology	287	2	0.7
Ni	2,892	0	0.0
Total	**8,150**	**16**	**0.2**

Source: AMEC, 2006

Sampling consistency

AMEC reviewed the sample intervals as stored in the database and compared the sample material with the original logs from 50 drillholes from V1 and 42 drillholes from V2 (3.6% and 4.8% of the holes, respectively, included in the database). AMEC checked the main lithologic types and the sample intervals, which were adequately recorded. The sample data were properly identified in the sample bags and tags. Sample intervals (From–To) agreed with major lithologic changes on drill logs and respected the main lithologic boundaries.

Geological interpretations

AMEC reviewed all the geological sections from V1 (48 sections) and from V2 (38 sections), located at 50 m intervals, and reviewed the geometry of the interpreted geological shapes in the sections. Additionally, AMEC reviewed the original logs from 20 holes from V1 and 20 holes from V2 (1.4% and 2.3% of the holes, respectively, included in the database), and visually cross-checked them against the information displayed in the corresponding geological sections. AMEC also checked the original logs versus the RC chips from 13 holes from V1 and 17 holes from V2 (0.9% and 1.9% of the holes, respectively, included in the database), and vs. the remaining core of two diamond drillholes, one from each deposit.

AMEC recognised that the interpretation respected the data recorded in the logs and the sections, as well as the interpretation from adjoining sections, and was consistent with the known characteristics of this deposit type. The lithologic model had been diligently constructed in conformance with industry standards practices. AMEC did observe that in some sections the interpolation rules applied to ferruginous Saprolite bodies that pinched out were not consistent (the pinching out distance was irregularly established).

In general, geological interpretations were suitable to support resource estimates.

Conclusions

AMEC made the following conclusions:

- CVRD used very detailed and accurate written procedures to guide practically every aspect of the geological work
- Drilling, logging, sampling, and geological interpretation of the V1 and V2 deposits were conducted consistently and diligently

- Database integrity had been favourably tested; the database entry error rates were within acceptable ranges
- The QAQC protocols in application by CVRD for sampling, sample preparation and assaying were generally adequate: precision, accuracy and contamination were regularly determined
- AMEC processed the laboratory duplicate assays for Ni and Co and confirmed that the preparation variance and the analytical precision for these elements appeared to have been within acceptable limits
- AMEC reviewed the analysis prepared by CVRD and Agoratek for the analytical accuracy based on inserted standards, and confirmed the absence of significant biases for Ni, SiO_2 and Co, and a relative larger, although still acceptable, bias for MgO (4.5%)
- However, the check assay results yielded contradictory results: a larger, although still acceptable MgO bias (-4.5%) relative bias; and substantial Co bias (-19%) and MnO bias (19.5%) of ALS Chemex as compared to Gamik were apparent
- Despite the above-mentioned facts, AMEC believed that the assay data from these exploration campaigns could be used for resource and reserve estimation purposes
- The density determination procedures applied by CVRD at V1 and V2 were adequate and correspond to industry standards.

12.5 Data verification by HZM in 2016 and 2017

12.5.1 2016

HZM advised the author of due diligence items completed by HZM during a site visit from 21 to 23 September 2016:

- Drillhole logging from eight core holes were checked
- HZM checked that drillhole database conformed to assay certificates on four selected holes with significant SAP intersections
- HZM checked that core and RC chippings and rejects are available in the storage sheds
- HZM compared two selected DDH and twin RC holes.

HZM advised the author that all the checks were satisfactory.

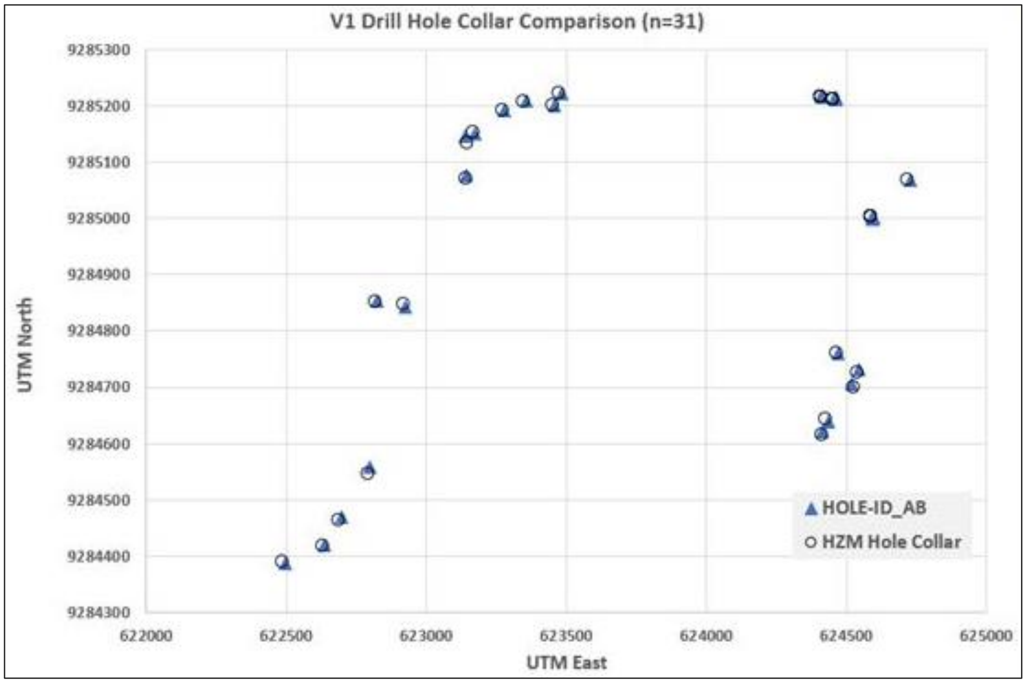
12.5.2 2017

Between 17 and 20 October 2017, a HZM team visited Vermelho targets V1 and V2 to locate and measure coordinates for DDH and RC drillholes, pits, outcrops, and access tracks. Coordinates were measured with a handheld Garmin GPS map 62S instrument configured for the SAD 69 datum.

A total of 66 drillholes, monitoring wells and pits were located, 37 at V1 and 29 at V2. Of this total, 54 drillholes were identified in the Vermelho drillhole database and were used in the comparison. The database coordinates are also based on the SAD 69 datum.

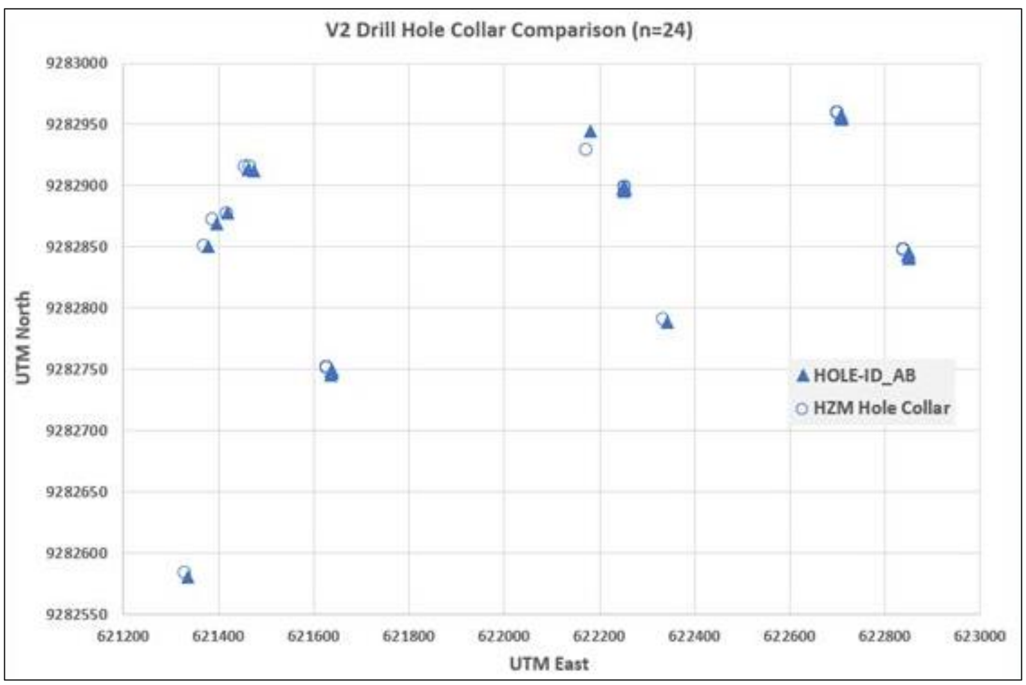
Of the 55 drillholes, 31 are at target V1 and 24 at target V2 (Figure 12.3 and Figure 12.4).

Figure 12.3 Location of verified drillholes at V1



Source: HZM

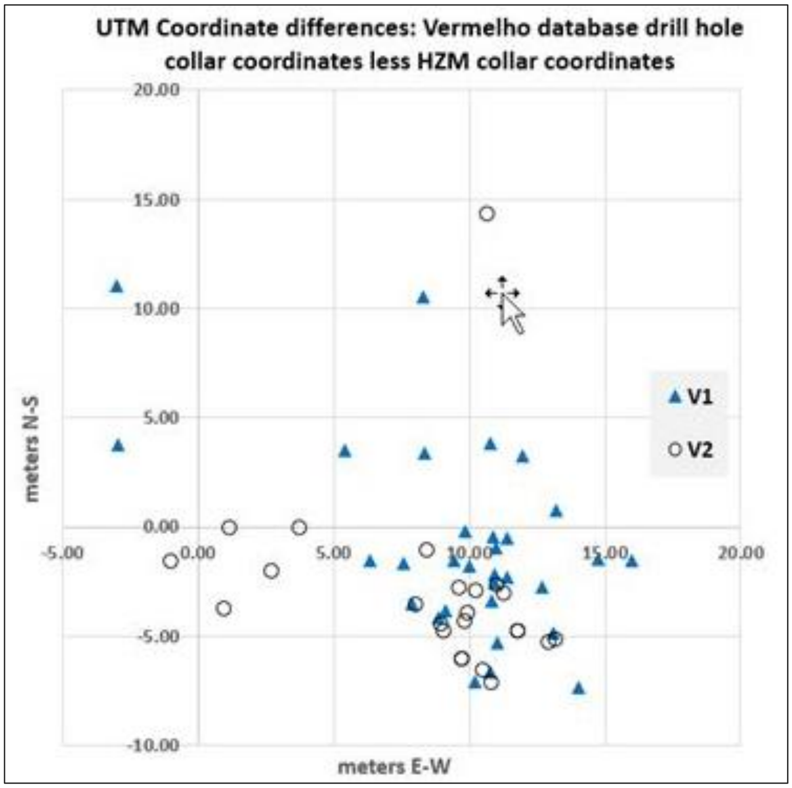
Figure 12.4 Location of verified drillholes at V2



Source: HZM

Figure 12.5 shows the absolute difference in metres between the coordinate pairs. HZM collar coordinate measurements are, on average, 9.2 m east and 1.8 m south of the of the Vermelho collar coordinates identified in the CVRD drillhole database.

Figure 12.5 Difference in collar coordinates



Source: HZM

The measured coordinates compared to the database coordinates showed a maximum planar difference of 16 m, considered to be within GPS precision. Based on this evaluation the drillhole database coordinates are believed by HZM to accurately reflect the location of the drillholes.

12.6 Qualified Person's opinion on the adequacy of the data for the purposes used in the technical report

The field operations used to acquire the data for Vermelho Mineral Resources were checked several ways so that a view of data integrity could be formed by the author. Drilling and sampling procedures appeared to be satisfactory at the time of the site visit, and the author relied on the earlier observations of Golder with respect to the quality of survey control and collar locations.

The author conducted checks on the consistency of CVRD's geological logging from a key section from V2, and this was found to be satisfactory.

The author recommended assaying of the actual samples taken for density measurements, rather than relying on the assays from the surrounding material.

In 2003, CVRD was in the process of collecting additional geological and assay data to support a resource estimate for the FS and it was necessary to compile the fact geological mapping, drill logging and interpretation with the assays in preparation for resource estimation. Integrity checks of the resource database were recommended because the brief checks made at the time of the site visit showed that errors (however minor) exist. In view of the re-analysis of over limit and extreme grades it was prudent to build an integrity database and conduct correlation checks with the database at site.

The author concluded from his observations and Golder's report that the field procedures to collect data are satisfactory for a JORC (2004) and CIM (2003) compliant MRE.

Further assessment of the geological interpretation and contact analysis was required to better domain the laterite profile. A transition horizon may be useful in reducing the mixing of grade populations at the SAPFE/SAP contact. The basement surface should be determined from geological logging and then compared with a 0.3% to 0.5% Ni contoured surface.

13 MINERAL PROCESSING AND METALLURGICAL TESTING

13.1 Introduction

The Vermelho Nickel-Cobalt Project was developed by Vale (CVRD) with the objective of becoming its principal nickel-cobalt operation. Extensive work was undertaken on the project at Scoping (PEA), Prefeasibility and Feasibility stages, which included drilling and pitting programs totalling 152,000 m, full scale pilot testwork and detailed engineering studies. The Project was subsequently taken through a Feasibility program with CVRD announcing a positive development decision in 2005. The Project was designed around the construction of a HPAL plant to process the nickel/cobalt laterite ore. The FS included a five-year metallurgical testwork and pilot plant program which delivered 96% average leaching extraction rates of nickel and cobalt, in addition LME grade nickel – cathode was produced. The FS showed production capacity of 46,000 t/a of metallic nickel, and 2,500 t/a of metallic cobalt, with an expected commercial life of 40 years. Vermelho was subsequently placed on hold after delivery of the FS upon an internal review.

Process flowsheet development for nickel laterite deposits is dependent upon the metallurgical characteristics (both chemical composition and physical form) of the laterite mineral types (limonite, transition, and saprolite). To correctly characterise the material, it is necessary to carry out the appropriate metallurgical testwork and through this establish an appropriate flowsheet. Selection of a suitably representative sample set from the main lithologies in each deposit (and the associated mineral resource) is key to this process.

It should be noted that the testwork conducted, and presented in this Technical Report, on the Vermelho deposits has been conducted by CVRD and its consultants and reported in GRD-Minproc (2005) prior to its acquisition by HZM. HZM has not conducted any testwork on the Vermelho deposit and no process route has been finalised by HZM for the deposit. The following is extracted from GRD-Minproc (2005), reviewed and amended by the author for inclusion in this Technical Report.

Table 13.1 Glossary of some abbreviations used in this section

Abbreviation	Description
AR	Ammonia re-leach
EW	Electro-winning
HPAL	High Pressure Acid Leach
LME	London Metal Exchange
MCP	Mixed Carbonate Precipitate
MHP	Mixed Hydroxide Precipitate
MSP	Mixed Sulphide Precipitate
PAL	Pressure acid leach
POX	Partial oxidation
SX	Solvent extraction

13.2 Process testwork – Prefeasibility Study

Metallurgical testing at prefeasibility stage was designed to cover all project options to be evaluated financially and was comprised of two main programs:

- A pilot plant program for process development and engineering data collection
- A bench scale program for evaluation of variability within the orebody, specifically ore behaviour for beneficiation, leaching, settling and slurry rheology.

The pilot plant program was performed at Lakefield Oretest, Australia from November 2002 to March 2003, and the variability testwork was performed concurrently at CVRD's Mineral Development Centre, located close to the main project office. Cross-checks of bench-scale test procedures and chemical analysis between laboratories were performed throughout the program.

13.2.1 Sampling

Much attention was devoted to ensure that the samples used for the testwork were representative. The following procedures were adopted:

- Both bench-scale and pilot programs used large diameter drill core samples.
- Drilling was distributed geographically throughout both deposits, as shown in Figure 13.1 and Figure 13.2 and covered major ore types and lithologies.
- The composition of the overall sample was adjusted to have the same chemical composition of the life-of-mine as per the Scoping Study mine plan.
- The variability program used 10% of the 2,500 samples available, with 1 m collected from every 10 m of the mineralised laterite profile, which ranges typically from 40 m to 80 m. In this way, samples for the pilot and bench testwork were interrelated and represented the same geological domains.

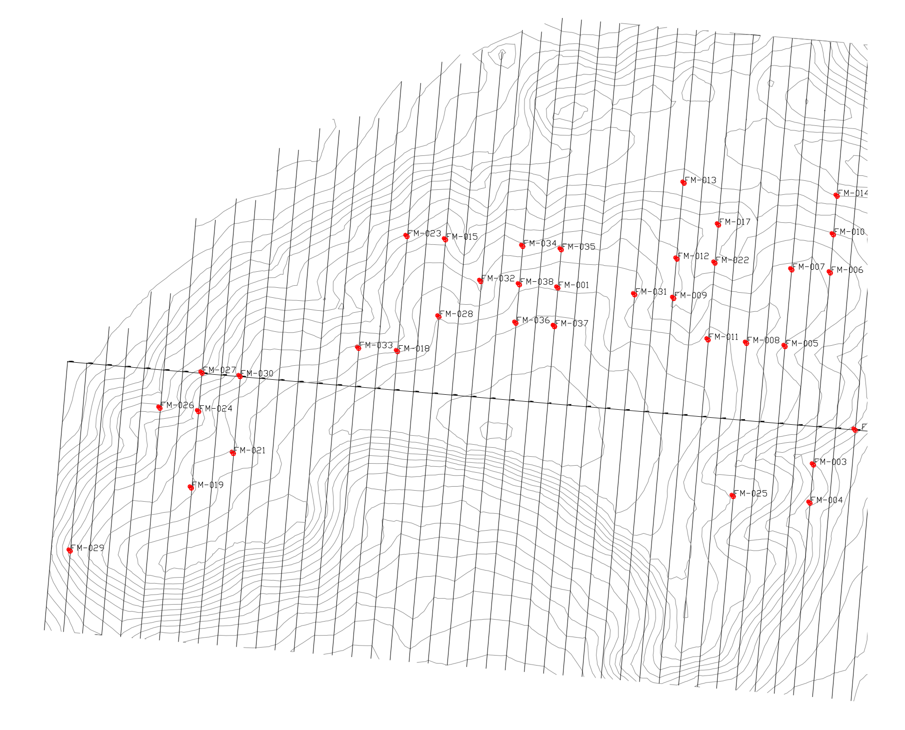
The drill core samples were composited according to their crystalline silica content into four large volume samples for pilot and process development testwork. These were:

- "LowSi" sample, representing mainly a ferruginous saprolite ore type (SapFe), comprised of limonite with a small amount of silicates or quartz
- "HighSi" sample, representing mainly a siliceous saprolite ore type (SapSi), comprised of roughly 50% relatively coarse SiO_2 (as quartz) with the remaining mass as fine limonite
- "MidSi" sample, representing an intermediate ore type (SapFeSi), comprised of roughly 35% coarse SiO_2 with the remaining mass as fine limonite and fine SiO_2
- A blended sample, composed of amounts of the three samples above, and included all major ore types.

Small amounts of the saprolite ore type (garnierite), found in the contacts and immediately below the main ore types were blended within the samples, to simulate some blending of the oxidised ore with a low Mg garnierite that will occur at the mine.

The composition scheme of the samples allows direct correlation of pilot plant and variability samples, since each of the bulk pilot samples tested has its variability counterparts. Also, subsamples of the pilot bulk composites were used for the same bench scale tests in the variability study, to assess scale-up and validate the test methodology.

Figure 13.1 Schematic of large diameter drilling sites – V1 deposit



Source: GRD-Minproc

Figure 13.2 Schematic of large diameter drilling sites – V2 deposit

Source: GRD-Minproc

13.2.2 Pilot testwork

The pilot plant program was designed considering that pressure acid leaching of limonitic laterite nickel ores is a commercialised process and that pilot plant design and operating experience exists from four operating industrial plants. Therefore, pilot scale testing is deemed sufficient for collection of process engineering data, and a demonstration scale plant is not deemed necessary as scale-up and equipment design is based on existing industrial operations.

The design of the pilot plant program also considered that the complexity of process flowsheet and related engineering, and that the variation between laterite ores requires a significant amount of pilot testing for new projects to quantify process parameters and to collect engineering data.

To ensure collection of required data for a sound PFS report, equipment suppliers and reagent vendors, namely Ciba, Cognis, Delkor, Eimco, Filtres Philiipe-RPA, Larox, Ondeo-Nalco, Outokumpu and SNF-Floerger participated in the pilot program to collect data for specific reagent selection and equipment sizing.

Pilot testing comprised four beneficiation tests and three HPAL runs with a total of 21 days of operation: the HPAL-MHP circuit operated for 14 days and PAL-MSP circuit operated for seven days. The MHP circuit pilot plant included all unit operations including production of nickel cathode, whereas the MSP circuit pilot plant produced mixed nickel-carbonate sulphide that was refined at bench scale until production of nickel powder.

Overall, the technical viability of processing Vermelho ore by a PAL-based process route was confirmed by the pilot plant program. No fatal technical flaws were observed in the beneficiation step or in any of the hydrometallurgical flowsheets that were evaluated, namely:

- HPAL/MHP/Ammonia Re-leach/SX/EW
- HPAL/MHP/ Ammonia Re-leach /Mixed Carbonate Precipitation
- PAL/MHP/AR/SX/Precipitation/Calcination
- PAL/MSP
- PAL/MSP/POX/SX/Hydrogen Reduction.

Testwork results indicated favourable ore behaviour, with good rheological characteristics, high nickel and cobalt extractions, low relative acid consumption, high refining recoveries and a positive response to both MHP and MSP routes.

Table 13.2 presents the chemical assays of the pilot plant products. LME specifications were achieved for metallic nickel and cobalt products. Product composition was used as inputs to market assessment of final and intermediate nickel and cobalt products.

Table 13.2 Pilot plant products

Element	Nickel (cathode)		Intermediate products		Metals products (green briquettes)		Mixed Carbonate Precipitate (ppm)	$NiCo_3$ Bulk Precipitate (ppm)	NiO Powder (ppm)	CoS Precipitate (ppm)
	LME spec. (ppm)	CVRD product (ppm)	Mixed Hydroxide Precipitate (%)	Mixed Sulphide Precipitate (%)	Nickel (ppm)	Cobalt (ppm)				
Al	-	5	0.24	0.40	15	25	50	<5	25	200
As	100	5	-	0.01	-	-	<5	<5	<5	135
Ca	-	15	0.13	0.01	5	20	60	80	186	700
Co	1,500	75	2.43	3.22	235	99.89%	10,850	7.5	15	35.7%
Cr	-	2	0.01	0.02	3	5	12	<2	4	30
Cu	200	2	0.16	0.12	2	20	1,870	2	3	605
Fe	200	83	0.18	3.60	35	100	95	10	40	250
Mg	-	2	1.6	0.02	8	3	460	40	67	16.7
Mn	50	1	4.2	0.004	0	5	4,205	6	10	25
Ni	99.98%	99.99%	38.3	54.6	99.95%	525	41%	46.4%		1,170
Pb	100	25	-	-	-	-	<2	<2	1	37
S	100	20	4.25	37.3	130	290	1.85%	300	171	37.1%
Si	50	10	0.46	0.24	20	0	110	50	20	250
Zn	60	2	0.82	0.72	3	0	9,770	10	26	8.9%
NiO	-	-	-	-	-	-	-	-	99.5%	-

Source GRD-Minproc 2005

13.2.3 Batch variability testwork

Beneficiation

Batch scale variability tests were conducted at the CVRD Mineral Development Centre. Tests were conducted with 220 individual drill core samples of 6” x 1 m, weighting approximately 20–25 kg dry basis. Each sample was crushed to -2” and a split was taken for scrubbing at 55% solids, 45 rpm and six minutes residence time. The scrubbed material was then screened at ¼” (6 mm), 32# (0.5 mm), 100# (0.15 mm) and 200# (0.74 mm). Each fraction was assayed for Al, Co, Cr, Fe, Mg, Mn, Ni, and Si. Element upgrades and mass recovered were assessed for 100# and 200#.

The main outcome of the variability program was the demonstration of the predictability of upgrading behaviour by geology and chemical composition, as well as the applicability of the models based on the variability testwork to predict results of pilot plant tests.

Leaching

Fifty beneficiated samples were selected for leaching variability testwork, aimed to verify leaching extractions and acid consumption for individual samples. The main findings of this program were the minimal variation of nickel extraction between the samples tested, as well as excellent predictability of acid consumption as a function of chemical composition.

13.3 Process testwork – Final Feasibility Study

As the process route for nickel production was fully defined in the PFS, testwork at the FFS was aimed to further optimise and demonstrate, in longer-term campaigns and under steady state conditions, the complete flowsheet. This objective was set to provide consistent data for the engineering design and minimise risks.

The availability of consistent ore-specific process data and the experience of the design team related to lessons learned in nickel laterite plants was considered key by CVRD when contracting and designing the FFS testwork. In this way, personnel with previous operational experience in nickel laterite plants was deployed by GRD-Minproc and CVRD at the contracted laboratory (SGS Lakefield Oretest) to oversee plant operations and participate in all testwork related meetings.

13.3.1 Integrated pilot testwork

The integrated pilot testwork took place from 16 April to 2 October 2004, and included beneficiation, PAL, precipitation, Ni refining and Co refining circuits.

Sample composition

Samples for the testwork were obtained by large diameter diamond drilling within the area delimited as the 10-year pit for both V1 and V2 deposits. The drilling location was done by CVRD Geology team and external consultant Dominic Bongarçon (Agoratek) and was aimed to ensure sample representivity and assisted using beneficiation upgrade equations to predict a Ni and Mg grades to autoclave close to the average 10-year mining plan.

A total of 6,640 1 m interval samples were delivered to SGS Lakefield Oretest for pilot testwork, with approximately 550 inter-twinned samples sent to the CVRD Mineral Development Centre for batch variability testwork.

The 1 m interval samples were blended to supply eight bulk samples for beneficiation testwork. The criteria used for the beneficiation composites was to obtain different compositions regarding Si and Mg content, to cover expected extremes in the mine planning.

The beneficiation products were then used to compose the feed samples for four HPAL nickel refining campaigns. The composition was done with different portions of each beneficiation product and aimed to provide four distinct samples with Ni and Mg grades similar to the 10-year mining plan. In this way, the pilot testwork could capture any existent mineralogical unknown variability, as it simulated the formation of blending stockpiles in the industrial operation.

Testwork concept and objectives

The testwork concept for FFS aimed to demonstrate the selected MHP project flowsheet in steady state, using continuous runs for samples representative of the first 10 years of operation of the project. While finetuning optimisation for selected unit operations were still be undertaken, most operational parameters have already been obtained during the PFS.

Main targets for such pilot plant campaign were as follows:

- Process and operational demonstration at high availabilities for extended periods.
- Address any recommendations and issues highlighted from the previous pilot campaigns and/or PFS.
- Demonstration of main controls and operating strategy for all key unit operations.
- Collection of data for design criteria and equipment specifications for FFS (recoveries, reagent consumption, product grades).

- Confirmation of upgrade relationships.
- Collection of samples for additional vendor testwork, coordinated with pilot plant operation, such as operation disruptions were minimised. The following vendors and consultants attended the pilot plant: GLV, Outokumpu, Westech, Delkor, Filtres Phillipe, Consep, Corrosion Services Pty, Wah Chang, Lightnin, Ekato, Philadelphia Mixtec, Cognis, Nalco, SNF Floerger, Ciba, Rheochem.
- Monitoring of recycles and build-ups of nickel, cobalt and impurities throughout the circuit during an extended period.
- Additional monitoring of scaling and corrosion parameters throughout the circuit.

The pilot plant was designed and operated with the intention to maximise circuit integration and minimising the effect of circuits being filled, metal tenor build-ups, PLS surge productions, as well as the any semi-continuous steps.

Beneficiation circuit

Eight samples (~12.5 t dry basis each) were subjected to individual beneficiation runs. After beneficiation, samples were processed in parallel units of Eimco-Deep cone and Outokumpu paste thickeners for the campaigns, to allow a comparative evaluation.

Four samples were also submitted to cyclone tests, to collect data for engineering design, since the industrial plant uses cyclones for the finest size classification.

Pressure acid leach plant and MHP/effluent and residues treatment

Pressure acid leach plant and MHP circuit was fully continuous and incorporate all the seeding and circuit recycles, as well as on-stream effluent and residues treatment.

Four campaigns were performed:

- A four-day optimisation run prior to the first 14-day run to fill the downstream circuits and verify plant mechanical reliability and process control capabilities
- Continuous operation during three runs of 28 x 12-hour shifts at average availability of 98%.

A 70 L autoclave was used. A total of 1,070 hours of continuous operation was completed over a nine-week period, processing 21.4 t (dry) of slurry to produce in total 1,055 kg of quality MHP cake containing 221 kg of nickel and 10.5 kg of cobalt.

Nickel refining

The MHP produced in the three upstream pilot plant demonstration campaigns was be processed in parallel and continuously in three runs of 26 x 12-hour shifts.

Nickel refining incorporated all unit operations from ammonia re-leach to nickel electrowinning, allowing recycle of the raffinate for leaching and the precipitation of cobalt sulphide in a bleed stream. The circuit also included stages of copper and zinc removal.

A total of 696 hours of operation was completed in the three runs processing all MHP produced in the upstream processing area, to produce 83.6 kg of LME-grade Ni cathode (the remaining of nickel contained in MHP remained in the circuit inventory).

Cobalt refining

Due to the limited cobalt content in ore, the CoS feed was stored from the three nickel pilot campaigns to provide sufficient amount for a cobalt refining pilot campaign, incorporating all unit operations from acid re-leach of cobalt sulphide to cobalt electrowinning.

13.3.2 Variability testwork

Bench-scale variability

Variability testwork was mainly aimed to provide more data for upgrading equations for beneficiation.

Bench-scale variability program included additional 368 samples, aimed at providing a wider database for beneficiation correlation, and to enhance the representivity of the model of the deposits. The samples processed in the FFS phase have shown the same behaviour of the previous testwork, thus allowing the use of all 550 testwork results to develop and validate final correlations for beneficiation upgrade.

The variability program also processed composite samples to confirm the smoothing effect in variability due to blending of 1 m, 20 kg individual samples into composites (mining blocks).

Additional variability acid leach testwork was also performed to supplement data from previous testwork.

Rheological variability was also assessed by Rheochem, using samples from bench-scale and pilot testwork.

13.3.3 Crushing testwork

Crushing testwork with large volume samples was performed at industrial MMD crushers installed in Igarape Bahia site, with large volume samples taken by excavating existing road faces and ore outcrops. Additional laboratory crushing characterisation was also to be performed to assess expected feed size distribution to beneficiation circuit.

14 MINERAL RESOURCE ESTIMATES

14.1 Summary

During February 2018, the author reviewed the historical MREs (Section 6.2) and concluded that the FFS_25_2_m MRE that was audited by Snowden in 2005, is appropriate for adoption as a current MRE and concluded that the reporting conforms to the requirements of the JORC Code (2012 Edition).

At a cut-off grade of 0.90% Ni Equivalent (where NiEq = Ni % + 6 x Co%), a total of 161.4 Mt at a grade of 1.34% NiEq is defined as a Measured Mineral Resource and a total of 6.4 Mt at a grade of 1.29% NiEq is defined as an Indicated Mineral Resource. This gives a combined tonnage of 167.8 Mt at a grade of 1.34% NiEq for Measured and Indicated Mineral Resources using a cut-off grade of 0.90% NiEq. A further 2.8 Mt at a grade of 1.23% NiEq is defined as an Inferred Mineral Resource at a cut-off grade of 0.90% NiEq.

The author is not aware of any issues that materially affect the Mineral Resources in a detrimental sense.

14.2 Method

The FFS_25_2_m estimates were prepared in the following steps by CVRD:

- Data preparation
- Geological interpretation and horizon modelling
- Establishment of block models and definitions
- Compositing of assay intervals
- Exploratory data analysis and variography
- Ordinary kriging estimation method in unfolded space
- Model validation
- Calculation of dry density
- Classification of estimates with respect to the JORC Code (2012 Edition) and CIM Definition Standards for Mineral Resources (by the author)
- Resource tabulation and resource reporting (by the author).

Description of the MRE process is described in Snowden (2005) and reviewed extracts are provided below.

14.3 Data preparation

This is discussed in Sections 10, 11 and 12.

14.4 Geological interpretation

14.4.1 Topography

Drillhole collar locations were checked against the topographic surface provided by CVRD and no errors were found.

It was noted that the topographical surface extends below the interpreted base of cover and base of the Alto Al_2O_3 surfaces. CVRD confirmed that the topographical surface was correct and that the other surfaces were adjusted to this surface during the block modelling process. A minimum surface is generated to correct for surface overlaps and all surfaces and solids are adjusted to be below the topographical surface. The percentage rock field was checked against the topographical surface and no errors were found. Based on this percentage rock field a percentage ore and a percentage waste are then assigned to the block model. These were checked to ensure that the percentage ore and percentage waste equalled the percentage rock below topography.

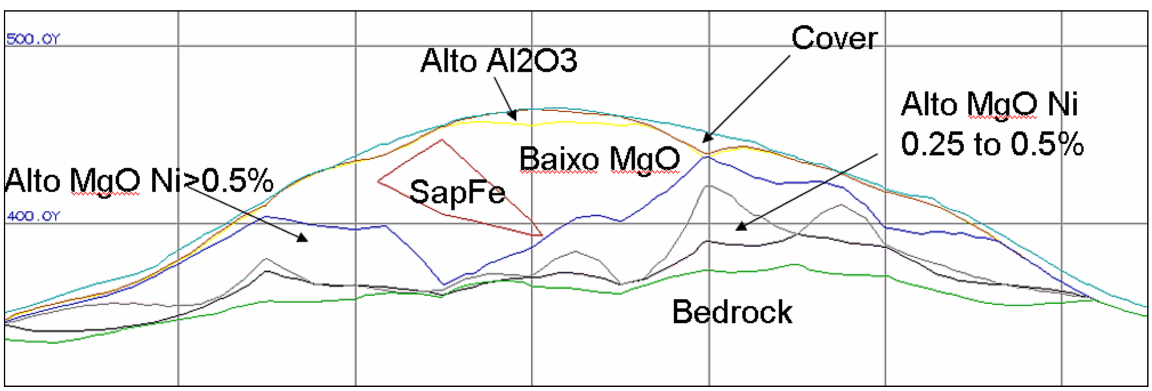
Resource reporting was checked to determine that the percentage rock field was implemented during resource reporting and it was confirmed that the final resource reports for V1 and V2 have been reported below topography.

14.4.2 Mineralised domains

The resource is contained within saprolite and the base of the resource is defined by the extent of the +0.25% Ni envelope. The base of the Low Ni Alto MgO (with 0.25% to 0.5% Ni) has been interpreted as a relatively smooth surface. It is understood that the bedrock surface between the saprolite and the bedrock (the weathering front) is not as smooth as has been interpreted from the available data by CVRD, and that it is generally extremely irregular. However, as the base of the resource model is generally above the bedrock surface, this is not regarded as being an issue for the resource model.

The resource models have been domained based on a combination of weathering, lithology and chemistry. The mineralised horizon has been subdivided into five domains for resource modelling at V2. These domains are as follows: Alto Al_2O_3, Baixo MgO, High Ni Alto MgO, Low Ni Alto MgO and SapFe (Figure 14.1). In addition to these domains, a sixth domain which comprises gabbro dykes has been used for the resource modelling process for V1. The majority of the resource is contained within the Baixo MgO and High Ni Alto MgO horizons.

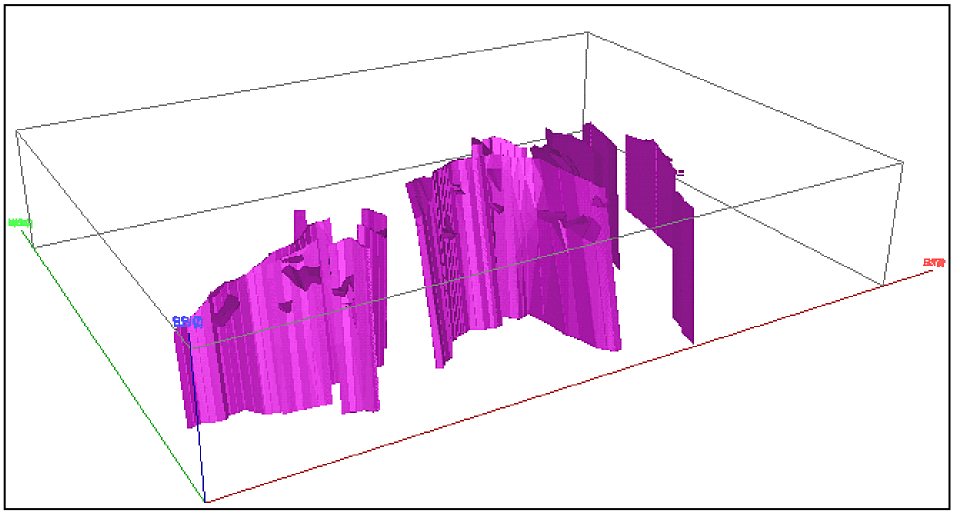
Figure 14.1 Example schematic section showing geological domains used for resource models



Note: This is a screen snapshot from Gemcom software. Grid spacing is 100 m. "400Y" is 400 m elevation.

As part of her review, C. Standing of Snowden examined drill core from two representative core holes from the V1 and V2 deposits and confirmed the geological logging of these holes. Snowden reviewed the interpretation undertaken on cross section by Walter Riel of CVRD and confirmed that these provided a reasonable 2D representation of the interpreted domains. The Alto Al_2O_3, Baixo MgO, High Ni Alto MgO and Low Ni Alto MgO have been interpreted as sub-horizontal zones that follow topography and/or bedrock interpretations, in line with the definition that they are controlled by weathering and associated chemical movement. The SapFe zones tend to concentrate within the Baixo MgO horizon and have variable orientations which have been interpreted with reference to the local surface orientation of the other domains. At V1, the gabbro dykes have a steep, and often vertical orientation, with some interpreted near horizontal lenses branching off the main dykes (Figure 14.2).

Figure 14.2 Extent of gabbro dykes at V1



The digitised outlines used to represent these interpretations in Gemcom were reviewed on section. The solid models and surfaces that were subsequently developed from these outlines, to provide 3D representations of the mineralised and waste domains that were used to control the resource modelling process at V1 and V2, were reviewed. A few recommendations were made by Snowden, to improve the definition of the base of the Alto Al_2O_3 horizon, and the definition of the SapFe domains between sections. These areas were reviewed by CVRD and, where possible, the interpretation was revised for both the V1 and V2 resource models.

Snowden is satisfied that all stages of the geological interpretation have been carried out in a very thorough and consistent manner and believes that the finalised 3D interpretations provide a good representation of domaining that is required to control the resource model.

14.4.3 Dilution

Dilution has been incorporated into the resource model as internal waste (as illustrated in Figure 14.3 and Figure 14.4) and at the base of the resource models. The example section from V2 (Figure 14.5) illustrates the block model coloured by the waste percentage that has been incorporated into the blocks, which shows the majority of the waste has been added at the base of the Low Ni Alto MgO surface.

Diluted models were generated for V1 and V2, based on the assumption that the entire 25 m(E) x 25 m(N) x 2 m(RL) block would be mined, and incorporated a background grade for the waste component of each block. Following discussions with Snowden and CVRD engineering personnel, it was decided that mining would be more selective than the 25 m(E) x 25 m(N) x 2 m(RL) block and that the undiluted model should be used for the mining study.

Figure 14.3 Internal waste at V2

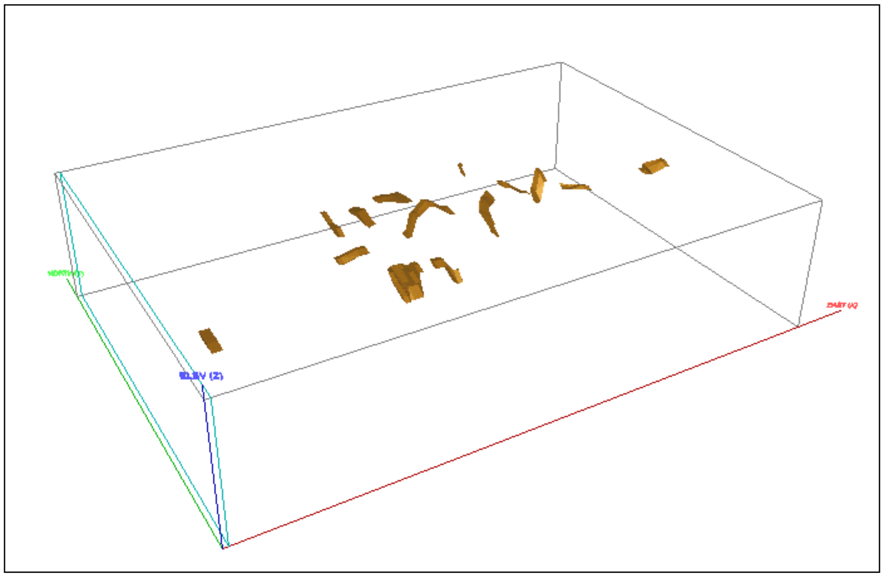


Figure 14.4 Internal waste at V1

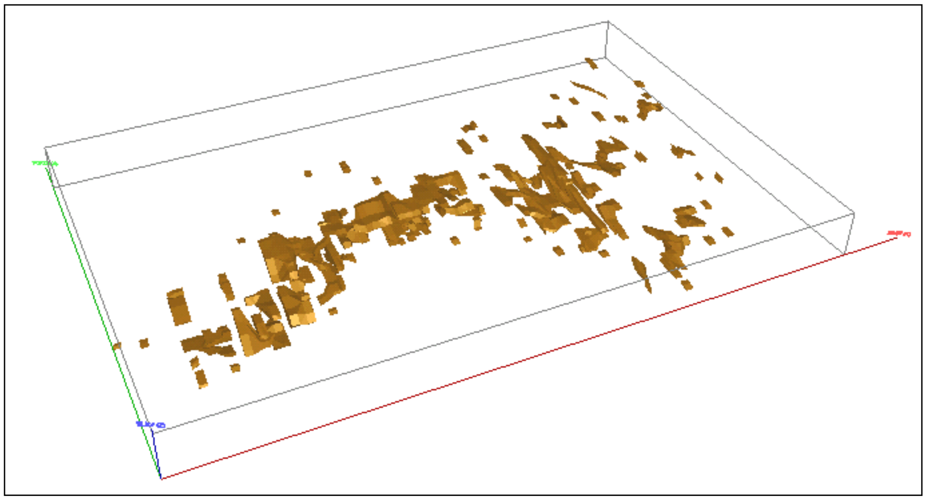
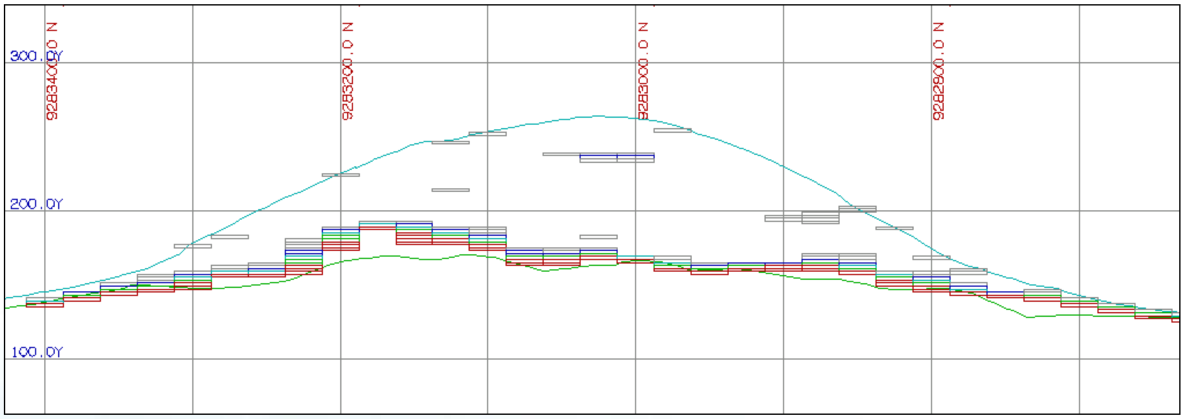


Figure 14.5 V2 along block model 621937.5 mE (column 30) – percentage waste incorporated into blocks



Note: 0.01–20% grey, 20–40% blue, 40–60% light blue, 60–80% green, 80–100% red.

14.4.4 Coding of data and block model

Coding of the input data was checked by confirming the location of the coded data with respect to the surfaces and solid models. The locations of coded blocks were also checked against these surfaces and solids. No incorrectly coded data or blocks were apparent.

14.5 Data analysis

14.5.1 Statistical analysis

The domain coding used by CVRD identifies five weathering domains (cover, saprolite, SapFe, bedrock and boulders), three chemical domains (Alto Al_2O_3, Alto MgO and Baixo MgO), two domains based on Ni grade (High >0.5% Ni and Low 0.25% to 0.5% Ni) and four geological domains (gabbro, pyroxenite, serpentinite and boulders). Combinations of the weathering, chemical, Ni and geological domains have resulted in the definition of 43 sub-domains at V2 and 61 sub-domains at V1. Detailed statistical analysis, undertaken by CVRD and presented to Snowden in the form of graphs and tables, was used to combine these sub-domains into the final five mineralised domains for grade estimation at V2 and the final six mineralised domains for grade estimation at V1.

There is some degree of population mixing present in some of the domain/element distributions but the grade distributions within each of the domains are generally well defined and are suitable for grade estimation. The coefficients of variation are generally less than one and where they are higher this has been addressed by grade-capping.

CVRD examined the data distributions for each variable/domain combination and grade capping was implemented to control the influence of outlier grades. The distributions generally have low coefficients of variation and examination of the distributions in log-scale by Snowden indicates that only minimal or no capping is required. Where top cap grades were selected by CVRD they are all >98th percentile and are regarded as being appropriate for block grade estimation.

Some grade capping of Fe and MgO has been applied to control the lower end of the data distribution at V2. Snowden does not regard this as good practice, however as it has affected only 25 Fe values and 96 MgO values this issue is not regarded as significant. It affects less than 0.2% of the data.

The PFS data contained high grade assays for some elements (MgO, Al_2O_3 and Fe_2O_3) that had been capped by the laboratory. Where possible these samples have been re-analysed and the uncapped data has been used for the FFS. A small number of MgO capped data still remains (~1.5% of data from within the mineralised domains at V2 and ~0.5% of the data from V1) and it is understood that these are from samples that no longer have pulps available. A de-spiking exercise undertaken by Snowden for a conditional simulation study at V2 indicates that the remnant capping will have had a minor influence on MgO and that the mean grade could be expected to increase from 10.85% to 10.90% MgO.

Graphs displaying the results of the contact analysis undertaken by CVRD were reviewed by Snowden. Distinct differences in grade trends exist at the domain contacts for all the ten variables examined (Ni, Co, MgO, Al_2O_3, Fe_2O_3, MnO, SiO_2, Cr, Cu and Zn), except for the contact between the Alto Al_2O_3 and Baixo MgO domain where only Al_2O_3 has a distinct difference in the grade trend. Initially hard boundaries were applied for all variable and domain combinations. For grade estimation of Ni, Co, MgO, Fe_2O_3, MnO, SiO_2, Cr and Cu into the Alto Al_2O_3 and Baixo MgO domains at V2, this was revised, and a soft boundary was applied for the boundary between these domains.

Snowden believes that the statistical analysis and the contact analysis have been methodical and that the resultant defined domains and boundary conditions provide good control for block grade estimation.

14.5.2 Variogram analysis and kriging parameters

Detailed variography was undertaken by CVRD in the unfolded coordinate system for each variable within the domains defined for grade estimation. Two reports containing variogram maps, directional variogram plots and interpreted models and tables of interpreted parameters were supplied to Snowden. Following the review of the V2 variography results, revisions were made to the interpreted orientation of maximum continuity in the SapFe domain at V2.

Variogram analysis has been methodical; only a few minor problems were noted for V2, as included in Section 12.3.1. At V1 some long range vertical structures were interpreted that were not verified by the experimental variogram (e.g. within the 2310 domain Ni, SiO_2 and Co were interpreted to have long range structures of 350 m, 80 m and 70 m respectively; Snowden believes that ranges of ~30 m are evident from the experimental variograms). As a restriction of a maximum of 4 samples per drillhole is applied during grade estimation for all the domains (except for Al_2O_3 within the gabbro dykes at V1 where the maximum was set to 3), which will restrict the effective vertical search to 4 m, this was not regarded as a major issue and will have had little effect on the resource models.

Draft V1 documentation provided for kriging parameters was often inconsistent with the parameters in the kriging profiles and kriging “lis” files. A few inconsistencies were also noted in the table provided for the variogram parameters and those provided in the variogram report and used for kriging (e.g. the 2320 Al_2O_3 nugget effect and sill 1 values, and the directions for the short-range structures for Cr and Cu in 4210). Similarly, a few inconsistencies were noted between the search ranges, the maximum number of points per drillhole, the minimum number of points and the z discretisation, as documented in the table of parameters used for kriging provided by CVRD, and the search ranges actually used, as recorded in the kriging profiles. It is expected that this draft will be revised by CVRD prior to the final documentation. This does not affect the resource estimation as the parameters used for kriging were consistent with those interpreted from the variograms.

14.5.3 Bulk density data

The bulk density data available for the PFS Vermelho resource estimate comprised 167 measurements for V1 and 228 for V2. CVRD substantially increased the number of density measurements to 727 measurements for V1 and 811 for V2 and implemented better control and methodology for the density measurements. Detailed analysis of the density data in relation to data collection methodology, moisture content, depth and rock domain (including weathering) was undertaken by CVRD. Apparent discrepancies in the data were investigated by CVRD and can be explained by the selection of the methodology being dependent on the nature of rock being sampled. CVRD determined that all the data was valid. The strategy developed for ore and waste density estimation into the model was based on a combination of estimation techniques that were controlled by the rock domain and the amount of data available. Estimation methodologies applied include ordinary kriging, nearest neighbour from point data, attributing the mean from the adjacent blocks, and attributing the declustered mean from the adjacent blocks. The estimation was undertaken in real coordinate space (i.e. not unfolded). Component ore density estimates for each “rock type” folder were volume weighted to develop the integrated undiluted and diluted ore density models for V1 and V2.

Snowden concurred with the methodology used to develop the ore and waste density models for each rock domain. Snowden reviewed the integrated models and only one minor problem was noted at V1 where five blocks (Table 14.1) were found to have extreme ore densities values of >47 t/m^3. This is believed to have resulted from an error in the ore percentage component of the Alto Al_2O_3 folder, where values of 3000 were present. This error has not been perpetuated in the integration of the grade variables and is only a problem for the ore density. These values were replaced with 1.57 t/m^3 prior to the mining study for the 2005 FFS.

Table 14.1 Errors in V1 ore density model

Easting	Northing	Elevation	Rock type	Ore density	% Ore	Classification
622787.5	9284338	485	2110	85.92	55.34	3000
623087.5	9284462	473	2110	71.14	67	3000
623937.5	9284462	483	2110	47.38	100	3000
623937.5	9284488	485	2110	47.64	100	3000
623937.5	9284488	487	2110	47.67	99.11	3000

Snowden believes that the ore and waste density models are of a good standard and are suitable for a FFS level study.

14.6 Unfolding

Snowden endorsed the use of unfolding to improve grade connectivity in the variography analysis and the estimation process. Data was unfolded to the base of the Alto Al_2O_3 domain to control variography analysis and block grade estimation of all grade variables into the Alto Al_2O_3 domain and Al_2O_3 into the Baixo MgO domain. The SapFe, Baixo MgO, High Ni Alto MgO and Low Ni Alto MgO data were unfolded to the base of the Baixo MgO domains to control variography analysis and block grade estimation of all variables into these domains, except the Al_2O_3 in the Baixo MgO domain as mentioned in Section 14.5.1.

Gemcom's unfolding transformation can generate artefacts such as well-positioned blocks close to data remaining uninformed. To overcome this problem CVRD used the estimated grades from adjacent blocks to determine the grade of the uninformed blocks using a nearest neighbour technique; blocks that were affected in this way account for <1% of the total blocks. This was also addressed during the classification, whereby blocks that were not estimated during kriging due to unfolding problems were given an Inferred classification. As mentioned in Section 14.9, the classification was revised where the blocks were intersected by a drillhole, and after confirmation that the block grades reflected the drillhole grades, these were given an Indicated classification.

14.7 Grade estimation

Ordinary kriging was applied to generate block estimates for the Ni, Co, MgO, Al_2O_3, Fe_2O_3, MnO, SiO_2, Cr, Cu and Zn. In addition to grade capping, a restricted search was applied that restricted the influence of grades above the 97.5^{th} percentile to 25 mE x 25 mN x 2 mRL.

Snowden endorses the grade estimation procedure used and the method is supported by the grade population characteristics. Some minor discrepancies were noted where the draft documentation did not match the parameters listed in the kriging output files; however, the parameters applied for grade estimation are consistent with the interpreted variogram parameters.

At V1, it was noted that the kriging runs have recorded some duplicate values in the Baixo MgO, Alto Al_2O_3 and SapFe domain data. These are not actual duplicate data and have resulted from the unfolding process. During block grade estimation Gemcom states that "these duplicate points are temporarily fixed for this run by moving them far away from any block or estimation point" and so they are excluded from the block grade estimation. The data points, that have been unfolded to the same locations, are from drillholes 1FM006 and 1FP056 and contribute less than 0.3% of the data.

14.8 Block model validation

Analysis of the block models showed that there were no uninformed blocks and that, with the exception of a few problem density values (as discussed in Section 14.5.3), each data field contained permissible entries – i.e. all values were within allowable ranges and there were no foreign codes evident.

3D visualisation of the drillhole data and the block model grades indicates good visual validation of the block model grades. Trend plots were provided by CVRD for all grade variable and domain combinations. These illustrate the mean block grades, along with the mean grade of the data and the numbers of input data, by incremental northing, easting and elevation. The validation plots all indicate that there is a good correlation between the input grades and the block grades.

14.9 Classification

CVRD has applied sample spacing criteria for resource classification of the V1 and V2 models. The criteria were developed from the Ni variography and the number of search points within the search ellipse, the number of points used for block grade estimation, the anisotropic distance to the nearest point, and the kriging run number were used for classification. Snowden checked the implementation of the classification criteria and, following discussion with CVRD, the classification of some blocks was amended by CVRD. Blocks that had been classified as Inferred and that were intersected by a drillhole, were upgraded to an Indicated classification, after confirmation that the block grades reflected the drillhole grades. For some blocks the criteria for the number of points (used for estimation and/or within the search ellipse) was relaxed in areas where the domains were thin (which limited the sample availability) but had been sufficiently drilled to warrant a Measured classification.

The author considers that this is an appropriate method to classify a global resource estimate based on Ni grade. Final classification addresses criteria listed in Table 1 of JORC[1] (2012 edition).

14.10 Integration of component models

Final diluted and undiluted models were developed by integration of the five component rock folders for V2 and six component rock folders for V1 for all the grade and density variables. The variables were volume weighted by the percentage ore present in each rock type to obtain the final block grade and ore density for the undiluted models. As mentioned in Section 14.4.3, a background grade was assigned to the waste component of each rock to derive a diluted grade for the integrated models.

The Gemcom scripts for the volume weighting of the variable were checked and no errors were found. However, it appears that there may be some precision problems with low grade variables in Gemcom and errors were noted in some of the final undiluted Fe_2O_3 grades, for the V2 model, and final undiluted Cu grades, for the V1 model. These were corrected by CVRD as part of the review process.

14.11 Resource reporting

The classified resource, based on the undiluted block models, reported by CVRD for V1 and V2 were checked by Snowden and the author. The block models are reported using Gemcom v 6.2 (Table 14.2). The basis of the NiEq calculation is the equation NiEq% = Ni% + (6 x Co%), based upon the relative average cash prices for nickel and cobalt metals, as reported on the LME for the six-month period 2 November 2017 to 3 April 2018 (US$12,830 Ni, US$79,402 Co). The NiEq calculation assumes similar nickel and cobalt recoveries as the necessary testwork has not been undertaken by HZM for the intended processing options.

[1] JORC 2012 Australasian code for the reporting mineral resources and ore reserves (the JORC Code)

Table 14.2 V1 + V2 – combined classified Resource report for Vermelho by NiEq cut-offs

Cut-off NiEq%	Tonnage (Mt)	NiEq%	Ni %	Ni metal (kt)	Co %	Co metal (kt)	Fe_2O_3 %	SiO_2 %	MgO %
Measured									
0.8	185.4	1.28	0.96	1,781	0.05	99	31.5	43.1	9.58
0.9	**161.4**	**1.34**	**1.01**	**1,629**	**0.06**	**90**	**31.5**	**42.6**	**9.95**
1.0	138.5	1.41	1.06	1,469	0.06	81	31.4	42.1	10.2
1.2	92.7	1.56	1.19	1,098	0.06	59	31.3	40.9	10.9
Indicated									
0.8	7.7	1.22	0.88	68	0.06	4	27.2	50.6	7.21
0.9	**6.4**	**1.29**	**0.93**	**59**	**0.06**	**4**	**27.5**	**50.3**	**6.85**
1.0	5.2	1.37	0.99	51	0.06	3	27.9	49.9	6.61
1.2	3.3	1.54	1.11	36	0.07	2	28.1	49.0	6.73
Measured and Indicated									
0.8	193.1	1.28	0.96	1,848	0.05	103	31.4	43.4	9.49
0.9	**167.8**	**1.34**	**1.01**	**1,688**	**0.06**	**94**	**31.3**	**42.9**	**9.83**
1.0	143.7	1.41	1.06	1,520	0.06	84	31.3	42.3	10.1
1.2	96.0	1.56	1.18	1,135	0.06	61	31.2	41.1	10.8
Inferred									
0.8	3.8	1.13	0.87	33	0.04	2	24.2	41.8	15.3
0.9	**2.8**	**1.23**	**0.94**	**27**	**0.05**	**1**	**25.9**	**41.8**	**13.5**
1.0	2.1	1.33	1.01	21	0.05	1	27.3	41.8	11.9
1.2	1.2	1.51	1.13	13	0.06	1	28.7	41.5	10.7

15 MINERAL RESERVE ESTIMATES

No current Mineral Reserve is reported in this Technical Report.

The previous operator, CVRD completed a FS in 2005 and completed Mineral Reserve estimates of a historical nature in 2005. The historical Mineral Reserves for the Vermelho Nickel-Cobalt Project are presented in Section 6.3 of this report.

16 MINING METHODS

The nickel deposits of the Pará State are near surface and suitable for conventional truck and shovel open pit mining. This has been the method put forward for the HZM Araguaia Nickel Project located approximately 85 km to the south-east. However, no mining method study has been conducted by HZM for the Vermelho Nickel-Cobalt Project for this Technical Report.

17 RECOVERY METHODS

No recovery method has been investigated for the Vermelho Nickel-Cobalt Project by HZM and reported in this Technical Report.

18 PROJECT INFRASTRUCTURE

No project infrastructure study has been completed for the Vermelho Nickel-Cobalt Project by HZM and reported in this Technical Report.

19 MARKET STUDIES AND CONTRACTS

No market studies and contracts have been completed for the Vermelho Nickel-Cobalt Project by HZM and reported in this Technical Report.

20 ENVIRONMENTAL STUDIES, PERMITTING, AND SOCIAL OR COMMUNITY IMPACT

Not applicable to the Vermelho Nickel-Cobalt Project at this time. HZM has not submitted any permit applications to regulatory agencies for exploration or mining activities. A summary of the required permits for exploration activities can be found in Section 4.6 of this report.

21 CAPITAL AND OPERATING COSTS

The capital and operating costs for the Vermelho Nickel-Cobalt Project have not been investigated by HZM and reported in this Technical Report.

22 ECONOMIC ANALYSIS

No economic analysis is reported in this Technical Report.

23 ADJACENT PROPERTIES

There is no information from adjacent properties applicable to the Vermelho Nickel-Cobalt Project for disclosure in this Technical Report.

24 OTHER RELEVANT DATA AND INFORMATION

There is no other relevant data and information to disclose.

25 INTERPRETATION AND CONCLUSIONS

The Vermelho licence acquired by HZM is within the Carajás Mining District, an active mineral exploration and mining region with advanced infrastructure and services to support development of Vermelho. The previous operator had completed a FS to produce nickel and cobalt from open pit mining of the V1 and V2 deposits and processing via the HPAL method.

HZM is currently finalising a FS on its Araguaia nickel cobalt deposits located approximately 85–150 km from Vermelho and is proposing open pit mining from numerous deposits and processing via the RKEF method. HZM is familiar with operating in the region and is to consider what synergies exist in the development of the Araguaia and Vermelho projects.

The Vermelho area was explored in various stages by CVRD from 1974 to 2004 involving approximately 152,000 m of combined drilling and pitting (Table 25.1).

The drilling grid density was substantially enhanced in 2002 to 2004, and most of the resources were upgraded to the Measured category as defined in JORC (2004). Pilot plant metallurgical studies were conducted in Australia. A PFS was prepared in 2003, and a FS was completed in August 2004 by GRD-Minproc (2005). This study confirmed the positive economic outcomes obtained in previous studies and showed production capacity of 46,000 t/a of metallic nickel and 2,500 t/a of metallic cobalt. Vale (formerly CVRD) elected to place Vermelho on hold after delivery of the FS.

Table 25.1 Summary of CVRD exploration

Description	V1		V2		Project area		Total	
	Unit	Drilling (m)	Unit	Drilling (m)	Unit	Drilling (m)	Unit	Drilling (m)
Pit excavation	251	3,903	231	3,585			482	7,487
Large-diameter drilling	86	3,582	152	7,333			238	10,915
Diamond drilling	39	2,931	24	1,806			63	4,736
Rotary percussion	1,289	72,875	867	50,768	65	1,370	2,221	125,013
Exploration pits					11	60	11	60
Mixed geotechnical drilling					20	788	20	788
Percussive geotechnical drilling					75	783	75	783
Auger drilling	15	8	13	8	296	265	324	280
Rotary geotechnical drilling	9	945	9	906			18	1,851
Totals	**1,689**	**84,243**	**1,296**	**64,405**	**467**	**3,265**	**3,452**	**151,913**

Source: Extracted from CVRD, 2004

The geological setting of the Vermelho nickel-cobalt deposits is well understood. The deposits consist of two hills named V1 and V2 aligned on a northeast-southwest trend, overlying ultramafic bodies. The ultramafic bodies have had an extensive history of tropical weathering, which has produced a thick profile of nickel-enriched lateritic saprolite.

The V1 and V2 deposits form flat lying topographical highs. The V1 hill extends for approximately 2.4 km east-west, ranging from 700 m to 1.6 km north-south. The V2 hill has an east-west elongation, and extends for approximately 1.9 km east-west, ranging from 600 m to 900 m north-south. The V1 deposit has an average thickness of 53 m and a maximum thickness of 146 m, whereas the V2 deposit has an average thickness of 56 m and a maximum thickness of 115 m.

Two main mineralisation types can be recognised: silicate at the base and oxide at the top of the weathering profile. The mineralogical composition of the silicate zone, with 1.8% NiO in average, consists largely of serpentine, chlorite, and spinels, with quartz and goethite in minor amounts. Serpentine and chlorite are the main nickel-bearing minerals, nickel being about equally distributed between the two phases (2% to 3% NiO). There is no significant development of an enriched transition mineralisation type between the oxide and silicate horizons.

Independent reviews of CVRD's operations at Vermelho have found that survey, drilling, sampling procedures and sample preparation and analysis protocols were adequate to support the estimation of Mineral Resources. During February 2018, the author reviewed the historic MREs (Section 6.2) and concluded that the CVRD_25_2_m MRE that was audited by Snowden in 2005, is appropriate for adoption as a current MRE and concluded that the reporting conforms to the requirements of the JORC Code (2012 Edition).

At a cut-off grade of 0.90% NiEq (where NiEq = Ni % + 6 x Co%), a total of 161.4 Mt at a grade of 1.34% NiEq is defined as a Measured Mineral Resource and a total of 6.4 Mt at a grade of 1.29% NiEq is defined as an Indicated Mineral Resource. This gives a combined tonnage of 167.8 Mt at a grade of 1.34% NiEq for Measured and Indicated Mineral Resources using a cut-off grade of 0.90% NiEq. A further 2.8 Mt at a grade of 1.23% NiEq is defined as an Inferred Mineral Resource at a cut-off grade of 0.90% NiEq.

The metallurgical testwork completed to date is considered representative of the mineralisation available within the Vermelho deposits. The testwork completed has shown the mineralised material at Vermelho to be comparable to typical laterite deposits and amenable to HPAL processing.

Open pit mining is typical for this type of nickel laterite project, is frequently employed and well understood throughout the industry, and is common practice in Brazil. Subject to the necessary studies and positive results, there is no reason why Vermelho cannot be extracted using this method.

The current Project status is summarised as:

- The previous EIA RIMA, LP and all environmental licences relating to Vermelho mine and process plant contain background studies that will be useful to guide new social and environmental studies in the region.
- Once the concept design for the project is determined by the technical team within HZM, a new social and environmental impact assessment (EIA RIMA) will be conducted with the objective of obtaining an LP, and later LI to construct the Vermelho project in line with HZM's proposed Vermelho project characteristics.
- The company will require engagement with community groups in the region, as well as authorities, such as, but not limited to:
  - SEMAS – Para State Environmental Licensing agency
  - INCRA – Brazilian Land Authority
  - ITERPA – Para State Land Authority
  - IPHAN – Brazilian Institute of Historic and Artistic Heritage.

26 RECOMMENDATIONS

The author recommends the following:

- Processing options (RKEF or HPAL) for Vermelho require consideration by HZM. If based on this review RKEF is the preferred processing route, then additional testwork is required. If existing samples are inadequate, then additional drilling will be required.
- Based on a current MRE and process options review, HZM should complete a PEA to determine the potential viability of the Project.

27 REFERENCES

Author	Title
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CIM, 2003	CIM Estimation of Mineral Resources and Mineral Reserves Best Practice Guidelines, adopted by CIM Council on November 23, 2003
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CVRD, 2004	Resource Estimate Report Feasibility Study Niquel do Vermelho Project. Prepared by CVRD Staff, September 2004
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SGS, 2004	CVRD Integrated Pilot Plant – Final Feasibilty Study Final Report – Nickel. Job No:T300. Prepared by Lakefield Oretest Pty Ltd. October 2004.
Snowden, 2004	Niquel do Vermelho site visit – Project 4414. Memorandum to Vanessa Torres from A. F. Ross. Snowden Mining Industry Consultants Pty Ltd. 14 January 2004.
Snowden, 2005	CVRD Niquel do Vermelho Mining Feasibility Study. Project No 4820. Snowden Mining Industry Consultants Pty Ltd. 20 January, 2005
Snowden, 2005	CVRD: Niquel do Vermelho – Supplementary Mining and Resource Work. Project 4820. May 2005.
Snowden, 2008	Resource Model Update. Project 564. December 2008. Draft report.
SRK, 2007	Relatório De Estimativa De Recursos Do Depósito Níquel Do Vermelho, Canaã Dos Carajás, Pa.

28 DATES AND SIGNATURE

Name of Report:

NI 43-101 Technical Report on the Vermelho Project, Para State, Brazil

2nd June 2018

Issued by:

Horizonte Minerals Plc

SIGNED 

Andrew F. Ross **2 June 2018**

29 CERTIFICATE OF QUALIFIED PERSON

I, Andrew F. Ross, Principal Consultant of Snowden Mining Industry Consultants Pty Ltd, Level 6, 130 Stirling Street, Perth, Western Australia do hereby certify that:

a) I am the author of the technical report titled "NI 43-101 Technical Report on the Vermelho Project, Para State, Brazil" dated 2nd June 2018 (the "Technical Report") prepared for Horizonte Minerals PLC.

b) I graduated with an Honours Degree in Bachelor of Science in Geology from the University of Adelaide in 1972. In 1985, I graduated with a Master of Science degree in Mining and Exploration Geology from James Cook University of North Queensland. I am a Fellow of the Australasian Institute of Mining and Metallurgy. I have worked as a geologist almost continuously for a total of 46 years since graduation. I have been involved in resource evaluation consulting for 22 years, including resource estimation of nickel laterite deposits for at least five years. I have read the definition of "qualified person" set out in NI 43-101 ("the Instrument") and certify that by reason of my education, affiliation with a professional association and past relevant work experience, I fulfil the requirements of a "qualified person" for the purposes of the Instrument.

c) I visited the Vermelho Nickel-Cobalt Project Property from 9 to 12 December 2003.

d) I am responsible for the preparation of all sections of the Technical Report.

e) I am independent of the issuer as defined in section 1.5 of the Instrument.

f) I have no prior involvement with the property that is the subject of the Technical Report apart from the site visit in 2003 during the drilling program conducted by CVRD.

g) I have read the Instrument and Form 43-101F1, and the Technical Report has been prepared in compliance with that instrument and form.

h) As of the effective date of this Technical Report, to the best of my knowledge, information and belief, the Technical Report contains all the scientific and technical information that is required to be disclosed to make the Technical Report not misleading.

Dated at Perth, Western Australia, on 2nd June 2018

Andrew F. Ross, MSc, FAusIMM