Cosmos Nickel Project, Kathleen Valley

by

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Abstract

The Cosmos and Cosmos Deeps deposits together comprise the Cosmos Nickel Project, which is owned and operated by Sir Samuel Mines NL, a wholly owned subsidiary of Jubilee Mines NL. These two discrete, high grade, massive Ni–Fe sulfide deposits have a total Mineral Resource of 961 000 t at 8.2% Ni. Minor by-products include Cu, Co, and platinum group elements (PGE).

Cosmos is a typical Kambalda-style, komatiite-associated, massive sulfide deposit located close to surface, whereas the Cosmos Deeps deposit is a massive sulfide deposit that is interpreted to have been at least partly structurally remobilised, and is now hosted within the felsic volcanic rocks that form the footwall to the Cosmos deposit. Open pit mining of the Cosmos deposit is completed, and the Cosmos Deeps deposit is an underground mining operation using a combination of longhole open stopes and mechanized cut and fill.

Introduction

The Cosmos Nickel Project is located in the Kathleen Valley area, about 40 km north of Leinster in Western Australia (Fig. 1). It is located on the SIR SAMUEL (SG 51-13) 1:250 000 scale map sheet at latitude 27°36'04"S and longitude 120°34'28"E, about 700 km northeast of Perth and 700 km north of the port of Esperance.

In August 1997, routine evaluation of a prospective greenstone belt using a combination of geological, geochemical, and geophysical exploration techniques resulted in the discovery of the Cosmos deposit. Before mining commenced, the deposit contained a Mineral Resource of 401 000 t at 8.2% Ni. Openpit mining of the Cosmos deposit commenced in October 1999, with about 10 000 t of nickel metal in concentrate being produced per year, and production continued until mid-2003.

The Cosmos Deeps deposit was discovered in February 2000, following the drilling and geophysical testing of a conceptual geological target. The deposit has a Mineral Resource of 560 000 t at 8.2% Ni. Development of the underground mine commenced in December 2001, and ore production commenced in mid-2003.

The ore is processed through the Cosmos flotation plant at a rate of 400 t per day. To February 2004, 520 000 t of ore at a grade of 8.51% Ni has been processed, yielding about 217 000 t of sulfide concentrate grading about 20% Ni, with nickel recoveries averaging 95.3%. The product is exported to Canada via the port of Esperance. Based upon current ore reserves, and maintaining the current rate of nickel production, the Cosmos Nickel Project has an expected mine life until at least 2008.

Discovery and resources

The discovery of the Cosmos orebody in September 1997 was a turning point in Jubilee's evolution. The mine's rapid development, which culminated with first concentrate production in April 2000, marked Jubilee's transformation from explorer to miner and producer in just over two years.

During this period, the company negotiated native title agreements with indigenous claimant groups, clearing the way for the project to go ahead, completed a bankable feasibility study, signed a life of mine off-take agreement with Inco Limited of Canada, let major contracts to selected tenderers, and obtained a full debt finance package. Construction commenced in October 1999 and the Cosmos treatment plant was commissioned in April 2000.

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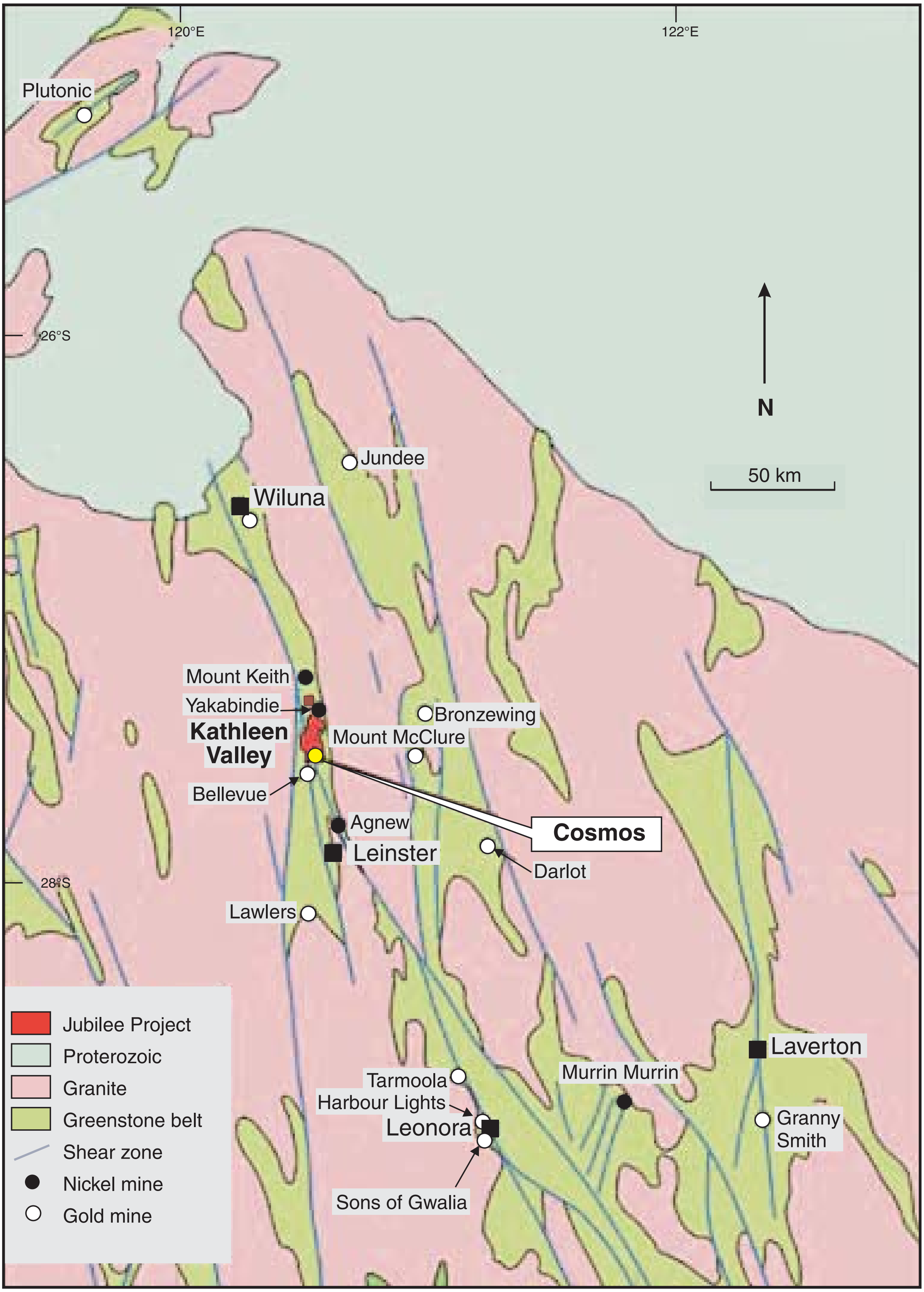

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Figure 1. Location and regional geology of the Cosmos Nickel Project in the Kathleen Valley area

In early 1997, Jubilee made the decision to broaden its exploration focus to other commodities apart from gold, and this included sulfide nickel. The company recognized that its project areas within the Sir Samuel district contained a portion of the ultramafic units that elsewhere in the district host significant nickel sulfide resources, and therefore Jubilee's properties also had the potential to be prospective for this commodity type.

The Sir Samuel district has been explored intermittently for sulfide nickel since the late 1960s. The area around Cosmos was first explored by Anaconda Australia Inc. in 1970–72, and was known as the Mount Goode project. An ultramafic unit was identified and early reconnaissance work confirmed its prospectivity. This was drill tested with widely spaced lines of shallow rotary holes, several deep percussion holes, and several diamond drillholes. Many of the rotary holes returned elevated Ni values (up to 4–5% Ni), associated with high Cu values, from the weathered zone, and the follow-up percussion and diamond drillholes intersected several zones of disseminated nickel sulfide mineralization. It is now known that one of these diamond drillholes was located only about 100 m south of the Cosmos deposit, with the others located some 200–400 m north of Cosmos. At the end of the 1972 field season, Anaconda decided to work elsewhere in the district, and the Mount Goode project was terminated. Later, in the 1970s, WMC undertook some minor exploration but no significant results were obtained, and nickel exploration in this area lapsed until Jubilee commenced work in 1997.

Discovery of Cosmos

Jubilee commenced exploration in the vicinity of Anaconda's Mount Goode project, which was situated within the southern part of Jubilee's property. Initially, a reconnaissance rotary airblast (RAB) drilling program outlined a large zone of coincident near-surface Ni and Cu anomalism, thus confirming the earlier Anaconda results, and the prospect was named 'Cosmos'. This was followed by a reverse circulation (RC) drilling program, which intersected disseminated nickel sulfide mineralization.

The next phase of exploration comprised a multipronged geophysical approach involving a detailed moving loop electromagnetic (EM) survey, and a follow-up fixed loop EM survey. The EM surveys defined a very strongly conductive body about 150–200 m long and 100–150 m deep, commencing 50 m below surface. A line of RAB holes was drilled across the peak of the EM response, and one hole intersected strongly anomalous Ni, Cu, and PGE values.

The prospective geology, highly anomalous geochemistry, and the presence of disseminated nickel sulfide mineralization justified a decision to commence diamond drilling to test the modelled bedrock conductor. The geophysical component of this exploration program is discussed in detail by Craven et al. (2000).

The first diamond drillhole, JCD001, was drilled in August 1997 and intersected a 3 m-wide zone of massive sulfide mineralization grading at 7.5% Ni. The second drillhole was collared 40 m to the south, and intersected 22.3 m at 9.3% Ni in massive pentlandite–pyrrhotite mineralization. Some four months, 82 holes, and about 16 000 m of drilling later, the drill-out phase of the Cosmos deposit was completed. In February 1998, the Mineral Resource for the Cosmos deposit was announced as 401 000 t at 8.2% Ni. Upon completion of a feasibility study in June 1998, an Ore Reserve of 420 000 t at 7.5% Ni was announced.

Discovery of Cosmos Deeps

Soon after the commencement of open pit mining of the Cosmos deposit, continued exploration led to the discovery of the Cosmos Deeps deposit in January 2000 (Figs 2 and 3). Based upon a conceptual geological study that investigated the potential for repetitions of the Cosmos mineralization at depth, four 600 m-deep diamond drillholes were drilled beneath and along strike from the openpit. Spaced at 200 m intervals, these holes were designed to test the basal contact of the Cosmos ultramafic unit and its adjacent footwall zone, and provide EM coverage of the downdip extensions of the Cosmos mine sequence. Downhole EM surveys were carried out and one conductor was detected.

The target was subsequently drill tested and the first hole, JCD100, passed through the target horizon (base of ultramafic unit) without intersecting any nickel sulfide mineralization. However, when extending the hole into the felsic footwall in order to provide EM coverage of the target horizon, the hole passed through 5 m of massive sulfide mineralization grading at 8.8% Ni. During the next eight months, 65 diamond drillholes totalling about 23 200 m were drilled. In September 2000, the Mineral Resource for the Cosmos Deeps was announced as 560 000 t at 8.2% Ni. Upon completion of a feasibility study in April 2001, an Ore Reserve of 520 000 t at 7.2% Ni was announced.

Geological setting

Cosmos is situated within the Agnew–Wiluna portion of the Norseman–Wiluna greenstone belt, in the northeastern Eastern Goldfields Province of Western Australia. This is Australia's premier nickel sulfide producing district, containing the Mount Keith and Leinster mines, and the undeveloped deposits of Yakabindie, Cliffs, and Honeymoon Well. This portion of the belt is strongly attenuated, and characterized by large scale faults, complex folding, and typically steep dips. The greenstone sequence is bounded to the east and west by large granitoid bodies. The Cosmos project area is near the junction of the northwesterly trending regional Keith–Kilkenny Tectonic Zone and the northerly trending Miranda Shear. The junction is characterized by intense shearing and deformation, which has resulted in major local structural complexities.

Locally, the project area is divided into three geological zones, locally termed the Western, Central, and

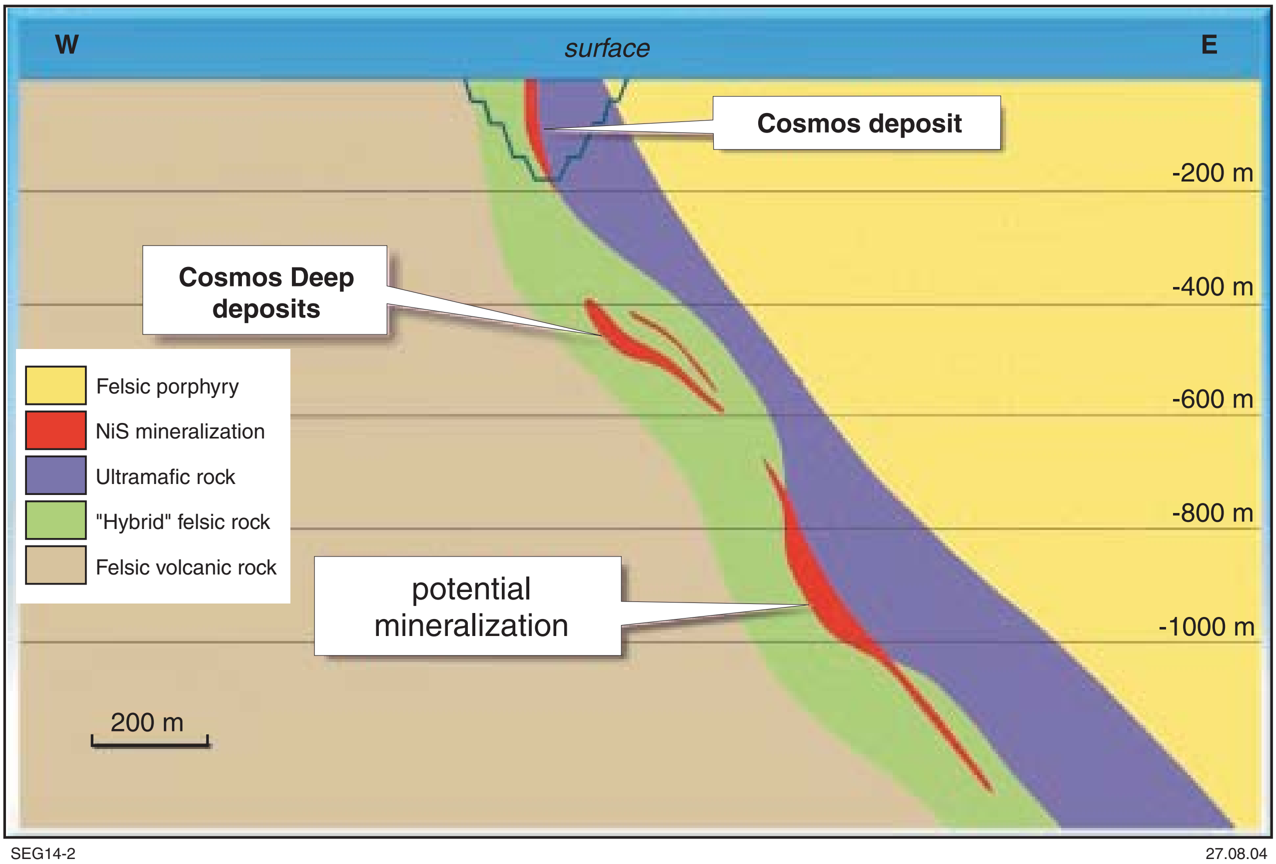

Figure 2. Geological cross section showing the geological setting of the Cosmos and Cosmos Deeps deposits

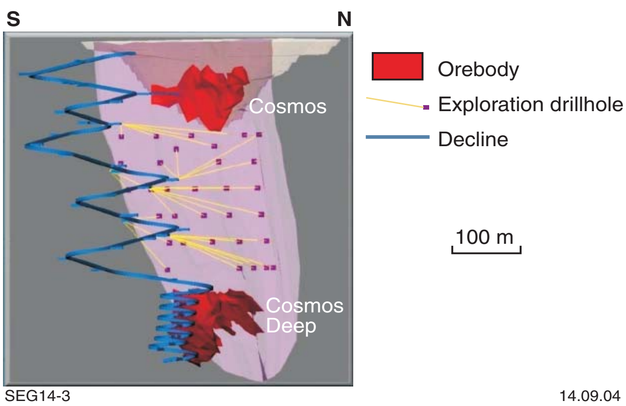

Figure 3. Three-dimensional illustration showing open pit development of the Cosmos deposit and underground development of the Cosmos Deep deposit

Eastern Zones. The Western Zone consists of a northeasterly striking and southeast-facing sequence of tholeiitic lavas, differentiated gabbroic sills, and ultramafic chloritic schists, metamorphosed to upper greenschist facies. The Eastern Zone comprises a northerly striking, east-dipping sequence of felsic, mafic and ultramafic volcanic and sedimentary rocks, with an upper greenschist to mid-amphibolite metamorphic grade. The ultramafic rocks consists of a series of komatiitic lava flows containing primary igeneous textures, including spinifex and cumulate textures, which have been variably hydrothermally altered. The ultramafic rocks in the Eastern Zone contain the nickel sulfide deposits at Leinster, Yakabindie, Mount Keith, and Honeymoon Well, and, before the discovery of Cosmos, were historically the target for most nickel exploration in the district.

The Western and Eastern Zones are separated by the Central Zone, which is a mixed package of rocks comprising the heterogeneous Jones Creek Conglomerate; felsic, mafic, and ultramafic volcanic rocks; felsic volcanoclastic sedimentary rocks; and doleritic and felsic porphyry intrusions. The Cosmos and Cosmos Deeps deposits are hosted within the Central Zone.

State of knowledge of the deposits

Local geology

The Cosmos deposits represent an essentially in situ accumulation of primary magmatic Ni–Fe sulfides. Mineralization is dominated by massive and semi-massive (breccia and stringer), Ni–Fe sulfides located at the base of an ultramafic unit hosted within the Central Zone. The ultramafic unit strikes north, is east facing, and dips between 50° east and vertical. It is structurally attenuated, varies up to 200 m in width, and is scattered within the Cosmos property over a distance of about 15 km. The ultramafic unit is strongly hydrothermally altered, serpentinized, and subsequently metamorphically recrystallized, and primary igneous textures are rarely preserved.

Around Cosmos, rocks are strongly weathered to a depth of about 30 m, the level of a cavernous silica layer. Beneath this, sulfide mineralization commences at about 40–60 m below surface. Before mining started, there were minor exposures of a gossan representing the weathered surface expression of the Cosmos sulfide mineralization.

At the southern end of the property, to the east, and overlying the ultramafic unit is a quartz–feldspar porphyry intrusion that is, in turn, overlain by the Jones Creek Conglomerate. The lower contact of the porphyry strikes northwest, potentially crosscutting and truncating the ultramafic unit in places. The porphyry is interpreted to terminate the Cosmos mineralization at the northern end of the pit, but drilling indicates that some ultramafic rocks remain along this contact and are mineralized in places. To the north, the ultramafic sequence widens again until terminated by what is interpreted to be an offsetting northeasterly trending fault.

Underlying the ultramafic unit and, in most areas, forming the footwall to the Cosmos massive sulfide mineralization is a mixed sequence of felsic breccia, volcanic and sedimentary rocks, and porphyries. The Cosmos Deeps mineralization, which consists of several zones of massive, breccia, and stringer Ni–Fe sulfides, is contained entirely within this package of rocks.

Recent structural studies of the Cosmos Deeps deposit have demonstrated that the contact between the footwall rocks and massive sulfides is most likely primary. Mineralization is fully enclosed in this footwall package of felsic breccia, volcanic and sedimentary rocks, and porphyries (with few ultramafic rocks), suggesting that that the hangingwall rocks have been thrust over the mineralization, thereby removing the ultramafic host. Additional information is being gathered to test this interpretation and develop the concept.

Further minor sulfide mineralization is present throughout the deposit as Fe, Ni, Cu, Pb, and Zn sulfides, as disseminated grains, fracture fillings, or within quartz veinlets. A dolerite dyke intrudes the ultramafic and felsic footwall in the southern part of the Cosmos area. The dyke commences about 40 m below surface, and is up to 50 m wide (east–west), 140 m long (north–south), and open at depth. It is massive, with no obvious signs of jointing or shearing, and has a fine-grained reaction rim at the contact with surrounding rocks. The upper surface plunges at about 50° to the north, and forms the footwall to the massive sulfide mineralization in the central part of the Cosmos deposit.

The Cosmos district is mostly covered by a veneer of alluvial sand and a few metres of residual lateritic soils. Bedrock exposures are rare and usually consist of small, isolated outcrops or subcrops of weathered felsic porphyry and felsic volcanic rocks. The area is cut by wide shallow creeks, which only flow occasionally and are mostly filled with sand. Vegetation consists of widely scattered shrubs, with the thickest growth in the drainage channels.

Cosmos mineralization

The Cosmos deposit comprises one discrete zone of massive and semi-massive sulfides that extends over a strike length of some 240 m, and has a vertical depth extent of about 120 m. The body has an average true width of about 7 m, with a maximum of 20 m. Mineralization is stratabound between the overlying ultramafic unit and the underlying dolerite and felsic volcanic rocks. There are sharp, relatively undeformed, contacts on both the hanging- and footwalls. Continuity of grade and width of mineralization are strong, both along strike and downdip. The massive sulfide domain is the most common ore type. It is defined as consisting of 81–100% sulfides containing moderate to abundant inclusions of felsic footwall rock and ultramafic hangingwall rock. Locally, there are minor disseminated sulfides within the ultramafic inclusions and the ultramafic rocks directly overlying massive and semi-massive mineralization.

From the surface to the base of complete oxidation (about 40 m deep), the sulfide body has weathered to a vuggy goethite–silicate rock. Sporadic outcrops of gossan were exposed prior to commencement of mining. Geochemically, this gossan contained elevated values of Ni, Cu, PGE, and other pathfinder elements.

The supergene and transitional zones are below 40 m depth, and are characterized by an alteration assemblage of violarite–pyrite–marcasite after pentlandite–pyrrhotite. With increasing depth, the proportion of pentlandite–pyrrhotite increases until about 60 m below surface, where the mineral assemblage is mostly primary.

Within the primary zone, the mineralization consists of intergrowths of equal proportions of pentlandite and pyrrhotite with subsidiary chalcopyrite. Pentlandite is the dominant Ni-bearing sulfide species, with only scattered grains of other nickel sulfide minerals being observed petrologically. Accessory sulfides include pyrite, sphalerite, and galena. Much of the primary ore consists of coarse pentlandite crystals, up to 2 cm in diameter, in a matrix of finely intergrown pentlandite and pyrrhotite. Less commonly, there are alternating pentlandite- and pyrrhotite-rich bands up to a few centimetres thick. Chalcopyrite forms fine to coarse blebs through the massive sulfide, particularly near the base of the body, and also rims silicate inclusions.

Cosmos Deeps mineralization

The Cosmos Deeps deposit consists of several bodies of massive, breccia, and stringer nickel sulfide mineralization contained entirely within the felsic footwall to the Cosmos ultramafic unit. These bodies have been termed the Main Zone and Hangingwall Zones. The Main Zone is a large coherent body of massive sulfides that contains over 90% of the total nickel endowment of the deposit, and has been defined in the Measured and Indicated Mineral Resource categories. It demonstrates excellent internal geological and grade continuity, and, consequently, most of the Mineral Resource was converted to the Proved and Probable Ore Reserve categories. The Hangingwall Zones consist of several discrete ribbons of sulfide mineralization located 10–30 m stratigraphically above the Main Zone. Their widths vary and, as there is a high degree of internal dilution, they have poor grade continuity. Consequently, the Hangingwall Zones have been assigned to the Inferred Mineral Resource category, and have not been converted to an ore reserve. The Hangingwall Zones will be further explored and delineated from underground.

The Main Zone begins about 450 m below surface and extends to at least 600 m in depth. It is about 120 m long, has a maximum thickness of 20 m, and dips to the northeast at about 35°. The mineralization has a very sharp footwall contact and an erratic, feathery hangingwall contact, and remains open both along strike and downdip. The Cosmos Deeps mineralization is mineralogically similar to that of the Cosmos deposit, with coarse grained pentlandite crystals in a fine grained matrix of intergrown pentlandite–pyrrhotite mineralization, with equivalent amounts overall of pentlandite and pyrrhotite. The nickel content of the 100% massive sulfides is almost always greater than 12% Ni, although the grade of mineralization depends on the volume of inclusions. Medium to fine grained chalcopyrite is common near the margins of the mineralization and rimming felsic inclusions. There are some significant differences, however, between the Cosmos and Cosmos Deeps deposits.

The Cosmos Deeps mineralization contains:
- large cubes of pyrite (up to 15 cm) scattered randomly through the massive ore;
- felsic, ultramafic, and dolerite clasts up to 1 m across;
- significant accumulations of massive sphalerite and galena, which are present on the northern footwall.

Geological and genetic models for the deposits

Cosmos

The Cosmos mineralization occurs as a massive nickel sulfide deposit typical of the Type 1 style of mineralization as defined by Dowling and Hill (1998). Examples additional to Cosmos include Kambalda, Silver Swan, Perseverance, and Rocky’s Reward. Cosmos is a syngenetic deposit located along the basal contact of a komatiitic lava channel. The presence of partially rounded felsic footwall inclusions suggests that there was partial melting and thermal erosion of the sulfide-rich felsic substrate. However, the absence of matrix and disseminated mineralization directly above the deposit suggests that the sulfide body was decoupled from the primary komatiite liquid. Subsequent structural activity has resulted in the sequence being tilted into a steeply east-dipping and east-facing position. Metamorphism has recrystallized pentlandite into coarse grained granoblasts within a fine grained, mixed sulfide matrix, with localized mineralogical banding produced by a low intensity ductile tectonic regime.

Cosmos Deeps

The Cosmos Deeps deposit has, until recently, been interpreted as a body of massive nickel sulfide mineralization that was structurally remobilized from the Cosmos deposit into a dilational zone within the felsic footwall.

Supporting evidence for this model includes:
- similar sulfide mineralogies and geochemical signatures of the two mineralized bodies;
- distinct breccia and recrystallization textures within the sulfide mineralization;
- eclectic mixture of different wallrock clast types present within the sulfide mineralization;
- encapsulation of the orebody within a footwall rock package at least 60 m beneath the base of the ultramafic unit;
- presence of en echelon extensional fractures filled with sulfides, including pentlandite, hosted within the footwall rock package and oriented parallel to the main ore horizon;

- location of the Cosmos Deeps mineralization where there is a significant change in the orientations of the bounding structures and the geological units.

As discussed above, an alternative model is being developed following a detailed structural review based on mapping of underground exposures. The new model suggests that the basal contact of the sulfides is largely in situ, with little or no structural modification. Evidence that the hangingwall is comprised of the same rock package and little ultramafic unit remains in contact with the sulfides is explained by thrusting of the hangingwall package over the massive sulfides, and structural removal of the ultramafic unit. Minor remobilization of the sulfides along thrust planes has resulted in the development of the hangingwall lodes and incorporation of country rock into the sulfide body. Detailed evaluation of this model is underway.

Significance of the Cosmos Deposits in exploration models

There are several significant aspect of the Cosmos and Cosmos Deeps deposits that have implications for the exploration for such bodies.

1. Prior to these discoveries, all known nickel sulfide occurrences in this district were contained within the ultramafic units of the eastern part of the greenstone belt. The Cosmos and Cosmos Deeps deposits are in the Western Ultramafic unit (Dowling and Hill, 1990) and, to date, are the only nickel sulfide deposits to have been discovered in this unit. This has opened up a new area of nickel sulfide prospectivity.

2. The location of Cosmos Deeps within the footwall stratigraphy has similarities with many other deposits (Rockys Reward, Maggie Hays, and 1A Shoot). It continues to highlight the need to focus nickel exploration within the footwall sequences of ultramafic sequences as well as throughout the ultramafic rocks.

3. These discoveries have demonstrated that very high grade nickel sulfide deposits, similar to Silver Swan and some at Kambalda, can and do occur in the Agnew–Wiluna district. The extremely high unit value of this type of deposit makes them an attractive exploration target.

4. The Cosmos deposit is close to the surface, and gossan was present at surface, indicating that undiscovered nickel sulfide deposits can and probably still do exist in Western Australia, even in areas that have undergone significant levels of previous exploration.

Mine production

The Cosmos Nickel Project is based on both openpit and underground (underneath the Cosmos pit) mining. Mining commenced in October 1999 using conventional selective openpit techniques. Openpit mining was completed in July 2003.

Development of the Ilias decline, to access the Cosmos Deeps orebody, commenced in December 2001. The decline was developed at a gradient of 1 in 7 down, to intersect the orebody some 500 m below surface. The first ore was produced from Cosmos Deeps in June 2003, with production from the mineable reserve of 520 000 t at 7.2% Ni (containing 37 000 t of nickel metal) expected to continue until 2008.

The project uses conventional processing technology developed by the world's major nickel producers over the past 40–50 years. The plant comprises a crusher, semi-autogenous grinding (SAG) mill, flotation plant, cyclones, thickener, and filter, and is designed to annually process 150 000 t of ore to produce 10 000 t nickel in concentrate. Considerable effort has been expended in optimizing the performance of the plant, and recoveries in excess of 97% are being achieved on a regular basis.

The concentrate is dispatched by road to Leonora and then by rail to Esperance for shipping to Inco under an off-take agreement that included the first 30 000 t of nickel metal from the Cosmos Deeps project. Based on current reserves, Cosmos will be a profitable producer until at least 2008.

Mine production

This paper is an updated and edited version of a paper prepared by Tony Rovira. There have been additions and deletions to reflect new information. As previously acknowledged by Tony, I thank all Jubilee Mine's geoscientific colleagues (past and present) whose fieldwork, research, and advice have resulted in the current detailed understanding of the geology of the Cosmos and Cosmos Deeps ore deposits. There has also been significant input from various consultants and academic workers. The manuscript was proofread by Karyn Lyons, Steve Vallance, and Peter Thompson, whose suggestions were gratefully received.

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