GEOLOGICAL SURVEY OF FINLAND
Report of Investigation 180
2010

Quantitative mineral resource assessment of platinum, palladium, gold, nickel, and copper in undiscovered PGE deposits in mafic-ultramafic layered intrusions in Finland

GTK

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GEOLOGIAN TUTKIMUSKESKUS

Tutkimusraportti 180

GEOLOGICAL SURVEY OF FINLAND

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Kalevi Rasilainen, Pasi Eilu, Tapio Halkoaho, Markku Iljina and Tuomo Karinen

QUANTITATIVE MINERAL RESOURCE ASSESSMENT OF PLATINUM, PALLADIUM, GOLD, NICKEL, AND COPPER IN UNDISCOVERED PGE DEPOSITS IN MAFIC-ULTRAMAFIC LAYERED INTRUSIONS IN FINLAND

Espoo 2010

Cover photo: Test pit at the Konttijärvi PGE deposit. Photo: P. Eilu 2008.

Rasilainen, K., Eilu, P., Halkoaho, T., Iljina, M. & Karinen, T. 2010. Quantitative mineral resource assessment of platinum, palladium, gold, nickel, and copper in undiscovered PGE deposits in mafic-ultramafic layered intrusions in Finland. *Geological Survey of Finland, Report of Investigation 180*, 32 pages, 8 figures, 7 tables and 5 appendices. Total pages 338.

Most of the known platinum group element (PGE) resources in Finland are in contact- and reef-type deposits in 2.45 Ga mafic-ultramafic layered intrusions. These intrusions also have the potential to contain the majority of possibly existing, yet undiscovered, PGE resources in Finland. The undiscovered Pt, Pd, Au, Ni, and Cu resources in contact- and reef-type deposits were estimated down to one kilometre depth using the three-part quantitative assessment method. This included the delineation of 19 contact-type and 24 reef-type permissive tracts, formation of a grade-tonnage model for the contact-type deposits and a separate model for each reef-type tract, estimation of the number of undiscovered deposits for each permissive tract, and Monte Carlo simulation to produce the frequency distributions of metal tonnages in the undiscovered deposits. The expected numbers of undiscovered contact- and reef-type deposits are 29 and 23, respectively. At the 50% probability level, these deposits contain at least 5,600 t Pt, 12,000 t Pd, 430 t Au, 4.2 Mt Ni, and 5.7 Mt Cu. Of this undiscovered resource, 88% of the Pt, 81% of the Pd, 60% of the Au, 50% of the Ni and 37% of the Cu is contained in reef-type deposits. The Koitelainen intrusion alone is estimated to contain 48% of all undiscovered Pt and 44% of Pd. The intrusions of the Portimo complex host about a third of the number of both the known and the expected undiscovered PGE deposits, but only 11% of the Pt and 14% of the Pd in the undiscovered resources. The Western Intrusion of the Koillismaa Complex is assessed to contain 20% and 21% of the undiscovered Pt and Pd, respectively. The known PGE resources in Finland are 91 t Pt and 237 t Pd in seven deposits, including the atypical Kevitsa deposit that alone contains 21% of the known Pt+Pd resources. Hence, the presently known deposits account for around 2% of the total assessed PGE endowment in Finland. However, this work gives no guarantee on how much of the estimated PGE will ever be discovered.

Keywords (GeoRef Thesaurus, AGI): platinum ores, layered intrusions, potential deposits, platinum, palladium, gold, nickel, copper, resources, evaluation, ore grade, tonnage, quantitative analysis, Proterozoic, Finland

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ISBN 978-952-217-116-0 (PDF)
ISSN 0781-4240

Rasilainen, K., Eilu, P., Halkoaho, T., Iljina, M. & Karinen, T. 2010. Quantitative mineral resource assessment of platinum, palladium, gold, nickel, and copper in undiscovered PGE deposits in mafic-ultramafic layered intrusions in Finland. *Geologian tutkimuskeskus, Tutkimusraportti 180*, 32 sivua, 8 kuvaa, 7 taulukkoa ja 5 liitettä. Kokonaissivumäärä 338.

Valtaosa Suomen tunnetuista platinametallien (PGE) varannoista sijaitsee kontakti- ja reef-tyyppisissä esiintymissä 2.45 miljardin vuoden ikäisissä mafisissa–ultramafisissa kerrosintruusioissa. Näiden intruusioiden arvioidaan myös sisältävän suurimman osan Suomen mahdollisesti olemassa olevista, vielä löytymättömistä PGE-varannoista. Tässä työssä arvioitiin löytymättömät Pt-, Pd-, Au-, Ni- ja Cu-varannot kontakti- ja reef-tyypin esiintymissä kilometrin syvyyteen asti käyttämällä kolmivaiheista kvantitatiivista arviointimenetelmää. Tähän kuului 19 kontaktityyppisen ja 24 reef-tyyppisen sallitun alueen rajaaminen, pitoisuus-tonnimäärämallin luominen kontaktityypin esiintymille ja erillisen mallin luominen jokaiselle reef-tyypin sallitulle alueelle, jokaisen sallitun alueen sisältämien löytymättömien esiintymien lukumäärän arviointi, ja löytymättömien esiintymien sisältämien metallimäärien frekvenssijakautumien arviointi Monte Carlo -simulaatioiden avulla. Löytymättömien kontaktityypin esiintymien odotettu lukumäärä on 29 ja löytymättömien reef-tyypin esiintymien 23. Nämä esiintymät sisältävät 50 % todennäköisyydellä ainakin 5 600 t Pt, 12 000 t Pd, 430 t Au, 4,2 Mt Ni ja 5,7 Mt Cu. Näissä resursseissa 88 % platinasta, 81 % palladiumista, 60 % kullasta, 50 % nikkelistä ja 37 % kuparista on reef-tyypin esiintymissä. Peräti 48 % löytymättömistä Pt- and 44 % Pd-resursseista arvioidaan olevan Koitelaisen intruusiossa. Portimo-kompleksin intruusiot sisältävät noin kolmanneksen sekä tunnetuista että löytymättömistä esiintymistä, mutta vain 11 % löytymättömistä Pt-varannoista ja 14 % löytymättömistä Pd-varannoista. Koillismaa-kompleksin läntisen intruusion arvioidaan sisältävän 20 % löytymättömistä Pt-varannoista ja 21 % löytymättömistä Pd-varannoista. Suomen tunnetut PGE-varannot ovat 91 t Pt ja 237 t Pd. Tähän sisältyy epätyypillinen Kevitsan esiintymä, joka yksin vastaa 21 % tunnetuista resursseista. Näiden lukujen valossa nykyään tunnettujen esiintymien osuus Suomen koko PGE-varannoista jää kahden prosentin tasolle. Tämän työ ei kuitenkaan ota kantaa siihen, paljonko arvioiduista löytymättömistä resursseista löydetään.

Julkaisu on englanninkielinen.

Asiasanat (Geosanasto, GTK): platinamalmit, kerrosintruusiot, potentiaaliset esiintymät, platina, palladium, kulta, nikkeli, kupari, varannot, arviointi, malmipitoisuus, tonnimäärä, kvantitatiivinen analyysi, proterotsooinen, Suomi

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1 INTRODUCTION

As the population and standard of living in the world continue to increase, the demand for mineral resources is growing. At the same time, the exploration for and development of new mineral resources all over the world is facing increasing competition from other land uses (e.g., Briskey et al. 2007, Cunningham et al. 2007, Hitzman 2007, Idman et al. 2007). Environmental concerns about the effects of mining are also having a growing influence on the development of new natural resources. In the modern world, Finland cannot solely rely on raw material imports for our manufacturing and other industries. The same holds for the entire European Union, which is already a major net importer of nearly all metallic ores and concentrates (Kauppa- ja teollisuusministeriö 2006, Commission of the European Communities 2008). We need to know our mineral resources and how they might be expanded. The essential information includes the location of the known resources, the location and amount of the possibly existing, yet undiscovered resources, and the uncertainty related to their existence. It is also important to know how the development of mineral deposits may affect other resources in the area, such as biological diversity, arable land, air, and water.

This report aims to answer the questions ‘where’ and ‘how much’. The report describes the process and results of a quantitative assessment of platinum (Pt), palladium (Pd), gold (Au), copper (Cu) and nickel (Ni) resources in undiscovered PGE deposits in layered mafic-ultramafic intrusions in Finland. The report contains two parts. The first part includes reviews of Finnish PGE deposit types and their geological environments, the assessment method, the data used, and the assessment process itself. A summary of the assessment results is provided and the results are discussed. The second part comprises the Appendices, which include the deposit models employed and detailed information on each permissive tract delineated.

The information provided here on the location and amount of undiscovered mineral resources is expected to be significant for effective land management planning and the sustainable development of mineral resources.

1.1 The Geological Survey of Finland assessment project

The demands defined above, and requirements from various stakeholders (including the National Audit Office of Finland) to produce more exact information on potential resources, resulted in the start-up of the project “National resources of useful minerals” in the Geological Survey of Finland (GTK) in 2008. The purpose of the project is to develop assessment tools and create information for national and regional planning of land use, natural resources management, and environmental actions. The work will enable accounting of metallic natural resources according to the principles of sustainable development. It will also produce new information for metallogenic and lithologic research and for national-level planning of mineral exploration.

The project started in 2008 with the selection of the working methods and the beginning of assessment of PGE resources. During 2009–2012, the resources of PGE, Ni, Cu, Zn and Au in deposit types known to occur in Finland will be assessed. The products of the project include national and areal mineral resource estimates, and a final report containing a summary of the results for all metals assessed, a description of the methods and international reference materials used, and an evaluation of the quality of the results.

The procedure selected to be used in the GTK assessments is based on the three-part quantitative assessment method of the U.S. Geological Survey (USGS) described by Singer (1993). The method *does not* define deposits or provide mineral resource or reserve estimates according to the present industrial standards, and its results should never be confused with proper reserve or resource estimates based on international standards (cf., Australasian Joint Ore Reserves Committee 2004, Moon & Evans 2006, National Instrument 43–101 2006). Rather, the assessment process produces probabilistic estimates of the total amount of metals *in situ* in undiscovered deposits down to one kilometre depth. The process,

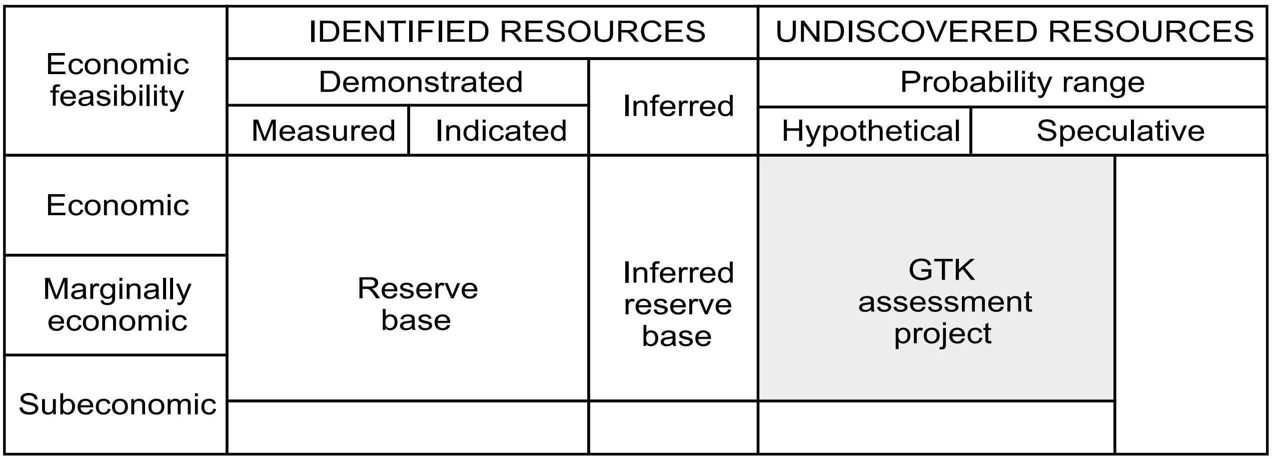

Figure 1. Classification of mineral resources used in GTK assessments (modified from U.S. Geological Survey National Mineral Resource Assessment Team 2000). Economic feasibility increases upwards and geological uncertainty increases to the right.

as used here, does not take into account the economic, technical, social or environmental factors that might affect the potential for economic extraction of a metal. Hence, part of the estimated undiscovered metals may be located in subeconomic occurrences (Figure 1) and it might be more appropriate to use the term 'metal endowment', which is not directly dependent on economic or technological factors (Harris 1984).

1.2 Terminology

Some terms essential for proper understanding of this report are briefly described below. The definitions are intended to follow the usage by the minerals industry and the resource assessment community (U.S. Bureau of Mines and U.S. Geological Survey 1980, U.S. Geological Survey National Mineral Resource Assessment Team 2000, Committee for Mineral Reserves International Reporting Standards 2006).

Mineral deposit
A mineral occurrence of sufficient size and grade that it might, under favourable circumstances, be considered to have economic potential.

Undiscovered mineral deposit
A mineral deposit believed to exist less than 1 km below the surface of the ground, or an incompletely explored mineral occurrence that could have sufficient size and grade to be classified as a deposit.

Mineral occurrence
A concentration of any useful mineral found in bedrock in sufficient quantity to suggest further exploration.

Mineral resource
A concentration or occurrence of material of economic interest in or on the Earth's crust in such form, quality and quantity that there are reasonable prospects for eventual economic extraction. The location, quantity, grade, continuity and other geological characteristics of a mineral resource are known, estimated or interpreted from specific geological evidence, sampling and knowledge.

Identified resources
Resources whose location, grade, quality, and quantity are known or can be estimated from specific geological evidence.

Undiscovered resources
Resources in undiscovered mineral deposits whose existence is postulated based on indirect geological evidence.

Hypothetical resources
Undiscovered resources in known types of mineral deposits postulated to exist in favourable geological settings where other well-explored deposits of the same types are known.

Speculative resources
Undiscovered resources that may occur either in known types of deposits in favourable geological settings where mineral discoveries have not been made, or in types of deposits as yet unrecognized for their economic potential.

Discovered resources
The total amount of identified resources and cumulative past production.

2 PGE DEPOSIT TYPES IN FINLAND

Layered intrusions contain the majority of world's economically viable PGE resources. Two intrusive complexes provide the majority of the PGEs: Bushveld in South Africa dominates platinum and Norilsk in northern Russia palladium production (Wilburn & Bleiwas 2004, Loferski 2008, Mungall & Naldrett 2008). In Finland, most of the known PGE deposits and occurrences are also hosted by mafic-ultramafic layered intrusions (Figure 2); these are ca. 2.45 Ga in age and are located in northern Finland (Alapieti & Lahtinen 1989, Alapieti et al. 1990).

The main known PGE resource beyond the 2.45 Ga intrusions in Finland is the ca. 2.05 Ga Kevitsa intrusion in central Lapland, hosting a large low-grade resource (Mutanen 1997). The komatiite-hosted nickel deposits in Neoarchaean greenstone belts of eastern Finland contain potentially exploitable PGE, but only as possible by-products from nickel occurrences (Kojonen 1981, Halkoaho & Luukkonen 2000, Vulcan Resources 2009). Within the Palaeoproterozoic Svecofennian domain of southern and western Finland, there is only minor PGE enrichment in the numerous Ni-Cu occurrences hosted by the ca. 1.89 Ga mafic-ultramafic orogenic intrusions (Häkli et al. 1976, Peltonen 2005). Placer or other types of PGE occurrences not mentioned above are not known from Finland.

2.1 Location and geological setting of 2.45 Ga layered intrusions in the Fennoscandian Shield

Early Palaeoproterozoic (2.5–2.4 Ga) layered intrusions occur within a large area in the north-eastern part of the Fennoscandian Shield in Finland, Russia and Sweden (Figure 2). They all straddle the Archaean–Proterozoic boundary within the shield. This location is most obvious for the Tornio–Näränkävaara belt extending east across Finland from Tornio. In close examination, the same setting is also clear for all the other ca 2.45 Ga intrusions in the shield, although their location may somewhat deviate from the exact Archaean–Proterozoic contact (e.g., Mutanen 1997). The emplacement of the intrusions is part of a large plume-related rifting event possibly related to the initial breakdown of the Neoarchaean supercontinent (Alapieti 2005). This magmatic event belongs to a global episode of igneous activity at the beginning of the Proterozoic that produced several layered intrusions and mafic dyke swarms on other cratons as well (Alapieti & Lahtinen 2002, Iljina & Hanski 2005).

The cumulate sequences of the 2.45 Ga layered intrusions in the Tornio–Näränkävaara belt were generated from various parental magmas that shared common features, including enrichment in LREE over HREE and depletion of Ti and other HFSE (Iljina & Hanski 2005). Intrusions in the western and central parts of the belt formed either entirely from an earlier Cr-richer (Kemi and Tornio, Figure 2) or from a later Cr-poorer (Suhanko and Konttijärvi, Figure 3) magma with a boninitic or siliceous high-magnesian basaltic affinity, or had influx of both magma types (Penikat and Narkaus, Figures 2 and 3). More evolved, tholeiitic basalt, parental magma for the Western Intrusion of the Koillismaa Complex resulted in significant Fe-Ti-V oxide enrichment

The magma types identified in the Tornio–Näränkävaara belt have a potential for significant Cr, Ni-Cu-PGE sulphide, PGE and Fe-Ti-V oxide mineralisation. Well-known examples of intrusions produced by these magma types and hosting large deposits elsewhere include the Bushveld Complex in South Africa (Cawthorn et al. 2002), the Stillwater complex in the USA (Zientek et al. 2002), and the Great Dyke in Zimbabwe (Oberthür 2002).

2.2 Main types of PGE deposits in mafic-ultramafic layered intrusions in Finland

There are two main categories of PGE deposits in the Finnish 2.45 Ga layered intrusions: contact type and reef type. Both kinds have been detected in a number of intrusions in Finland (Lahtinen et al. 1989, Mutanen 1997, Alapieti & Lahtinen 2002, Iljina & Hanski 2005). In addition to these types, PGE-enriched ultramafic pipes occur, for example, in the Bushveld layered intrusion (Wagner 1929, Bristow et al. 1993), but have not yet been found in the layered intrusions of the Fennoscandian Shield.

The contact-type deposits occur near the base or wall contacts of the intrusions (Figure 4), and the presence of mineralisation has little dependence on the host rock type in the intrusion. Mineralisation may also occur in the footwall rocks of the intrusion. This so-called offset-type mineralisation is seen as a subcategory of the contact type, as offset bodies probably formed during deformation, by remobilisation of PGE and sulphides from a normal contact-type deposit (Alapieti et al. 1989, Iljina 1994, Alapieti & Lahtinen 2002).

The contact-type deposits typically are 10 to 30 m thick. Their distribution within an intrusion is erratic and they can extend from the lower ultramafic layer downward to the basement rocks. The dominant

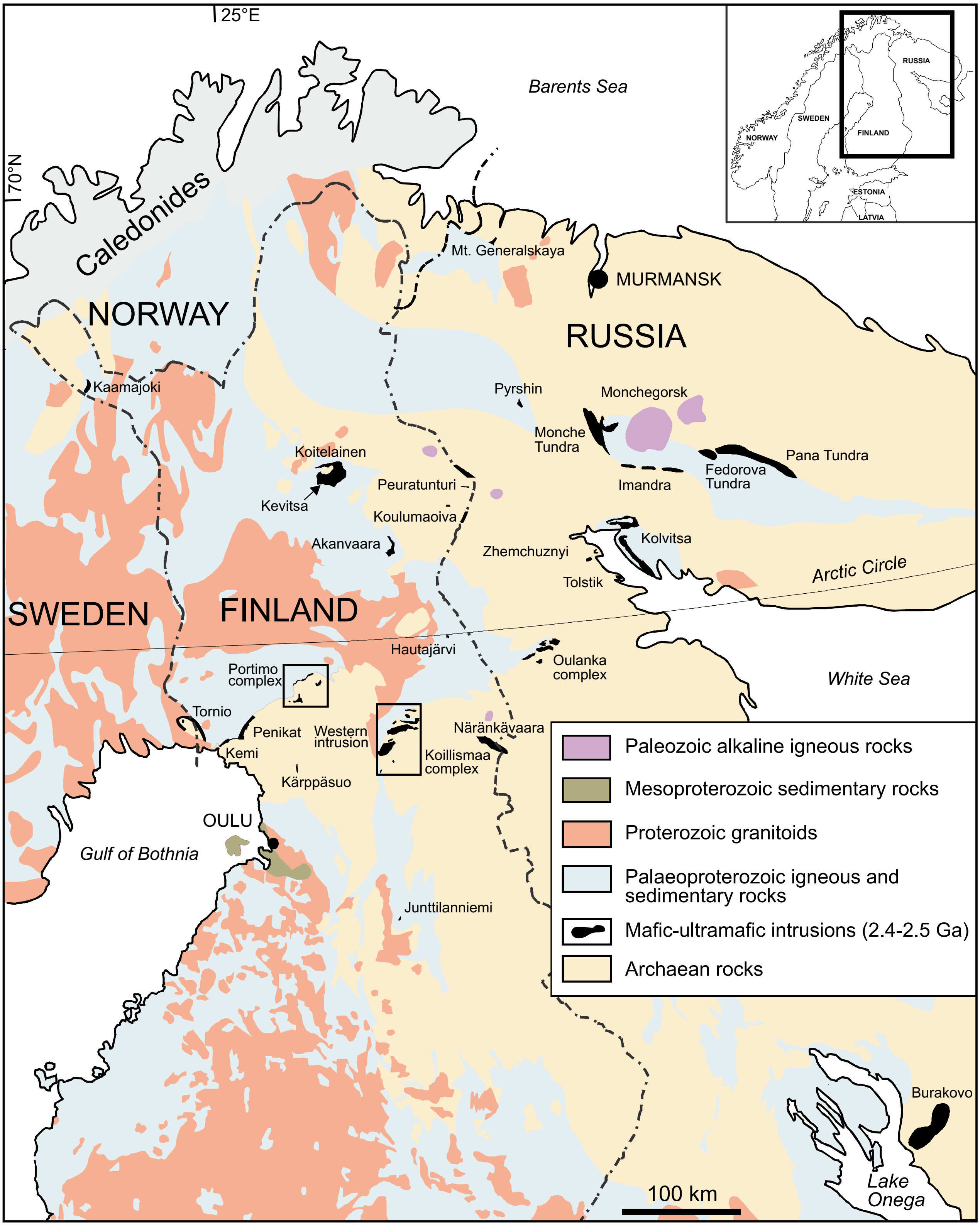

Figure 2. Location of the most important Palaeoproterozoic layered intrusions in the northern part of the Fennoscandian Shield. The map indicates all known layered intrusions in Finland where the PGEs are the main potential commodity. Areas of the Portimo complex and the Western Intrusion of the Koillismaa Complex covered by Figure 3 are shown by rectangles. Inset: the Fennoscandian Shield. Modified from Alapieti and Lahtinen (2002) and Koistinen et al. (2002).

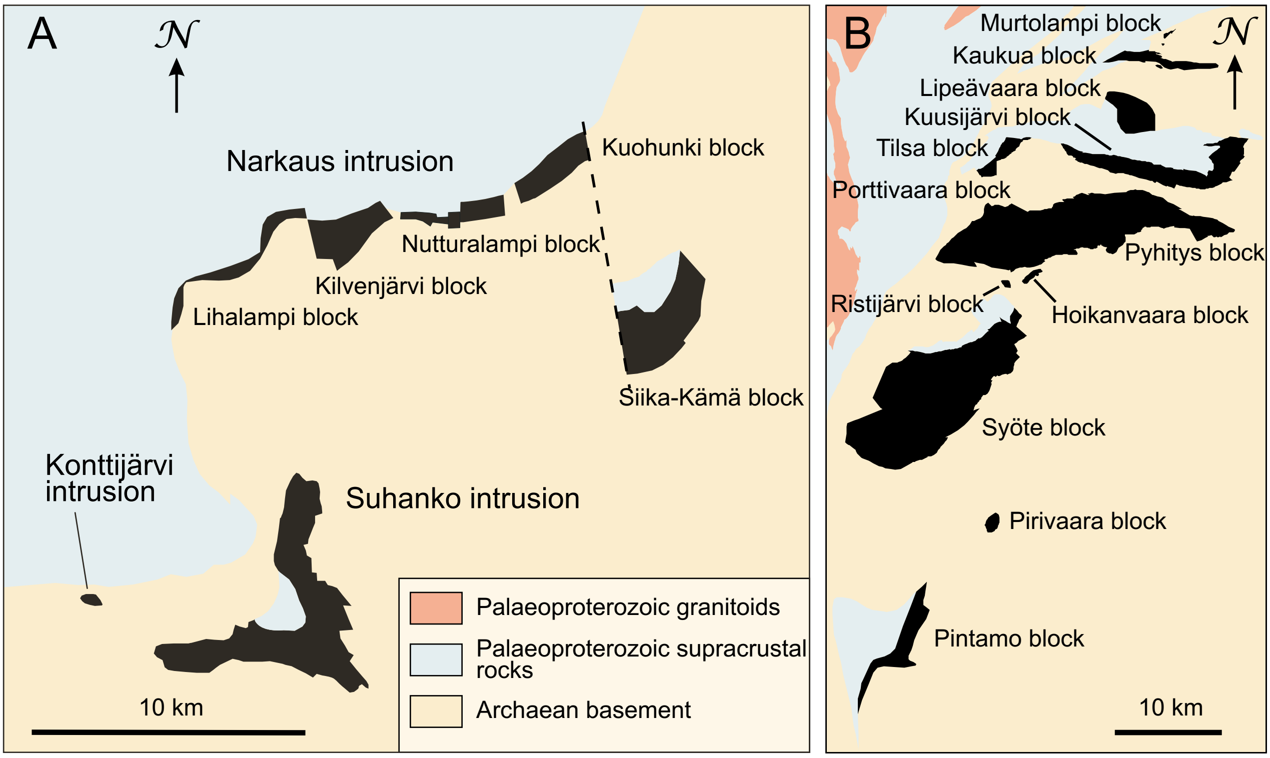

Figure 3. Mafic-ultramafic layered intrusions of the Portimo complex (A) and the Western Intrusion of the Koillismaa Complex (B). Modified from Iljina and Lee (2005).

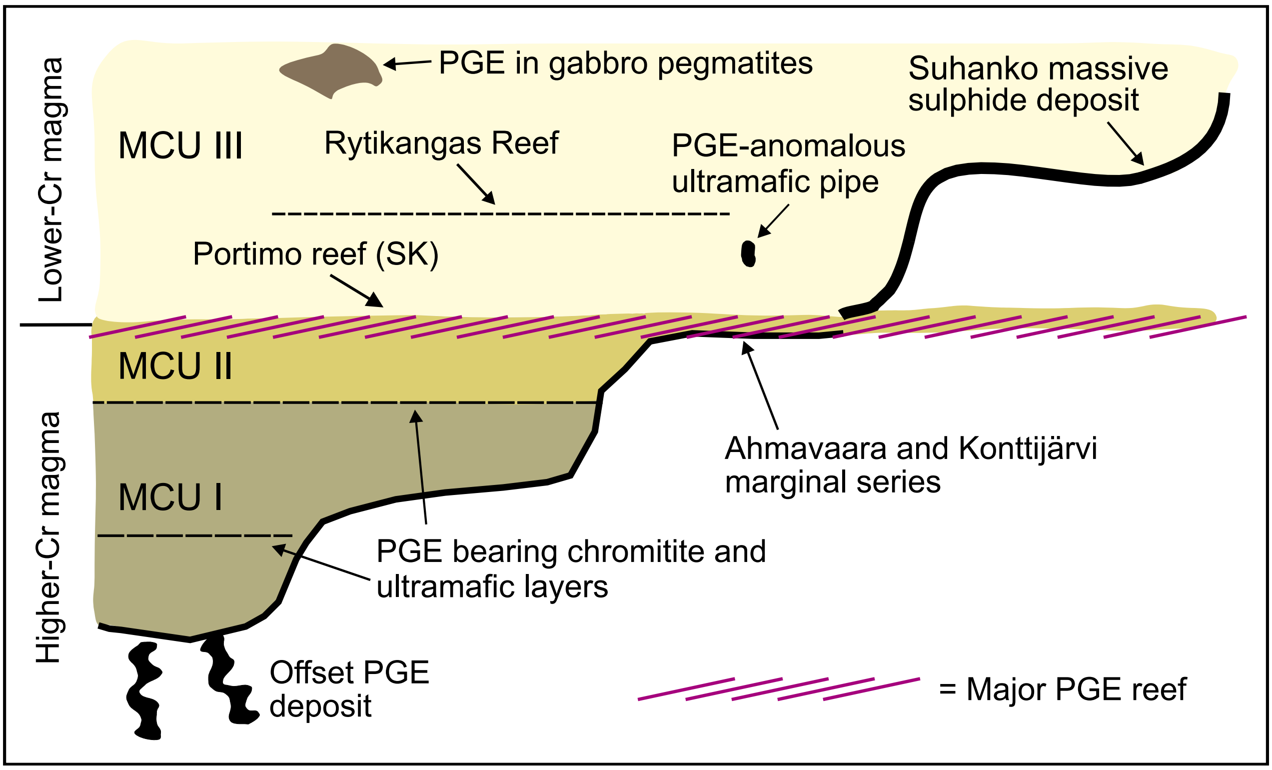

Figure 4. Schematic model on the siting of PGE occurrences in the layered intrusions of the Portimo complex. Modified from Iljina (1994).

sulphide assemblage is pyrrhotite-chalcopyrite-pentlandite, whereas the silicate mineralogy varies with the host rock type. The most common platinum-group minerals are sperrylite and various Pd-Sb-As and Pd-Te-Bi phases. Generally, the contact-type deposits contain 1–2.5 vol% sulphides, and their base metal contents vary around 0.06–0.10% Ni and 0.15–0.24% Cu (Alapieti & Lahtinen 2002).

Reef-type PGE deposits can occur in two different positions in a layered intrusion: in the border zone between rocks of two different magma pulses or megacyclic units, and as stratiform zones within a megacyclic unit (Figure 4). Examples of the first type include the SJ and PV Reefs in the Penikat layered intrusion and the SK Reef in the area of the Portimo complex. The AP Reef in the Penikat layered intrusion and the RK Reef in the Suhanko layered intrusion belong to the latter type. The occurrence of the first type has little dependence on host rock, as it may be hosted by various kinds of cumulates. However, it always occurs in a certain zone in an intrusion. The second subtype is more dependent on the host rock type, and it is mainly hosted by anorthositic and gabbronoritic cumulates. (Cawthorn 2005, Mungall 2007, Mungall & Naldrett 2008)

Reef-type deposits in the border zone between two different magma pulses or megacyclic units are typically from less than one metre to several metres thick, whereas reefs within a megacyclic unit usually have a thickness of 20–70 cm. In sulphide-bearing reefs (e.g., the AP and PV Reefs in the Penikat layered intrusion), the dominant sulphide assemblage is pyrrhotite-chalcopyrite-pentlandite. In the SJ Reef, base metal-free chromite and silicate variants have also been described (Halkoaho 1993). The silicate mineralogy of the reef-type deposits is dependent on the host rock type. The most common platinum-group minerals are sperrylite, braggite, and a variety of Pd-Sb-As and Pd-Te-Bi phases. Generally, a base metal-bearing reef deposit contains 0.8–2 vol% sulphides and their base metal contents are around 0.06–0.24% Ni and 0.11–0.36% Cu. The base metal-free chromite reef deposits normally contain less than 0.05% S and Cu, and about 0.08% Ni (includes nickel in silicates) (Alapieti & Lahtinen 2002). The silicate reef deposits have very low S and Cu contents, at <0.02 and <0.015%, respectively, all nickel is in silicates, and the Cr content is normally below 0.05% (Halkoaho 1993).

3 THE THREE-PART QUANTITATIVE RESOURCE ASSESSMENT METHOD

Numerous methods have been applied to the estimation of undiscovered mineral resources during the past decades, but the process still remains challenging and there are no universally accepted, definitive procedures (e.g., Lisitsin et al. 2007 and references therein). The procedure we selected is based on a three-part quantitative assessment method (Singer 1993) developed in the U.S. Geological Survey and used by the USGS and others since 1975 (Harris et al. 1993, Barton et al. 1995, Drew 1997, Singer 2007, Cunningham et al. 2008). The method is compatible with the goal of the GTK assessment project to estimate the undiscovered mineral endowment in Finland. The assessment is based on statistical methods of data analysis and integration and it treats and expresses uncertainty. It enables the use of varying amounts of objective geological data and subjective expert knowledge and generates reproducible assessment results.

The three-part method consists of the following components: (1) evaluation and selection or construction of descriptive models and grade-tonnage models for the deposit types under consideration, (2) delineation of areas according to the types of deposits permitted by the geology (permissive tracts), and (3) estimation of the number of undiscovered deposits of each deposit type. The estimated number of deposits is combined with the grade and tonnage distributions to model the total undiscovered metal endowment.

3.1 Deposit models

Deposit models designed for quantitative assessments are the cornerstone of the method. They are used to classify mineralised and barren environments, as well as types of known deposits, and to discriminate mineral deposits from mineral occurrences (Singer & Berger 2007). Several types of deposit models can be used in the three-part assessment method: descriptive models, grade-tonnage models, deposit density models, economic models and quantitative descriptive models. The descriptive models and grade-tonnage models are an essential component of the three-part method and they are used in all GTK assessments. Deposit density models, when available, can be used in the estimation of the number of undiscovered deposits for an area. Economic models and quantitative descriptive models have not been used in the GTK assessment project.

3.1.1 Descriptive models

A descriptive model consists of systematically arranged information describing all of the essential characteristics of a class of mineral deposits (Barton 1993). A descriptive model usually consists of two parts. The first part describes the geological environments in which the deposits occur. It contains information on favourable host rocks, possible source rocks, age ranges of mineralization, the depositional environment, tectonic setting, and associated deposit types. This part of the descriptive model plays a primary role in the delineation of tracts of land where the geology permits the occurrence of undiscovered deposits.

The second part of a descriptive model lists essential identifying characteristics by which deposits of the type might be recognized, including mineralogy, alteration, and geochemical and geophysical signatures. The second part is used to classify known deposits and occurrences. Identifying the types of known deposits is important for the tract delineation process, and it can sometimes help to delineate geological environments not indicated on geological maps.

3.1.2 Grade-tonnage models

A grade-tonnage model displays the frequency distributions of tonnages and average metal grades of well-studied and completely delineated deposits of a certain type (Singer 1993). These distributions are used as models for grades and tonnages of undiscovered deposits of the same type in geologically similar settings. They also help in differentiating between a deposit and a mineral occurrence, and in judging whether a deposit or group of deposits belongs to the type represented by the model. Grade-tonnage models are based on data on average metal grades and the associated tonnage, combining the total production and resources (including reserves) at the lowest possible cut-off grade.

It is very important to use the same sampling unit criteria for all deposits in the grade-tonnage model. Mixing old production data from some deposits with resource data from other deposits is probably the most common error in constructing grade-tonnage models (Singer & Berger 2007), and this will produce biased models. Another aspect of the sampling unit is spatial. A spatial rule identifying the minimum distance between two separate deposits of the same type should be defined and deposits closer to each other than the minimum distance should be combined in the grade-tonnage model.

3.2 Permissive tracts

A permissive tract is an area within which the geology permits the existence of mineral deposits of the type under consideration (Singer 1993). It is important to distinguish between areas favourable for the existence of deposits and permissive tracts; the former are a subset of the latter. The existence of a permissive tract in an area does not indicate any favourability for the occurrence of deposits within the area; neither has it anything to do with the likelihood of discovery of existing undiscovered deposits in the area.

Permissive tracts are based on criteria derived from descriptive models. Tract boundaries are defined so that the likelihood of deposits of the type under assessment occurring outside of the tract is negligible. In three-part assessment, the boundaries of the tracts are first defined based on mapped or inferred geology. Tracts may or may not contain known deposits. The existence of deposits is used to confirm and extend the tracts, but the lack of known deposits is not a reason to exclude any parts of the tract. Original tract boundaries are reduced only where it can be firmly demonstrated that a deposit type could not exist. This evidence could be based on geology, knowledge about unsuccessful exploration, or the presence of barren overburden exceeding the predetermined delineation depth limit.

3.3 Estimation of the number of undiscovered deposits

The third part of the assessment is the estimation of the number of undiscovered deposits of the type(s) that may exist in the delineated tracts. The estimates represent the probability that a certain fixed but unknown number of undiscovered deposits exist in the delineated tracts. The estimates are performed according to the deposit type and they must be consistent with the grade-tonnage models. This means that, for example, about half of the estimated number of deposits should be larger than the median tonnage given by the grade-tonnage model and about 10% of the estimated deposits should be larger than the upper 10^{th} quantile of the model. The spatial rule used to define a deposit in the grade-tonnage model must also be taken into account in the estimates. Well-explored deposits, for which published grade and tonnage values exist, are considered as discovered deposits, whereas known occurrences without reliable grade-tonnage estimates are counted as undiscovered.

Several methods can be used either directly or as guidelines to make the estimates. These include the frequency of deposits in well-explored areas (deposit density models), local deposit extrapolations, counting and assigning probabilities to anomalies, process constraints, relative frequencies of associated deposit types, and limits set by the total available area or total known amount of metal (Singer 2007). Some of these methods produce a single estimate of the expected number of deposits; others produce a probability distribution of the expected number of deposits. In the latter case, the spread of the number of deposit estimates associated with high and low quantiles of the probability distribution (for example, the 90% and 10% quantiles) indicates the uncertainty of the estimate. The expected number of deposits, or the estimated number of deposits associated with a given probability level, measures the favourability of the existence of a deposit type.

The estimates are typically made subjectively by a team of experts knowledgeable about the deposit type and the geology of the region. Such a process follows the Delphi technique (Chorlton et al. 2007), where each expert makes an estimate independently and all the estimates are then discussed to possibly reach a final consensus estimate.

3.4 Statistical evaluation

The parts of the assessment method described above produce consistent estimates of the number of undiscovered deposits for the delineated areas and of the probability distribution of grades and tonnages of the deposit type. As the final step in the assessment, these estimates are combined using statistical methods to achieve probability distributions of the quantities of contained metals and ore tonnages in the undiscovered deposits. Software using Monte Carlo simulation has been developed for this purpose (Root et al. 1992, Duval 2004).

4 ASSESSMENT OF PGE RESOURCES IN FINLAND

4.1 PGE resources covered by the assessment

This assessment only includes the PGE deposits hosted by the 2.45 Ga mafic-ultramafic layered intrusions. These deposits contain the major part of the known Finnish PGE resources and they also have the potential to hold the majority of the undiscovered resources. This is suggested by the known PGE occurrences and by the fact that PGE resources identified in other settings are relatively minor in Finland (Iljina et al. 2009), as mentioned above. Grade and tonnage data exist for the mafic-ultramafic layered intrusion-hosted deposit type globally. In addition, the Finnish intrusions have been explored to such an extent that it is possible to form a grade-tonnage model based on data from them. This permits the statistical assessment of the deposit category in Finland. On the other hand, the number of komatiite-hosted PGE-enriched deposits in Finland is far too small to construct a grade-tonnage model, and there are only scarce grade-tonnage data that include the PGE for this deposit type from outside Finland. The Kevitsa deposit forms a potentially large Ni-Cu-PGE resource, but it has no known analogies and our statistical testing showed that it does not fit into any of the existing grade-tonnage models of PGE deposits. Therefore, only the PGE deposits hosted by the ca 2.45 Ga mafic-ultramafic layered intrusions in Finland are included in this assessment.

4.2 GTK assessment progress

The GTK project "National resources of useful minerals" started at the beginning of 2008. During a brief starting phase, the USGS three-part method was selected to be used in the assessment of undiscovered mineral resources in Finland and the PGE were selected as the first metals to be assessed. Data gathering started immediately and continued until mid-May 2008, when the first workshop of the project was arranged. During the workshop, USGS geologists introduced the project team members to the three-part method of assessing undiscovered mineral resources. The available data on known PGE deposits and occurrences were evaluated, and contact- and reef-type PGE deposits were selected to be included in the assessment.

After the initial workshop, the work continued with the delineation of preliminary permissive tracts, the preparation of tract description documents and the development of descriptive and grade-tonnage models for the deposit types. The finalising of the permissive tracts and the estimation of the number of undiscovered deposits within the tracts was carried out in a series of workshops during the second half of 2008.

After the workshops, the Fennoscandian grade-tonnage model for contact-type deposits was finalised and specific grade-tonnage models were developed for each reef-type permissive tract. This was followed by Monte Carlo simulations of the undiscovered metal endowment for each tract and for various combinations of tracts. After these stages, the tract reports and other parts of the present report were finalised, during the second half of 2009.

4.3 Data used

All the available information on Finnish layered intrusions and PGE deposits and occurrences were used in the assessment. Geological maps on paper and in digital format, geochemical and geophysical survey data, reports and publications on known deposits and layered intrusions, exploration reports, and the experience of the assessment team were the primary sources of information used in this work. Some of the most significant data used in our work are mentioned below. All information used in the assessment work for any permissive tract is listed in the respective tract description document in Appendix 5.

The new Finnish bedrock GIS database, known as the 'Bedrock Map Database DigiKP Finland', formed the main source of lithologic data for this work. This in-house GIS database covers the whole of Finland and it has been reviewed and updated during 2008–2009. For most of the areas assessed, detailed maps produced by exploration and research campaigns were also available. For areas with poor outcrop and little or no drilling, the GTK low-altitude airborne magnetic, electromagnetic and radiometric survey data covering the whole of Finland (Hautaniemi et al. 2005) were utilised, especially for evaluating the extent of unexposed parts of layered intrusions. These data were supplemented by ground-survey gravity data for most of the layered intrusions. The GTK countrywide till-geochemical (Salminen 1995) and diamond-drill databases were also used in the identification and evaluation of the tracts.

4.4 Deposit models

4.4.1 Contact-type deposits

Published grade-tonnage data from well-studied contact-type PGE deposits within the Fennoscandian Shield are scarce (Table 1). These data were compared with the global models and data compiled at the USGS (Cox & Singer 1986, M. Zientek, written comm., 2009). Before the comparison, a spatial

Table 1. Tonnages and average grades for known contact-type PGE deposits associated with layered mafic-ultramafic intrusions in the Fennoscandian Shield. The tonnages are total resource estimates. Properties for spatially aggregated deposits are given at the bottom of the table.

Deposit	Tonnage (Mt)	Ni (%)	Cu (%)	Pt (g/t)	Pd (g/t)	Au (g/t)	Intrusion / Block
Konttijärvi	42.1	0.06	0.13	0.41	1.44	0.11	Konttijärvi
Ahmavaara	106.7	0.09	0.23	0.25	1.17	0.14	Suhanko
Suhanko	1.0	0.27	0.31	0.20	0.90	0.04	Suhanko
Vaaralampi	6.1	0.32	0.20	0.20	0.55	0.06	Suhanko
Niittylampi	1.0	0.67	0.49	0.27	0.68	0.01	Suhanko
Haukiaho	27.0	0.24	0.36	0.21	0.55	0.22	WI / Kuusijärvi
Lavotta	3.0	0.21	0.26	0.18	0.26	0.20	WI / Porttivaara
Rusamo	1.5	0.24	0.39	0.27	0.38	0.15	WI / Porttivaara
Fedorova	414.8	0.09	0.15	0.31	0.93	0.08	Fedorovo-Pansky
Generalskaya	53.3	0.27	0.46	0.20	2.05	0.03*	Mt. Generalskaya
Ahmavaara-Suhanko	107.7	0.09	0.23	0.25	1.16	0.14	
Vaaralampi-Niittylampi	7.1	0.37	0.24	0.21	0.57	0.05	

WI: Western intrusion of the Koillismaa layered intrusion complex.
*: Au grade in Generalskaya unknown, estimated by minimum Au grade in deposits from outside Fennoscandia.
References: Konttijärvi, Ahmavaara (Puritch et al. 2007); Suhanko, Vaaralampi, Niittylampi (Lahtinen 1991); Haukiaho (Iljina et al. 2005); Lavotta, Rusamo (Lahtinen 1983); Fedorova tonnes, Pd, Pt (Barrick Gold Corporation 2009), Au, Cu, Ni (Schissel et al. 2002); Generalskaya (Fennoscandian ore deposit database 2009).

rule was applied, according to which deposits were combined into one if the distance between them was less than one kilometre. This subjective decision was based on the study of the spatial relations of deposits within the global data. The application of the spatial rule resulted in the combination of the Ahmavaara deposit with the Suhanko and Niittylampi deposit with Vaaralampi (Table 1). After applying the spatial rule, the total number of known contact-type deposits in Fennoscandia was eight, six of which are in Finland. Although the characteristics of these deposits are conformable with the characteristics in a published descriptive model (Page 1986), statistical testing indicated that the Fennoscandian contact-type deposits form a distinct group deviating from global grade-tonnage data by having significantly lower tonnages and slightly higher Ni and Cu grades, and Pd/Pt values (Table 2, Figure 5). Due to these differences, a Fennoscandian contact-type PGE grade-tonnage model was created using the deposits listed in Table 1 and following the one-kilometre spatial rule described above. The final model consists of eight deposits (six from Finland, two from Russia) and is presented in Appendix 2. A descriptive model for the Fennoscandian contact-type PGE deposits was also developed, based on the characteristics of the known deposits and occurrences in Finland (Appendix 1).

Table 2. Summary statistics for the Fennoscandian and global contact-type PGE data. Results of statistical tests for normality of data, and for similarity of means between the Fennoscandian and global data are also shown. The statistical tests were run on logarithmic values of the tonnage and metal grade data.

	Tonnage (Mt)	Ni (%)	Cu (%)	Pt (g/t)	Pd (g/t)	Au (g/t)	Pd/Pt
Fennoscandian							
N of cases	8	8	8	8	8	8	8
Median	35	0.23	0.25	0.23	0.75	0.12	2.9
Arithmetic mean	82	0.20	0.28	0.25	0.92	0.12	3.7
Standard deviation	140	0.11	0.12	0.08	0.61	0.07	2.8
Minimum	1.5	0.06	0.13	0.18	0.26	0.03	1.4
Maximum	414.8	0.37	0.46	0.41	2.05	0.22	10
K-S test statistic	0.156	0.264	0.157	0.219	0.154	0.166	0.162
p-value	0.972	0.547	0.971	0.765	0.976	0.954	0.963
Global							
N of cases	16	16	16	16	16	16	16
Median	140	0.11	0.14	0.34	0.76	0.08	2.3
Arithmetic mean	300	0.11	0.20	0.48	0.81	0.10	3.2
Standard deviation	430	0.07	0.17	0.41	0.37	0.06	4.1
Minimum	4.8	0.01	0.03	0.03	0.24	0.03	1.1
Maximum	1668	0.21	0.62	1.44	1.71	0.21	18
K-S test statistic	0.083	0.200	0.111	0.152	0.161	0.106	0.190
p-value	0.999	0.483	0.977	0.802	0.742	0.985	0.555
Comparison of means							
Two-sample t-test	–2.312	2.023	1.701	–1.003	0.103	0.664	1.007
p-value	0.031	0.055	0.103	0.329	0.919	0.514	0.325

K-S test statistic: Kolmogorov-Smirnov test statistic for normality (logarithmic data).
Two-sample t-test: Two-sample t-test statistic for equality of two means (logarithmic data).
p-value: Statistical significance of the test statistic.
Median, mean, and standard deviation have been rounded to two significant digits.
References: Fennoscandian data, see Table 1; global data, M. Zientik (written comm., 2009).

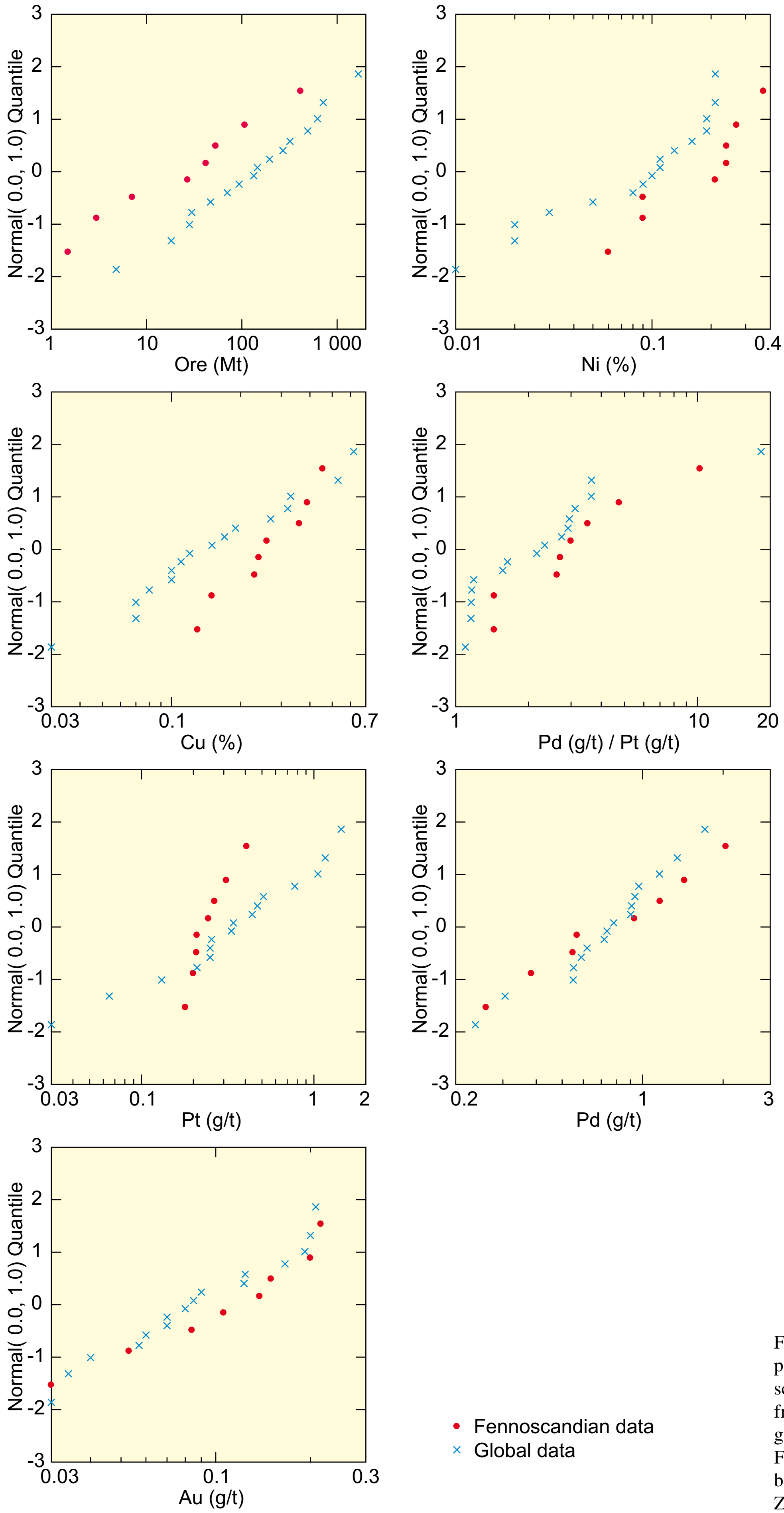

Figure 5. Normal probability plots of metals in the Fennoscandian contact-type deposits from Table 1 compared with global data from outside the Fennoscandian Shield. The global data was provided by M. Zientik (written comm., 2009).

4.4.2 Reef-type deposits

Several PGE reefs are known from the layered intrusions in Finland (Alapieti & Lahtinen 1986, Iljina 1994, Mutanen 1997). Five of these, the Sompujärvi (SJ), Ala-Penikka (AP), Paasivaara (PV), Siika-Kämä (SK) and Rytikangas (RK) reefs, hosted by the Penikat, Narkaus and Suhanko intrusions, potentially contain world-class resources (Iljina & Hanski 2005). However, no published resource data exist covering a whole reef-type deposit. This prevents the construction of a grade-tonnage model for reef-type deposits. On the other hand, the standard three-part assessment approach (Root et al. 1992, Singer 1993) using a general grade-tonnage model for reef deposits would not be valid for estimating the tonnages of undiscovered reef-type deposits. This is because the tonnage of a reef deposit is strongly dependent on the size of the host intrusion, due to the great lateral continuity of deposits of this type. Therefore, we modified the assessment method by generating a separate grade-tonnage model for each permissive tract. This was accomplished by estimating the tonnage of an undiscovered reef-type deposit individually for each tract and combining the estimated tonnage with a general grade model for Ni, Cu, Pt, Pd and Au in Finnish reef-type deposits. A descriptive model for the Finnish reef-type deposits was constructed using all available information on the known PGE reef-type occurrences in Finland (Appendix 3).

For each permissive tract, the tonnage of a possibly existing, undiscovered reef-type deposit was estimated by Monte Carlo simulation using Systat software (Systat 2007). Details of the process are given in Appendix 4 and it is only briefly summarised here. The calculation was based on the dimensions of the host intrusion or intrusive block along igneous layering and on the frequency distributions of reef thickness, reef density, and geological loss due to reef discontinuity. The surface dimensions of the intrusion were measured using ArcMAP software (Esri 2009) and the dimensions along igneous layering were calculated using dip information. The frequency distributions of reef thickness and density were estimated using data from Finnish PGE reefs and their immediate host rocks (Table 3). The geological loss was modelled using data from 28 reef-type deposits or properties from the Bushveld intrusion (M. Zientek, written comm., 2009) The loss describes the relative decrease in the amount of mineralised rock due to discontinuities in the reef caused by geological factors. The reef tonnage was estimated to the depth of one kilometre, or, in the case of shallower intrusive bodies, to the estimated or known depth of the body. The result of the estimation is a cumulative frequency distribution of reef tonnage for the permissive tract in question.

A general grade model for Ni, Cu, Pt, Pd and Au in reef-type deposits was constructed using data from Finnish PGE reefs (Table 4). For each permissive tract, a grade-tonnage model was then produced by combining the estimated reef tonnage for the tract with the general grade model for Finnish reef-type deposits. The general grade model and the estimated cumulative distributions of reef tonnage for each permissive tract are provided in Appendix 4.

Table 3. Summary statistics for reef thickness, density and geological loss data used in the estimation of reef tonnages. The statistical tests for normality of data were run on logarithmic values of thickness and non-transformed values of density and geological loss.

	Thickness (m)	Density (g/cm^3)	Loss (%)
N of cases	376	9	36
Median	1.47	2.94	24
Arithmetic mean	2.55	2.94	24
Standard deviation	3.37	0.03	7.8
Minimum	0.20	2.91	12
Maximum	35.0	3.00	41
K-S test statistic	0.053	0.206	0.122
p-value	0.012	0.371	0.185

K-S test statistic: Kolmogorov-Smirnov test statistic for normality (logarithmic data for thickness).
p-value: Statistical significance of the test statistic.
References: Thickness (Halkoaho, unpublished data; North American Palladium Ltd. 2006, 2007), Density (Puritch et al. 2007), Loss (M. Zientek, written comm., 2009).

Table 4. Summary statistics for grade data of diamond drill hole samples from the SJ and SK reefs and for the empirical distribution functions estimated from the data. The statistical tests for normality were run on logarithmic values of the metal grade data.

	Pt (g/t)	Pd (g/t)	Au (g/t)	Ni (%)	Cu (%)
Original data					
N of cases	325	325	325	57	85
Median	1.4	3.2	0.10	0.07	0.07
Arithmetic mean	3.4	6.5	0.14	0.09	0.11
Standard deviation	6.9	14	0.16	0.08	0.12
Minimum	0.01	0.03	0.002	0.02	0.0004
Maximum	76.4	173.3	1.5	0.60	0.74
K-S test statistic	0.074	0.083	0.069	0.099	0.130
p-value	0.000	0.000	0.001	0.171	0.001
Empirical distribution functions					
N of cases	26	26	26	26	26
Median	1.4	3.1	0.10	0.07	0.07
Arithmetic mean	3.4	6.4	0.13	0.08	0.10
Standard deviation	5.7	10	0.14	0.04	0.09
Minimum	0.22	0.67	0.01	0.035	0.001
Maximum	27.5	51	0.60	0.20	0.35
K-S test statistic	0.092	0.097	0.085	0.087	0.138
p-value	0.906	0.819	1.000	1.000	0.228

K-S test statistic: Kolmogorov-Smirnov test statistic for normality (logarithmic data).
p-value: Statistical significance of the test statistic.
Median, mean, and standard deviation have been rounded to two significant digits.
Data source: Halkoaho (unpublished data), North American Palladium Ltd. (2006, 2007).

4.5 Tract delineation

Permissive tracts were delineated separately for the reef- and contact-type PGE deposits (Figure 6), based on the information described in section 4.3. Maps of all the permissive tracts are presented in the tract reports in Appendix 5.

For each area, the expert (T. Halkoaho, M. Iljina, or T. Karinen) most familiar with the geology and PGE mineralisation of the region drew the tracts. The tracts are controlled by the presence of 2.45 Ga layered intrusions. This may have led to the omission of some areas of possible, albeit weak, PGE potential in those parts along the Archaean–Proterozoic boundary where 2.45 Ga intrusions have not been detected. However, as we found no direct or indirect indications of PGE enrichment beyond the tracts delineated, the presence of known layered 2.45 Ga intrusions remained the necessary requirement for the permissive tracts.

On a map, a permissive tract is a projection to the surface of the domain where geology allows the existence of the deposit type assessed. The permissive volumes of rock were delineated down to the depth of one kilometre, unless there was clear evidence (typically from drilling or geophysical survey) that the host intrusion is shallower. In the latter cases, the permissive domain was delineated down to the estimated or known depth of the intrusive body.

The existence of a well-developed marginal series – gabbronorites, pyroxenites, and peridotites – displaying reverse fractionation is characteristic of intrusions hosting contact-type PGE deposits (Alapieti et al. 1979, Alapieti 1982, Huhtelin et al. 1989, Iljina et al. 1989). The maximum thickness of the marginal series in the Finnish layered intrusions is 150 m (Iljina & Hanski 2005) and the most promising deposits are associated with marginal series that are more than 50 m thick. Offset PGE showings have been detected in the country rocks below the Narkaus intrusion in places where there is a possibility for contact-type mineralisation within the intrusion (Huhtelin et al. 1989). Based on available information, a zone extending 200 m below the base of the intrusion was

Figure 6. Location of permissive tracts for contact- and reef-type PGE deposits in Finland.

considered thick enough to contain all the possible offset-type mineralisation. Since the offset type is included in the contact type assessment, the potentially mineralised domain may be up to 350 m thick, unless there is a tectonic repetition of the marginal series sequence. On the other hand, contact-type mineralisation is not expected to occur beyond the marginal series or in an intrusion where the marginal series is boninitic, contains Cr-rich units, and indicates peaceful intrusion conditions. For such intrusions (Akanvaara, Junttilanniemi, Kemi, Näränkävaara, Penikat, and Tornio), or parts of intrusions, a contact-type permissive tract was not delineated.

Reef-type PGE deposits are stratiform and occur in certain stratigraphic levels of intrusions (Cawthorn 2005, Mungall 2007, Mungall & Naldrett 2008). The known reef-type PGE occurrences in the Penikat, Akanvaara, and Koitelainen intrusions and Portimo complex are located within the layered series in the upper part of the intrusion at and above the contact between an earlier Cr-rich and a later Cr-poorer magma unit (Lahtinen et al. 1989). Reef-type mineralisation is also known from the layered series of the Western Intrusion of the Koillismaa Complex (Alapieti 1982, Karinen 2010), although this intrusion lacks the megacyclic structure. Hence, in the western part of the Tornio–Näränkävaara belt, and in the Akanvaara and Koitelainen intrusions, the permissive tracts were delineated within the layered series at and above the contact between earlier Cr-rich and later Cr-poor magma units. In the Western Intrusion of the Koillismaa Complex, the tracts were delineated by the extent of the layered series of the intrusion above the marginal series. The latter procedure was also applied for the poorly known Kaamajoki, Kärppäsuo, Koulumaoiva, and Peuratunturi intrusions. No tract was delineated in the area between the Näränkävaara intrusion and the Western Intrusion of the Koillismaa Complex. The tract was omitted because both gravity surveys and drilling indicate that the upper contact of the possibly existing connecting dyke between these intrusive bodies is deeper than one kilometre.

4.6 Estimation of the number of undiscovered deposits

The number of undiscovered contact- and reef-type PGE deposits for each permissive tract was estimated in a series of workshops by T. Halkoaho, M. Iljina and T. Karinen, all of whom have a long experience in research and exploration of PGE deposits in the areas covered by the permissive tracts. Each expert independently estimated the number of undiscovered deposits at the 90%, 50%, and 10% probability levels for each permissive tract. These initial figures were provided for discussion, during which the participants explained and gave reasons for their estimates, and sometimes adjusted them. The purpose of the discussion was to see whether a consensus estimate could be reached. When a consensus was not reached, the averages of the estimates at each probability level were used as the final estimates at the 90%, 50%, and 10% probability levels.

4.7 Assessment of metal tonnages

The assessment of metal tonnages in the undiscovered PGE deposits was performed using the Eminers software (Root et al. 1992, Duval 2004). The software uses as input the data of the grade-tonnage model and the estimated numbers of undiscovered deposits at the 90%, 50%, and 10% probability levels. The software estimates an average non-parametric frequency distribution for the number of undiscovered deposits within a tract. It also estimates empirical and lognormal frequency distributions for the ore tonnage and metal grades in the grade-tonnage model. It then uses these estimated frequency distributions in Monte Carlo simulation and produces frequency distributions of ore and metal tonnages in the undiscovered deposits. The empirical frequency distributions of ore tonnages and metal grades were used in the simulations for the Finnish contact- and reef-type tracts.

The assessment of metal tonnages in the undiscovered PGE deposits was performed separately for each permissive tract. Since it is not statistically correct to add together the frequency distributions of ore and metal tonnages produced for each tract, total metal endowments were estimated separately for all undiscovered contact- and reef-type deposits. Finally, the grand total values for all undiscovered PGE deposits in Finland were estimated.

5 RESULTS AND DISCUSSION

The results of the Finnish PGE assessment work are summarised in Figures 6 to 8 and in Tables 5 to 7. The results for individual permissive tracts are presented in Appendix 5.

The results of the Monte Carlo simulations of undiscovered metal endowment are frequency distributions of ore and metal tonnages in the undiscovered deposits. These distributions combine the amount of undiscovered metal and the probability that this amount exists (Figure 7). Details of this information for each permissive tract are given in Appendix 5, where cumulative frequency distributions of undiscovered metal and ore tonnages are plotted and tonnages corresponding to several probability values

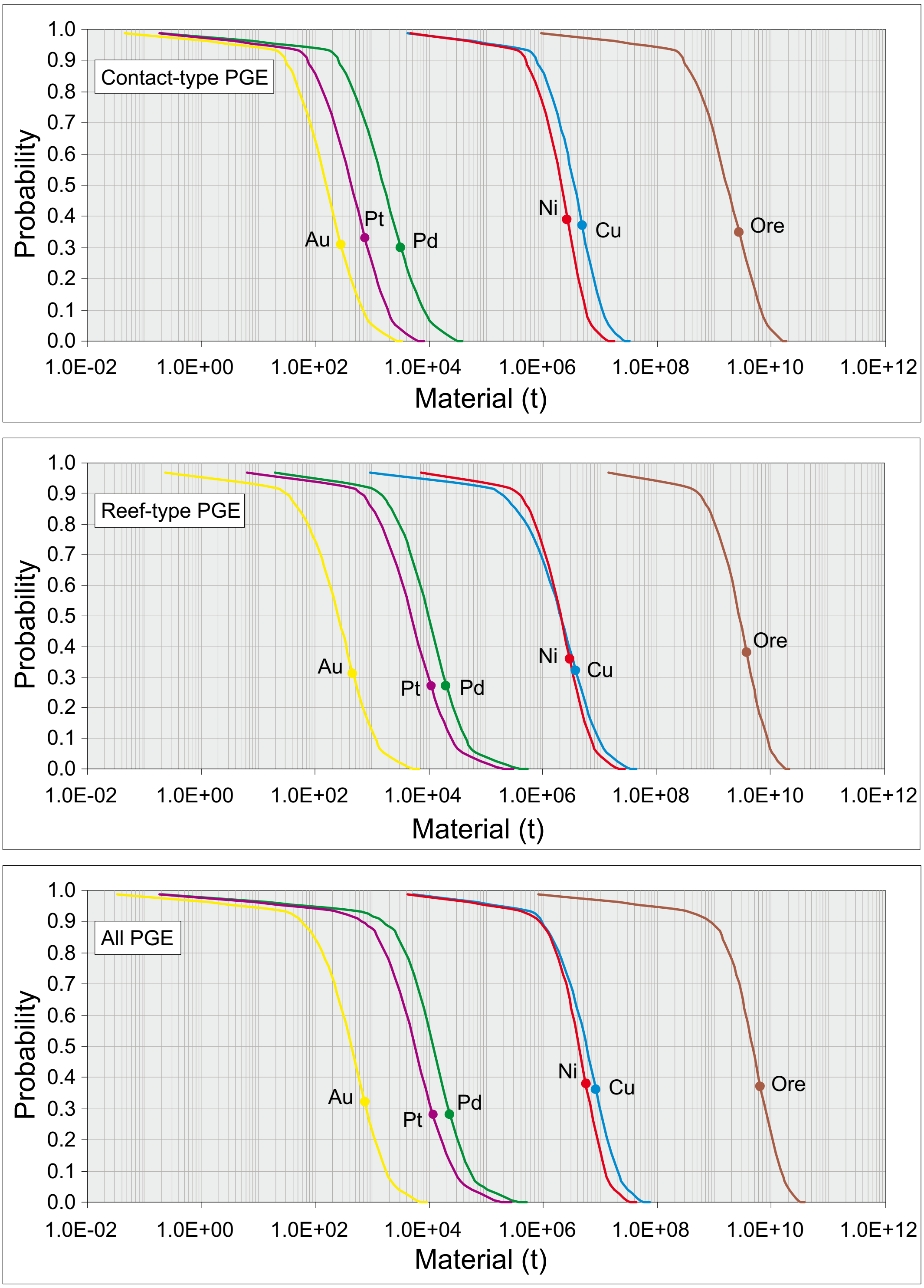

Figure 7. Cumulative frequency distributions of estimated metal and ore tonnages for undiscovered contact-type and reef-type PGE deposits, and for all undiscovered Finnish PGE deposits.

Table 5. Summary of principal results for permissive tracts of contact-type PGE deposits in Finland.

Tract name	Estimated number of undiscovered deposits						Number of known deposits	Total number of deposits	Known resources (t)						Median estimated undiscovered resources (t)						Total resources (t)					
	90	50	10	E	s	Cv			Pt	Pd	Au	Ni	Cu	Ore	Pt	Pd	Au	Ni	Cu	Ore	Pt	Pd	Au	Ni	Cu	Ore
HoikanvaaraContactPGE	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KaamajokiContactPGE	0	1	2	1.0	0.79	79	0	1.0	0	0	0	0	0	0	5	14	2	46,000	64,000	21,000,000	5	14	2	46,000	64,000	21,000,000
KärppäsuoContactPGE	1	1	2	1.2	0.55	45	0	1.2	0	0	0	0	0	0	10	35	4	77,000	110,000	42,000,000	10	35	4	77,000	110,000	42,000,000
KaukuaContactPGE	1	2	3	1.9	0.84	43	0	1.9	0	0	0	0	0	0	22	78	9	130,000	200,000	80,000,000	22	78	9	130,000	200,000	80,000,000
KoitelainenContactPGE	0	0	1	0.30	0.50	170	0	0.30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KonttijärviContactPGE	0	0	0	0	0		1	1	17	61	4.6	25,000	55,000	42,100,000	0	0	0	0	0	0	17	61	5	25,000	55,000	42,100,000
KoulumaoivaContactPGE	0	0	1	0.30	0.50	170	0	0.30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KuusijärviContactPGE	0	2	3	1.7	1.1	63	1	2.7	5.7	15	5.9	65,000	97,000	27,000,000	17	61	7	110,000	170,000	64,000,000	23	76	13	175,000	267,000	91,000,000
LipeävaaraContactPGE	0	1	2	1.0	0.79	79	0	1.0	0	0	0	0	0	0	5	14	2	45,000	64,000	21,000,000	5	14	2	45,000	64,000	21,000,000
MurtolampiContactPGE	0	0	1	0.30	0.50	170	0	0.30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NarkausContactPGE	7	9	11	8.5	1.8	21	0	8.5	0	0	0	0	0	0	200	770	70	750,000	1,400,000	740,000,000	200	770	70	750,000	1,400,000	740,000,000
PintamoContactPGE	1	2	3	1.9	0.84	43	0	1.9	0	0	0	0	0	0	22	83	9	130,000	210,000	79,000,000	22	83	9	130,000	210,000	79,000,000
PirivaaraContactPGE	0	1	1	0.70	0.41	58	0	0.70	0	0	0	0	0	0	2	6	1	23,000	30,000	9,000,000	2	6	1	23,000	30,000	9,000,000
PorttivaaraContactPGE	1	3	4	2.6	1.1	43	2	4.6	0.95	1.4	0.83	9,900	14,000	4,500,000	39	140	15	210,000	340,000	150,000,000	40	141	16	219,900	354,000	154,500,000
PyhitysContactPGE	0	0	1	0.30	0.50	170	0	0.30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RistijärviContactPGE	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SuhankoContactPGE	2	4	5	3.6	1.2	33	2	5.6	28	130	15	120,000	270,000	114,800,000	64	220	21	290,000	500,000	260,000,000	92	350	36	410,000	770,000	374,800,000
SyöteContactPGE	1	3	5	2.9	1.5	51	0	2.9	0	0	0	0	0	0	43	150	16	230,000	370,000	170,000,000	43	150	16	230,000	370,000	170,000,000
TilsaContatPGE	0	1	2	1.0	0.79	79	0	1.0	0	0	0	0	0	0	5	13	2	42,000	60,000	20,000,000	5	13	2	42,000	60,000	20,000,000
Total				29.2			6	35.2	52	207	26	219,900	436,000	188,400,000												
Average deposit									9	35	4	37,000	73,000	31,000,000	15	54	5	71,000	120,000	57,000,000	14	51	5	65,000	110,000	52,000,000

90, 50, 10 = Estimated number of undiscovered deposits associated with the 90%, 50%, and 10% quantiles.
E = Expected (mean) number of undiscovered deposits.
s = Standard deviation.
Cv = Coefficient of variation (%).
E and s are calculated using a regression equation (Singer & Menzie 2005).
Median estimated undiscovered resources represent the minimum amount of metals present at the probability of 50%, rounded to two significant digits.
Ore = Mineralized rock containing the metals.
Total = Total number of undiscovered and known deposits, total known resources rounded to full tonnes.
Average deposit = Arithmetic mean of metal tonnages in known, undiscovered, and all deposits. Rounded to two significant digits.

Table 6. Summary of principal results for permissive tracts of reef-type PGE deposits in Finland.

Tract name	Estimated number of undiscovered deposits						Number of known deposits	Total number of deposits	Known resources (t)						Median estimated undiscovered resources (t)						Total resources (t)					
	90	50	10	E	s	Cv			Pt	Pd	Au	Ni	Cu	Ore	Pt	Pd	Au	Ni	Cu	Ore	Pt	Pd	Au	Ni	Cu	Ore
AkanvaaraReefPGE	1	2	2	1.6	0.46	28	0	1.6	0	0	0	0	0	0	130	260	7	58,000	59,000	79,000,000	130	260	7	58,000	59,000	79,000,000
HoikanvaaraReefPGE	0	0	1	0.30	0.50	170	0	0.30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
JunttilanniemiReefPGE	0	0	1	0.30	0.50	170	0	0.30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KaamajokiReefPGE	0	1	1	0.70	0.41	58	0	0.70	0	0	0	0	0	0	14	32	1	7,300	5,000	11,000,000	14	32	1	7,300	5,000	11,000,000
KärppäsuoReefPGE	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KaukuaReefPGE	1	1	1	0.93	0.17	18	0	0.93	0	0	0	0	0	0	17	35	1	8,000	6,300	11,000,000	17	35	1	8,000	6,300	11,000,000
KemiReefPGE	0	1	2	1.0	0.79	79	0	1.0	0	0	0	0	0	0	69	140	4	34,000	26,000	49,000,000	69	140	4	34,000	26,000	49,000,000
KoitelainenReefPGE	1	2	3	1.9	0.84	43	0	1.9	0	0	0	0	0	0	2,700	5,300	140	1,100,000	1,100,000	1,500,000,000	2,700	5,300	140	1,100,000	1,100,000	1,500,000,000
KonttijarviReefPGE	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KoulumaoivaReefPGE	0	0	1	0.30	0.50	170	0	0.30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KuusijärviReefPGE	1	1	2	1.2	0.55	45	0	1.2	0	0	0	0	0	0	150	310	8	70,000	65,000	99,000,000	150	310	8	70,000	65,000	99,000,000
LipeävaaraReefPGE	1	1	1	0.93	0.17	18	0	0.93	0	0	0	0	0	0	16	34	1	7,700	6,000	11,000,000	16	34	1	7,700	6,000	11,000,000
MurtolampiReefPGE	0	0	1	0.30	0.50	170	0	0.30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NäränkävaaraReefPGE	0	1	2	1.0	0.79	79	0	1.0	0	0	0	0	0	0	81	170	4	40,000	32,000	57,000,000	81	170	4	40,000	32,000	57,000,000
NarkausReefPGE	1	2	2	1.6	0.46	28	0	1.6	0	0	0	0	0	0	120	240	6	50,000	51,000	70,000,000	120	240	6	50,000	51,000	70,000,000
PenikatReefPGE	3	3	4	3.1	0.65	21	0	3.1	0	0	0	0	0	0	660	1,300	34	250,000	290,000	340,000,000	660	1,300	34	250,000	290,000	340,000,000
PintamoReefPGE	1	1	1	0.93	0.17	18	0	0.93	0	0	0	0	0	0	120	250	7	59,000	50,000	83,000,000	120	250	7	59,000	50,000	83,000,000
PirivaaraReefPGE	0	0	1	0.30	0.50	170	0	0.30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PorttivaaraReefPGE	1	2	2	1.6	0.46	28	0	1.6	0	0	0	0	0	0	320	650	17	140,000	140,000	190,000,000	320	650	17	140,000	140,000	190,000,000
RistijärviReefPGE	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SuhankoReefPGE	2	2	2	1.9	0.22	12	0	1.9	0	0	0	0	0	0	240	470	13	100,000	100,000	140,000,000	240	470	13	100,000	100,000	140,000,000
SyöteReefPGE	1	2	2	1.6	0.46	28	0	1.6	0	0	0	0	0	0	380	760	20	160,000	160,000	220,000,000	380	760	20	160,000	160,000	220,000,000
TilsaReefPGE	0	0	1	0.30	0.50	170	0	0.30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TornioReefPGE	0	1	1	0.70	0.41	58	0	0.70	0	0	0	0	0	0	24	51	1	13,000	8,300	20,000,000	24	51	1	13,000	8,300	20,000,000
Total				22.5			0	22.5																		
Average deposit															220	450	12	93,000	93,000	130,000,000	220	450	12	93,000	93,000	130,000,000
Average deposit without Koitelainen															110	230	6	48,000	48,000	67,000,000	110	230	6	48,000	48,000	67,000,000

90, 50, 10 = Estimated number of undiscovered deposits associated with the 90%, 50%, and 10% quantiles.
E = Expected (mean) number of undiscovered deposits.
s = Standard deviation.
Cv = Coefficient of variation (%).
E and s are calculated using a regression equation (Singer & Menzie 2005).
Median estimated undiscovered resources represent the minimum amount of metals present at the probability of 50%, rounded to two significant digits.
Ore = Mineralized rock containing the metals.
Total = Total number of undiscovered and known deposits.
Average deposit = Arithmetic mean of metal tonnages in undiscovered deposits. Rounded to two significant digits.
Average deposit without Koitelainen = Arithmetic mean of metal tonnages in undiscovered deposits excluding Koitelainen. Rounded to two significant digits.

Table 7. Summary of estimated amounts of metal and ore for Finnish PGE deposits.

Contact-type PGE tracts

Material	At least the indicated amount at the probability of					Mean	Probability of	
	0.95	0.90	0.50	0.10	0.05		Mean or greater	None
Pt (t)	32	70	430	1,900	2,600	760	0.33	0.01
Pd (t)	110	240	1,600	8,100	12,000	3,200	0.30	0.01
Au (t)	13	28	160	690	1,000	280	0.31	0.01
Ni (t)	220,000	470,000	2,100,000	5,600,000	7,100,000	2,600,000	0.39	0.01
Cu (t)	340,000	730,000	3,500,000	11,000,000	14,000,000	4,800,000	0.37	0.01
Ore (Mt)	130	270	1,700	6,700	8,700	2,700	0.35	0.01

Reef-type PGE tracts

Material	At least the indicated amount at the probability of					Mean	Probability of	
	0.95	0.90	0.50	0.10	0.05		Mean or greater	None
Pt (t)	120	590	4,900	26,000	41,000	11,000	0.27	0.03
Pd (t)	250	1,300	9,700	44,000	70,000	20,000	0.27	0.03
Au (t)	6	29	260	1,100	1,600	470	0.31	0.03
Ni (t)	64,000	350,000	2,100,000	6,900,000	9,100,000	3,000,000	0.36	0.03
Cu (t)	33,000	170,000	2,100,000	9,500,000	14,000,000	3,800,000	0.32	0.03
Ore (Mt)	95	520	2,800	8,700	11,000	3,800	0.38	0.03

All PGE tracts

Material	At least the indicated amount at the probability of					Mean	Probability of	
	0.95	0.90	0.50	0.10	0.05		Mean or greater	None
Pt (t)	150	720	5,600	28,000	44,000	12,000	0.28	0.01
Pd (t)	360	1,700	12,000	53,000	81,000	23,000	0.28	0.01
Au (t)	19	59	430	1,800	2,500	740	0.32	0.01
Ni (t)	310,000	870,000	4,200,000	12,000,000	16,000,000	5,600,000	0.38	0.01
Cu (t)	410,000	910,000	5,700,000	20,000,000	27,000,000	8,500,000	0.36	0.01
Ore (Mt)	240	890	4,600	15,000	19,000	6,500	0.37	0.01

Ore = Mineralised rock containing the metals.

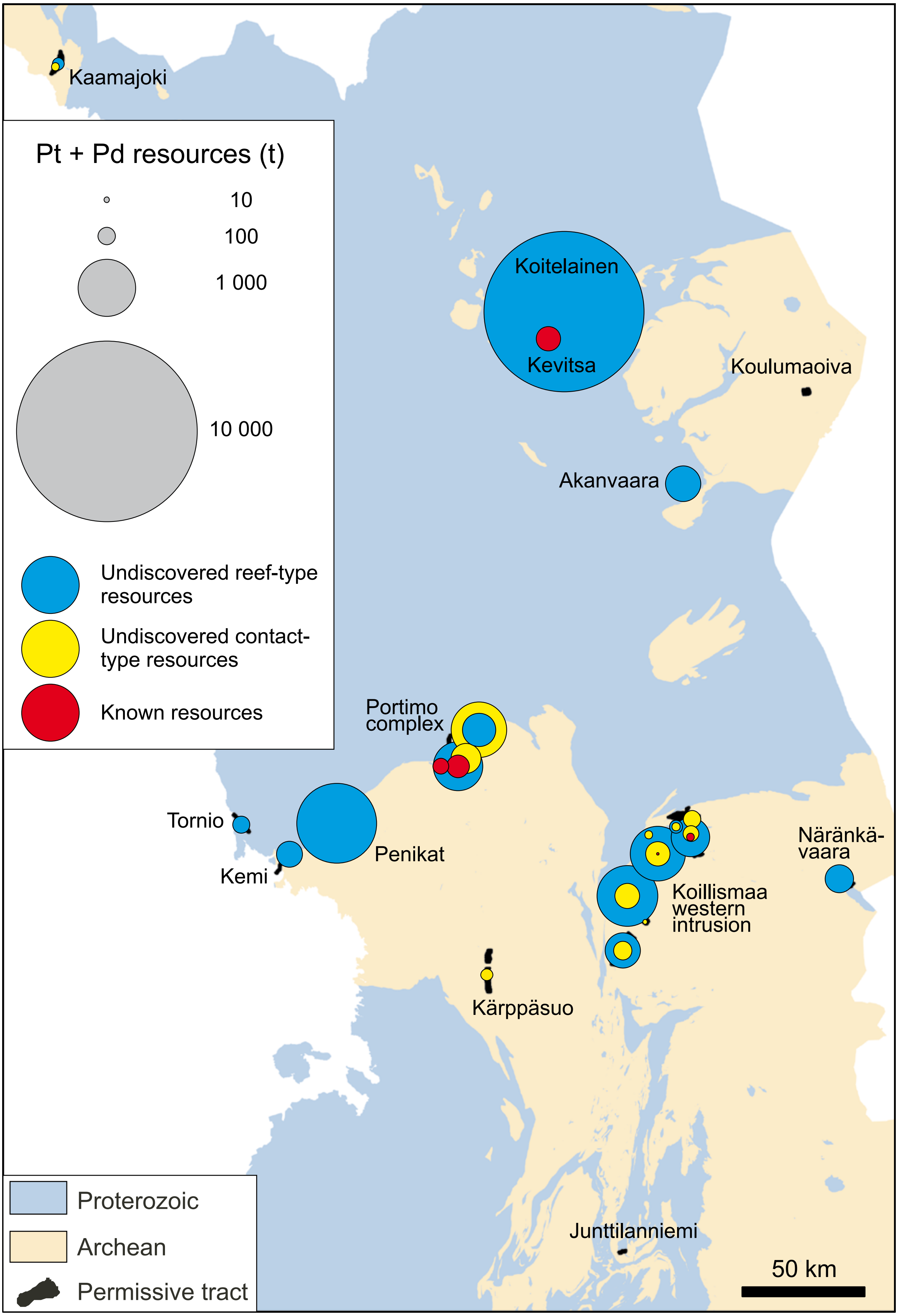

Figure 8. Known PGE resource in layered intrusions (Table 1) and Kevitsa, and the assessed undiscovered PGE endowment (Tables 3 and 4) in layered intrusions in Finland.

are tabulated. The arithmetic mean value of the frequency distribution for a metal can be considered as the expected amount of undiscovered metal. Since the frequency distributions of metal grades and tonnages in the grade-tonnage models are skewed and usually nearer to lognormal than normal distribution, the probabilities associated with the expected (mean) amounts of undiscovered metals and ore are less than 50%, generally around 30% for aggregated results and even less for individual permissive tracts. On the other hand, there is a 50% probability that at least the amount of undiscovered metal or ore given by the median (value associated with the 50% quantile) exists. This is why we prefer to report the median amount of undiscovered metal and ore in Tables 5 and 6, where results for individual permissive tracts are summarised. Table 7, which aggregates the total undiscovered PGE endowment over all contact- and reef-type tracts, and the grand total undiscovered PGE endowment in layered intrusions in Finland, gives several quantile values to better characterise the frequency distribution of undiscovered metal. In the following, median values, i.e., values corresponding to the 50% quantile of the cumulative frequency distribution of undiscovered metal, are used when discussing the amounts of undiscovered metals.

5.1 Permissive tracts delineated

In total, 19 contact-type and 24 reef-type permissive tracts for PGE deposits were delineated (Figure 6, Tables 5 and 6, Appendix 5). Together, these cover all the known 2.45 Ga layered intrusions and their immediate surroundings. The Akanvaara, Junttilanniemi, Kemi, Näränkävaara, Penikat, and Tornio intrusions have only a reef-type permissive tract. The other intrusions and intrusive blocks have both a reef-type and a contact-type tract, which partly or mostly overlap each other. Altogether, the tracts cover an area of approximately 1,300 km^2. This is only 0.4% of the total land area of Finland, which is 95% covered by Archaean and Palaeoproterozoic igneous and metamorphic bedrock (Koistinen et al. 2002). This is a rather extreme example of how the assessment method might be used in the initial phase of exploration to zoom into relevant areas.

5.2 2.45 Ga layered intrusion-hosted PGE resources in Finland

There are six known contact-type but no reef-type PGE deposits in Finland, defined following the same spatial rule as used for constructing the grade-tonnage model (Tables 5 and 6). We estimate that, to the depth of one kilometre, 29 contact-type and 23 reef-type deposits remain undiscovered in Finland. This means that only 17% of the existing contact-type deposits, or 10% of all PGE deposits, have been discovered to date.

Several reasons are possible for the lack of known reef-type deposits in Finland. The definition of a reef deposit as used here requires that the total tonnage of the whole reef is known. However, the existing resource estimates for all of the Finnish reef-type prospects only cover a portion of the reef. Further, reef-type mineralisation is more difficult to recognise and explore for than the more sulphide-rich contact-type mineralisation, which in Finland has been known and explored for as Ni-Cu sulphide mineralisation since the 1960s.

The size of the undiscovered PGE resources is even more striking when looking at the estimated metal contents of the undiscovered deposits. The six known contact-type deposits altogether contain 52 t Pt, 207 t Pd, 26 t Au, 0.22 Mt Ni, and 0.44 Mt Cu (Table 5). In contrast, the estimated total resources in the undiscovered contact- and reef-type deposits are 5,600 t Pt, 12,000 t Pd, 430 t Au, 4.2 Mt Ni, and 5.7 Mt Cu (Table 7). These figures indicate that about 98% of the total Finnish Pt+Pd+Au resources in layered intrusions in the uppermost 1 km of the present crust are in poorly explored and undiscovered deposits.

The total number of known and undiscovered contact-type deposits is larger than that of reef-type deposits. An average contact-type permissive tract contains two PGE deposits but an average reef-type tract contains only one PGE deposit (Tables 5 and 6). The likely cause of this is the relatively small stratigraphic thickness of most of the Finnish layered intrusions or intrusive blocks, which limits the number reefs that can exist. In contrast, stratigraphic thickness does not limit the occurrence of several contact-type deposits, which are controlled by the presence and extent of the marginal series rocks. Hence, even a rather small intrusive block may contain more than one contact-type deposit, as long as there is enough room for a more than one-kilometre distance between deposits. On the other hand, the metal content of a single reef deposit can be considerable, due to the dependence of reef area on intrusion size. In Finland, a prominent example of this is the Koitelainen intrusion with an average estimated tonnage of 1,100 Mt for a PGE-reef (Appendix 4). If the Koitelainen intrusion is left out, the average of estimated tonnages for undiscovered reef-type deposits is 67 Mt, which is 18% larger than the average of 57 Mt for undiscovered contact-type deposits (Tables 5 and 6).

Irrespective of the fact that the number of undiscovered contact-type deposits is larger, 88% of the estimated undiscovered Pt, 81% of Pd, 60% of Au, 50% of Ni, and 37% of Cu are contained in reef-type deposits (Table 7). The anomalously large estimated resources of the Koitelainen reef-type tract alone cover 48% of all undiscovered Pt, 44% of Pd, 33% of Au, 26% of Ni and 19% of Cu. However, if the Koitelainen reef-type tract is excluded, reef-type deposits are still estimated to contain 84% of all undiscovered Pt, 74% of Pd, 43% of Au, 32% of Ni and 22% of Cu. This reflects the markedly higher Pt and Pd concentrations and the lower Ni and Cu concentrations in the reef-type deposit model (Tables 1, 2 and 4).

Most of the known and estimated PGE resources in Finland, excluding Koitelainen, are in intrusions of the Tornio–Näränkävaara belt (Tables 5 and 6, Figure 8). The highest expected numbers of undiscovered deposits in a single intrusive body occur in two intrusions of the Portimo complex. The Narkaus and Suhanko intrusions are estimated to contain 10 and 6 undiscovered deposits, respectively. This makes up about one third of the number of all undiscovered PGE deposits. These two intrusions also contain two of the six known deposits. However, since most of the undiscovered deposits estimated to exist within the Portimo complex are of the contact-type, they only contain 11% of the Pt, 14% of the Pd and 26% of the Au, but 29% of the Ni and 35% of the Cu in the estimated total undiscovered metal endowment of layered intrusions in Finland.

The Western Intrusion of the Koillismaa Complex contains a significant PGE endowment in a relatively small area (Figure 8). This includes the tracts of Hoikanvaara, Kaukua, Kuusijärvi, Lipeävaara, Murtolampi, Pintamo, Pirivaara, Porttivaara, Pyhitys, Ristijärvi, Syöte and Tilsa (Figure 6, Tables 5 and 6). These tracts contain 44% of all the predicted undiscovered deposits and three of the known deposits. Their total estimated metal contents are 1,100 t Pt, 2,500 t Pd, 110 t Au, 1.4 Mt Ni, and 1.9 Mt Cu, which translates to 20% of the Pt, 21% of the Pd, 26% of the Au, 33% of the Ni and 33% of Cu in the undiscovered PGE deposits in Finland.

The largest estimated concentration of undiscovered PGE resources in Finland is associated with the Koitelainen intrusion, located in the Central Lapland greenstone belt adjacent to the Kevitsa intrusion (Figure 8). Although Kevitsa and Koitelainen occur next to each other, the age difference of about 400 Ma and the different characteristics of the Kevitsa deposit (Mutanen 1997) set the latter apart from all the Finnish contact- and reef-type PGE deposits. The amount of *in situ* contained PGE at Kevitsa, to the depth of 730 m and at a 0.1% Ni cut-off, have been estimated to be 30 t of Pd and 39 t of Pt (First Quantum Minerals Ltd. 2009). This represents 21% of the total known Pt+Pd resources in Finland. The estimated resources of undiscovered Pt+Pd for the adjacent Koitelainen intrusion are 8,000 t. Taken together, the known PGE resources of Kevitsa and the estimated undiscovered resources of Koitelainen suggest that the most significant PGE concentration beyond the Tornio–Näränkävaara belt might be associated with these two intrusions.

5.3 Finnish PGE endowment in the global context

The majority of global PGE production and known PGE resources are restricted to two countries. Of all PGE produced in 2008, South Africa's share was 77% of Pt and 39% Pd, and that of Russia 13% of Pt and 43% of Pd (US Geological Survey 2009). Most of the rest was produced by Canada, the USA and Zimbabwe. The known remaining global PGE resources are estimated to total more than 100,000 t, and 70% of these are in South Africa.

The presently known Finnish PGE resources are less than one percent of the known global resources. The median of the total undiscovered Pt+Pd resources estimated here for Finland is about 18% of the global resources. The known world PGE resources and the estimated undiscovered PGE resources in Finland are based on entirely different kinds of information and are not directly comparable. However, these figures indicate that the discovery of even a part of the unknown PGE resources of Finland could have a notable effect on the global PGE resources. Within Europe, the effect would be outstanding, as the European Union presently imports nearly 90% of the approximately 120 tonnes of PGE annually used by its industries (Johnson Matthey 2009).

5.4 Reliability and usability of the estimates

Sensitivity analysis shows that changes in grade and tonnage estimates have a much larger influence in the expected metal content in an assessment than changes in the expected number of deposits (Singer & Kouda 1999). Consequently, the greatest sources of possible error in the present assessment are associated with the grade-tonnage model used for the contact-type deposits, the tonnage estimates for the reefs, and the general grade model used for the reef-type deposits.

The grade-tonnage model data used in the assessment of contact-type deposits are based on deposits, none of which have been exploited at more than a test-mine scale. Excluding Ahmavaara, Konttijärvi, and Haukiaho, the resource estimates of the contact-type deposits are rather old and, in cases, based on scarce data (Lahtinen 1983, 1991). According to the grade-tonnage model used, the median size of a known Fennoscandian contact-type PGE deposit is 35 Mt of ore, whereas the median tonnage within the global data set is 140 Mt (Table 2). It is noteworthy that the tonnages of the three recently studied Fennoscandian deposits (Ahmavaara, Konttijärvi, Fedorovo) are among the four highest in the Fennoscandian model (Table 1) and cover almost exactly the interquartile range (38.4 Mt – 406 Mt) of the global data. Using the global contact-type grade-tonnage data as a model, the estimated total tonnage of undiscovered contact-type PGE resources in Finland would be 4,400 Mt of ore, which is 2.6 times higher than the 1,700 Mt acquired using the Fennoscandian grade-tonnage model (Table 7). For the contact-type deposits, the estimate based on the Fennoscandian grade-tonnage model can be regarded as conservative. However, the number of deposits in the model is small, and when more grade-tonnage data from well-delineated contact-type PGE deposits in Finland become available, the estimates given here should be re-evaluated

The estimated tonnages of undiscovered deposits are probably the most important sources of potential error for the reef-type assessment results. For each permissive tract, the tonnage of a possibly existing, undiscovered reef was estimated by Monte Carlo simulation as the product of reef area, reef thickness, reef density and geological loss, whereas the general grade model for the reef-type deposits was constructed using data from Finnish reefs (see Appendix 4 for details).

The frequency distribution of reef thickness used to estimate the reef tonnages, and the frequency distributions of metal grades used to construct the general grade model for Finnish reef-type deposits, are based on drill core data from the SK and SJ reefs. The number of available samples is large enough to model the frequency distributions of reef thickness and metal grades reliably (Tables 3 and 4). Although no reef-type deposits, as defined in this work, are known from Finland, the SJ and SK reefs have the potential to contain world-class resources (Iljina & Hanski 2005). Consequently, we consider that the metal grade and thickness frequency distributions estimated from the data adequately represent undiscovered Finnish reef-type PGE deposits. Nevertheless, these models should be re-evaluated as new reliable data from other reefs in Finland become available.

The density data used to model reef tonnages are rather scarce (Table 3). On the other hand, the range of density values for reefs is limited. This is why a possible error in the estimated density can only have a minor effect on the estimated reef tonnages, probably in the range of a few per cent.

Since no geological loss data were available for Finnish reef deposits, the loss model was based on data from 28 deposits or prospects from the Bushveld intrusion (Table 3, Appendix 4). Although the number of samples is adequate to produce a reliable model for the frequency distribution of the geological loss, the model is based on foreign deposits and its validity for Finnish reefs remains unconfirmed. Its use here is justified by the general similarity between the reefs in the Finnish layered intrusions and the Bushveld complex (Alapieti & Lahtinen 1986, Karinen 2010), but it remains the most probable source of systematic error in the assessment results.

The reef area was calculated using geological maps and GIS software. The accuracy of the geological maps was considered good, in the range of 100–200 m, due to the rather extensive exploration and research on the layered intrusions hosting PGE deposits in Finland. The error caused to the calculated reef area by map inaccuracy is insignificant compared with the error possibly caused when approximating the reef by a simple geometrical shape. Our subjective estimate is that this approximation caused an error of up to ±30% in the calculated reef area, and hence in the simulated reef tonnage, depending on the complexity of the shape of the intrusive body in question. This means that the assessed tonnages of undiscovered metals for individual reef-type permissive tracts might be up to one third too large or too small. However, in the aggregate results (Figure 7 and Table 7), part of these errors is probably cancelled out.

Overall, one must always be careful when using the results of assessments such as this. Although the method predicts the existence of a number of undiscovered deposits, it gives no guarantee that these deposits will ever be discovered. Many of the undiscovered deposits estimated to exist by this work are probably under hundreds of metres of barren rock, whereas others may crop out at the surface. Some of the buried deposits are likely to be beyond the reach of present day exploration technology, or their discovery may require exploration expenditures so large they are unlikely to be discovered in the near future. Although technological advances act over time to lower mining costs and allow formerly uneconomic occurrences to become operating mines, some of the undiscovered deposits estimated here might never be mined for one or more reasons, including relatively low tonnages or grades, deep burial, occurrence in or near environmentally sensitive areas, or occurrence in areas designated for other land uses than mining.

6 SUMMARY

Experts in layered intrusion-hosted PGE deposits and in metallogeny and geostatistics at the Geological Survey of Finland produced this assessment of undiscovered PGE resources within the uppermost one kilometre of Finnish bedrock. The assessment was performed using a three-part quantitative method developed in the U.S. Geological Survey and focused on layered intrusion-hosted contact- and reef-type PGE mineralisation styles.

This report provides numerical estimates of the expected endowment of Pt, Pd, Au, Ni, and Cu in undiscovered, potentially exploitable deposits. The main results are as follows:

1. The three-part quantitative assessment method developed by the USGS is suitable for assessing contact-type PGE deposits, but needs to be modified for use in assessing reef-type deposits.
2. Nearly all PGE resources in Finland are in contact- and reef-type deposits in ca. 2.45 Ga mafic-ultramafic layered intrusions. The Kevitsa deposit in northern Finland forms the sole major exception to this rule, as it is hosted by a ca. 2.06 Ga intrusion and its characteristics do not fit into any of the previously defined deposit categories.
3. A traditional grade-tonnage model can be used to estimate grade and tonnage variation in contact-type PGE deposits. The grades and tonnages of well-studied contact-type PGE deposits in the Fennoscandian Shield significantly deviate from global data. A grade-tonnage model for the Fennoscandian deposits was formed using data from six known and well-studied contact-type PGE deposits from Finland and two from Russia.
4. The size of the host intrusion is one of the most significant factors in controlling the size of a reef-type deposit. A reef tonnage model was constructed for each permissive tract and a general grade model was constructed for reef-type deposits, based on grade data from Finnish PGE reefs.
5. There are 19 contact-type and 24 reef-type permissive tracts for PGE deposits in Finland. They cover an area of 1,300 km^2, which is only 0.4% of the total land area of the country.
6. The permissive tracts were defined by the presence of 2.45 Ga layered intrusions. Along the Archaean–Proterozoic boundary, there might be such intrusions completely under bedrock cover. The PGE endowment contained by such intrusions remains unassessed. However, no direct or indirect indications were found of concealed intrusions, or of PGE enrichment beyond the tracts drawn.
7. The expected number of undiscovered contact-type PGE deposits within the permissive tracts is 29 and that of undiscovered reef-type deposits is 23.
8. The median metal endowment in undiscovered contact- and reef-type deposits in Finland is 5,600 t Pt and 12,000 t Pd. Reef-type deposits contain 88% of the Pt and 81% of the Pd in the undiscovered resources. Both contact- and reef-type deposits contain potentially significant concentrations of nickel, copper and gold. The base-metal values are typically higher in the former type, whereas gold grades are roughly similar in both types.
9. About 98% of the PGE endowment in Finland occurs in poorly explored and undiscovered deposits.
10. Most of the undiscovered deposits are hosted by the intrusions of the Tornio–Näränkävaara belt. The Suhanko and Narkaus intrusions of the Portimo complex host a third of the number of undiscovered deposits, but only 11% of the total undiscovered Pt and 14% of the total undiscovered Pd endowment in layered intrusions. The Western Intrusion of the Koillismaa Complex contains 44% of the number of undiscovered deposits and 21% of the Pt and 22% of the Pd in the undiscovered deposits. The Koitelainen intrusion alone contains 48% of all undiscovered Pt and 44% of all undiscovered Pd.
11. The PGE endowment estimated for Finland at the 50% probability level comprises 18% of the presently known global resources.
12. The assessed metal tonnages for the individual permissive tracts may be up to 30% too small or too large. Part of these errors is probably cancelled out in the summary results. The geological loss estimate is the most probable source of systematic error in the summary results.

ACKNOWLEDGMENTS

The work reported here would not have been possible without the information transfer from Michael Zientek and Mark Mihalasky from the USGS Global Mineral Resource Assessment Project. Discussions with Michael and Mark helped us to understand the three-part assessment method. Michael is also thanked for making available the grade, tonnage, reef thickness and geological loss data for contact- and reef-type PGE deposits being compiled at the USGS. We thank many of our colleagues at the GTK for providing data and insight into details of the geology of various layered intrusions.

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APPENDIX 1

DESCRIPTIVE MODEL FOR FENNOSCANDIAN CONTACT-TYPE PGE DEPOSITS

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APPROXIMATE SYNONYMS Duluth Cu-Ni-PGE

DESCRIPTION Disseminated and massive sulphides with PGE within 200 m of the basal contact of ca. 2.44 Ga mafic-ultramafic layered intrusions located near the contact zone between Archaean and Palaeoproterozoic rocks. This model also includes offset-type mineralization within 200 m of the intrusion contact.

EXAMPLES

Ahmavaara, Finland	(Purich et al. 2007)
Haukiaho, Finland	(Iljina et al. 2005)
Fedorovo, Russia	(Schissel et al. 2002)

GEOLOGICAL ENVIRONMENT
Rock Types Gabbro, norite, gabbronorite, pyroxenite, peridotite, troctolite, and anorthosite forming layered mafic-ultramafic intrusions. Associated with sulphur-bearing supracrustal rocks.
Textures Phase and cryptic layering sometimes present, rocks usually cumulates. The existence of a well developed marginal series – gabbronorites, pyroxenites, and peridotites – displaying reverse fractionation is characteristic of intrusions hosting contact-type PGE deposits. The most promising deposits are associated with a marginal series that is more than 50 m thick.
Age Range Palaeoproterozoic.
Depositional Environment Intruded during initial stage of continental rifting into cratonic gneisses and metasedimentary and metavolcanic rocks.
Tectonic Setting(s) Rift environment.
Associated Deposit Types Reef-type PGE, stratiform Cr, stratiform mafic-ultramafic Fe-Ti-V, stratiform mafic-ultramafic Ni-Cu, disseminated mafic-ultramafic Ni-Cu.

DEPOSIT DESCRIPTION
Mineralogy Pyrrhotite + chalcopyrite + pentlandite + PGE minerals ± pyrite.
Texture/Structure Disseminated and massive sulphides. Syn- and post-mineralisation deformation.
Ore Control Sulphides are commonly within the marginal series near the basal contact of the intrusion or sometimes in country rocks within 200 m of the contact. Morphology of the basal contact may control the placement of sulphides; they do not occur in places where the contact dips steeply.
Weathering Not present in Fennoscandian deposits.
Geochemical Signature Ni, Cu, PGE.

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APPENDIX 2

GRADE-TONNAGE MODEL FOR FENOSCANDIAN CONTACT-TYPE PGE DEPOSITS

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INTRODUCTION

This model contains data from 10 contact-type PGE deposits within the Fennoscandian Shield (Table 1). A spatial rule has been applied, according to which deposits nearer than 1,000 m to each other have been combined. Summary statistics for ore tonnage and metal grades are given in Table 2 and probability plots are shown in Figure 1. Statistical tests reported here indicate that the ore tonnage and metal grade data follow a lognormal distribution.

DATA

Table 1. Metal grade and ore tonnage data for Fennoscandian contact-type PGE deposits.

Deposit	Country	Tonnage (Mt)	Ni (%)	Cu (%)	Pt (g/t)	Pd (g/t)	Au (g/t)
Fedorova	Russia	414.8	0.09	0.15	0.311	0.933	0.084
Ahmavaara-Suhanko	Finland	107.7	0.09	0.23	0.245	1.163	0.138
General’skaya	Russia	53.37	0.27	0.46	0.200	2.050	0.030
Konttijärvi	Finland	42.17	0.06	0.13	0.408	1.436	0.106
Haukiaho	Finland	27	0.24	0.36	0.209	0.549	0.216
Vaaralampi-Niittylampi	Finland	7.1	0.37	0.24	0.210	0.569	0.053
Lavotta	Finland	3.0	0.21	0.26	0.180	0.260	0.200
Rusamo	Finland	1.5	0.24	0.39	0.266	0.384	0.150

Data sources: Konttijärvi, Ahmavaara (Puritch et al. 2007); Suhanko, Vaaralampi, Niittylampi (Lahtinen 1991); Haukiaho (Iljina et al. 2005); Lavotta, Rusamo (Lahtinen 1983); Fedorova tonnes, Pd, Pt (Barrick 2009), Au, Cu, Ni (Schissel et al. 2002); Generalskaya (Fennoscandian ore deposit database 2009).

STATISTICS

Table 2. Summary statistics for Fennoscandian contact-type PGE deposit data in Table 1.

	Tonnage	Ni	Cu	Pt	Pd	Au
Minimum	1.5	0.06	0.13	0.180	0.260	0.030
Maximum	414.8	0.37	0.46	0.408	2.050	0.216
Median	35	0.23	0.25	0.228	0.751	0.122
Arithmetic mean	82	0.20	0.28	0.254	0.918	0.122
Standard deviation	140	0.11	0.12	0.075	0.608	0.066

Median, mean, and standard deviation have been rounded to two significant digits for tonnage, Ni, and Cu and to three significant digits for Pt, Pd, and Au.

PROBABILITY PLOTS

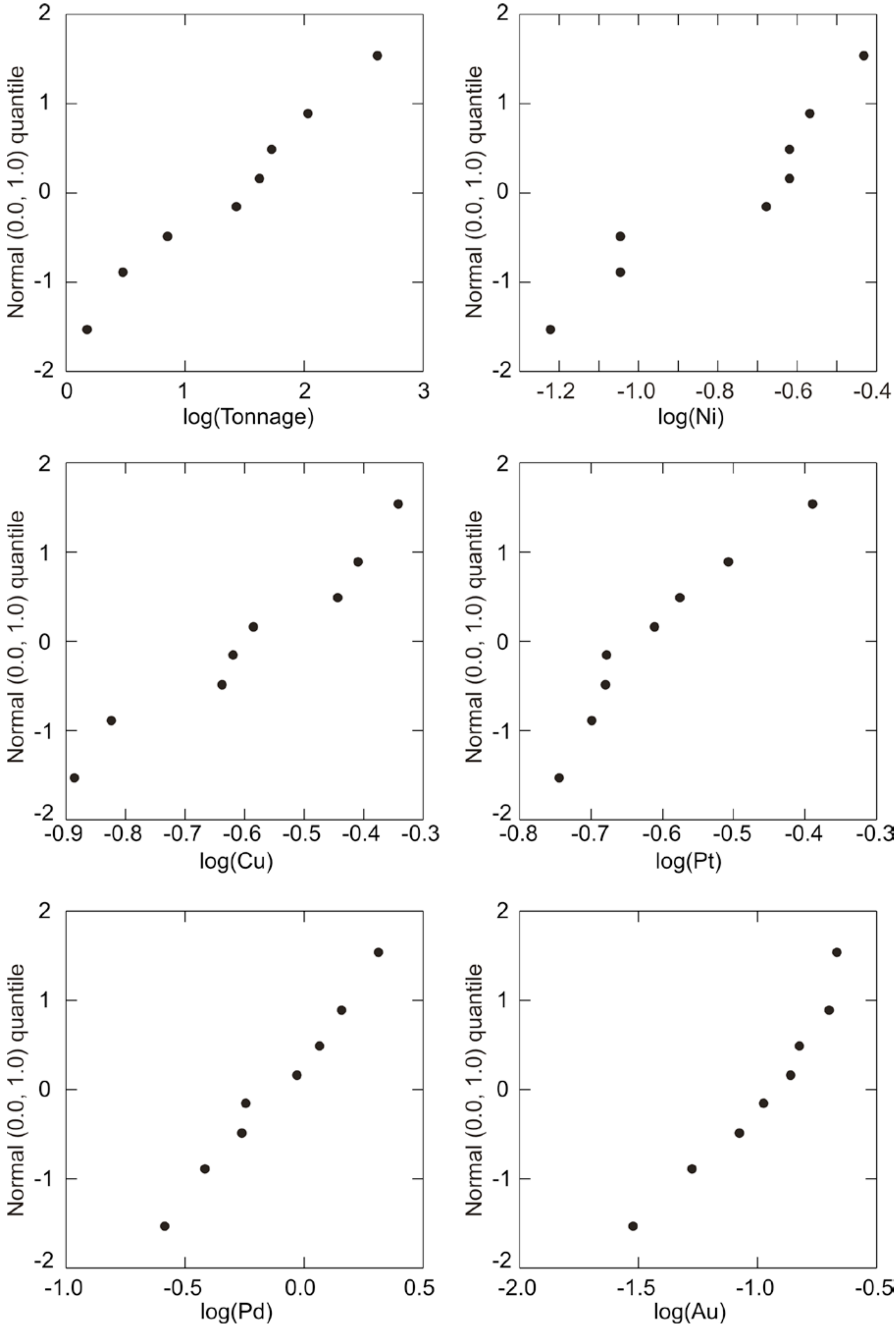

Figure 1. Normal probability plots of base-10 logarithms of metal grades and ore tonnage for the Fennoscandian contact-type PGE deposits in Table 1.

TESTS OF LOGNORMALITY

Variable Name : LOG_TONNES
Distribution : Normal

Estimated Parameter(s)
Location or Mean(mu) : 1.36707
Scale or SD(sigma) : 0.76516
Estimation of Parameter(s): Maximum Likelihood Method

Test Results
WARNING Chi-square test results may not be good for this sample size.
Kolmogorov-Smirnov Test Statistic : 0.15848
Lilliefors Probability : 1.00000

Shapiro-Wilk Test Statistic : 0.97194
p-value : 0.91279

Hypothesis of normality of LOG_TONNES not rejected

Variable Name : LOG_NI
Distribution : Normal

Estimated Parameter(s)
Location or Mean(mu) : –0.77889
Scale or SD(sigma) : 0.26556
Estimation of Parameter(s): Maximum Likelihood Method

Test Results
WARNING Chi-square test results may not be good for this sample size.
Kolmogorov-Smirnov Test Statistic : 0.27331
Lilliefors Probability : 0.07997

Shapiro-Wilk Test Statistic : 0.88550
p-value : 0.21240

Hypothesis of normality of LOG_NI not rejected

Variable Name : LOG_CU
Distribution : Normal

Estimated Parameter(s)
Location or Mean(mu) : –0.59346
Scale or SD(sigma) : 0.18070
Estimation of Parameter(s): Maximum Likelihood Method

Test Results
WARNING Chi-square test results may not be good for this sample size.
Kolmogorov-Smirnov Test Statistic : 0.17139
Lilliefors Probability : 0.90271

Shapiro-Wilk Test Statistic : 0.94369
p-value : 0.64771

Hypothesis of normality of LOG_CU not rejected

Variable Name : LOG_PT
Distribution : Normal

Estimated Parameter(s)
Location or Mean(mu) : –0.61048
Scale or SD(sigma) : 0.10955
Estimation of Parameter(s): Maximum Likelihood Method

Test Results
WARNING Chi-square test results may not be good for this sample size.
Kolmogorov-Smirnov Test Statistic : 0.23050
Lilliefors Probability : 0.26802

Shapiro-Wilk Test Statistic : 0.92372
p-value : 0.46075

Hypothesis of normality of LOG_PT not rejected

Variable Name : LOG_PD
Distribution : Normal

Estimated Parameter(s)
Location or Mean(mu) : –0.12521
Scale or SD(sigma) : 0.28384
Estimation of Parameter(s): Maximum Likelihood Method

Test Results
WARNING Chi-square test results may not be good for this sample size.
Kolmogorov-Smirnov Test Statistic : 0.16336
Lilliefors Probability : 1.00000

Shapiro-Wilk Test Statistic : 0.97572
p-value : 0.93873

Hypothesis of normality of LOG_PD not rejected

Variable Name : LOG_AU
Distribution : Normal

Estimated Parameter(s)
Location or Mean(mu) : –0.98720
Scale or SD(sigma) : 0.27558
Estimation of Parameter(s): Maximum Likelihood Method

Test Results
WARNING Chi-square test results may not be good for this sample size.
Kolmogorov-Smirnov Test Statistic : 0.17764
Lilliefors Probability : 0.81398

Shapiro-Wilk Test Statistic : 0.93015
p-value : 0.51743

Hypothesis of normality of LOG_AU not rejected

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APPENDIX 3

DESCRIPTIVE MODEL FOR FENNOSCANDIAN REEF-TYPE PGE DEPOSITS

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APPROXIMATE SYNONYMS Merensky Reef PGE

DESCRIPTION Stratiform disseminated PGE minerals with or without sulphides or chromite within the layered series of ca. 2.44 Ga mafic-ultramafic layered intrusions located near the contact zone between Archaean and Palaeoproterozoic rocks.

EXAMPLES

Sompujärvi reef, Ala-Penikka reef, Finland	(Halkoaho 1993)
Siika-Kämä reef, Finland	(Iljina 1994)

GEOLOGICAL ENVIRONMENT
Rock Types Gabbro, norite, gabbronorite, pyroxenite, peridotite, troctolite, and anorthosite forming layered mafic-ultramafic intrusions.
Textures Rhythmic and cryptic layering sometimes present, cumulate textures. Repetition of ultramafic and mafic rock sequences that constitute megacyclic units.
Age Range Palaeoproterozoic.
Depositional Environment Intruded during initial stage of continental rifting into cratonic gneisses and metasedimentary and metavolcanic rocks.
Tectonic Setting(s) Rift environment.
Associated Deposit Types Contact-type PGE, stratiform Cr, stratiform mafic-ultramafic Fe-Ti-V, stratiform mafic-ultramafic Ni-Cu.

DEPOSIT DESCRIPTION
Mineralogy PGE minerals ± chromite ± pyrrhotite ± chalcopyrite ± pentlandite ± pyrite.
Texture/Structure PGE minerals with or without disseminated sulphides or chromite.
Ore Control Contact zones of megacyclic units or disturbances inside megacyclic units.
Weathering Not present in Fennoscandian deposits.
Geochemical Signature PGE, Cr, Ni, Cu.

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APPENDIX 4

GRADE AND TONNAGE MODELS FOR FINNISH REEF-TYPE PGE DEPOSITS

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INTRODUCTION

Very little published information is available on ore tonnages for whole reef-type PGE deposits and further, ore tonnage is strongly dependent on the size of the host intrusion. Hence, it was not possible to create a general grade-tonnage model for Finnish reef-type deposits. Instead, a tonnage model for possibly existing reefs was created individually for each permissive tract and a general grade model was created for Finnish reef-type deposits. For each permissive tract, the tonnage model and the general grade model were then combined to produce a grade-tonnage model for the tract.

GRADE MODEL FOR FINNISH REEF-TYPE DEPOSITS

Data from the SJ (Halkoaho, unpublished data) and SK (North American Palladium Ltd. 2006, 2007) reefs from the Penikat layered intrusion were used to construct a general grade model for Finnish reef deposits. Due to the requirements of the Eminers software (Root et al. 1992, Duval 2004) used in the final stage of the assessment, a subset of 26 values was picked for each element from its grade frequency distribution at regular intervals. The smallest and largest values of the subset were then adjusted so that the mean of the subset was as near as possible to the mean of the original data (Table 1). This 26-sample subset was used as the empirical frequency distribution for the metal in question. The 26-sample data were input to the Eminers software as the empirical frequency distribution by editing the empirical distribution model file. Dependencies between metal grades estimated by Eminers were left unchanged. Summary statistics for the original data and the empirical distribution functions are given in Table 1. Cumulative distribution data for the empirical functions are given in Table 2 and compared with the original grade data in Figure 1.

Table 1. Summary statistics for diamond drill hole data from SJ and SK reefs and for the empirical distribution functions estimated from the data. Results of statistical tests for normality of data are also shown. The statistical tests were run on base-10 logarithmic values of the metal grade data.

	Pt (g/t)	Pd (g/t)	Au (g/t)	Ni (%)	Cu (%)
Original data					
N of cases	325	325	325	57	85
Median	1.4	3.2	0.10	0.07	0.07
Arithmetic mean	3.4	6.5	0.14	0.09	0.11
Standard deviation	6.9	14	0.16	0.08	0.12
Minimum	0.01	0.03	0.002	0.02	0.0004
Maximum	76.4	173.3	1.5	0.60	0.74
K-S test statistic	0.074	0.083	0.069	0.099	0.130
p-value	0.000	0.000	0.001	0.171	0.001
Empirical distribution functions					
N of cases	26	26	26	26	26
Median	1.4	3.1	0.10	0.07	0.07
Arithmetic mean	3.4	6.4	0.13	0.08	0.10
Standard deviation	5.7	10	0.14	0.04	0.09
Minimum	0.22	0.67	0.01	0.035	0.001
Maximum	27.5	51	0.60	0.20	0.35
K-S test statistic	0.092	0.097	0.085	0.087	0.138
p-value	0.906	0.819	1.000	1.000	0.228

K-S test statistic: Kolmogorov-Smirnov test statistic for normality (log-10 transformed data).
p-value: Statistical significance of the test statistic.
Median, mean, and standard deviation have been rounded to two significant digits.
Data source: Halkoaho (unpublished data), North American Palladium Ltd. (2006, 2007).

Table 2. Empirical cumulative distribution functions for grade data from SJ and SK reefs.

Ni (%)	Cu (%)	Pt (g/t)	Pd (g/t)	Au (g/t)
0.035	0.001	0.218	0.668	0.010
0.037	0.005	0.371	0.911	0.013
0.038	0.009	0.480	1.113	0.020
0.041	0.012	0.608	1.359	0.025
0.048	0.017	0.659	1.522	0.029
0.049	0.022	0.725	1.679	0.034
0.049	0.030	0.842	1.810	0.041
0.052	0.032	0.901	2.029	0.047
0.054	0.042	0.992	2.240	0.056
0.062	0.045	1.058	2.452	0.064
0.068	0.048	1.168	2.688	0.074
0.070	0.051	1.213	2.825	0.084
0.072	0.063	1.340	2.997	0.095
0.073	0.078	1.503	3.251	0.100
0.076	0.091	1.655	3.450	0.106
0.081	0.121	1.839	3.749	0.115
0.083	0.127	2.028	4.054	0.127
0.085	0.142	2.336	4.471	0.139
0.087	0.148	2.783	5.081	0.151
0.090	0.175	3.258	5.600	0.168
0.097	0.189	4.103	6.200	0.189
0.112	0.196	5.081	7.374	0.212
0.123	0.214	6.014	9.416	0.270
0.137	0.235	7.975	14.585	0.315
0.165	0.242	12.690	23.012	0.419
0.202	0.352	27.503	51.000	0.600

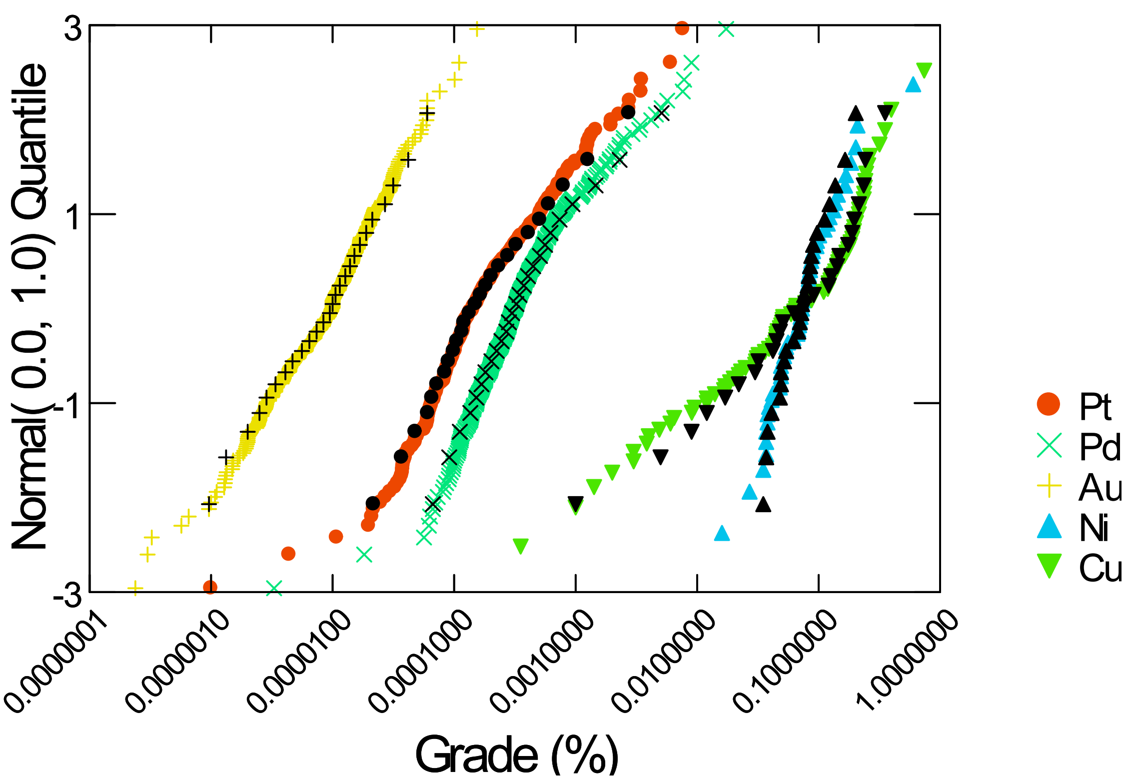

Figure 1. Probability plots for the original data from SJ and SK reefs (coloured symbols) and for the fitted empirical cumulative distributions in Table 2 (black symbols).

TONNAGE MODELS FOR PERMISSIVE TRACTS

For each permissive tract, the tonnage of a possibly existing, undiscovered reef-type deposit was estimated by Monte Carlo simulation using Systat software (Systat 2007). The procedure consisted of repeatedly estimating the equation:

(1) Reef tonnage = length * width * thickness * density * geological loss

where length, width, thickness, density, and geological loss refer to properties of the undiscovered reef.

Depending on the shape of the intrusive body in question, the permissive tract and the undiscovered reef were approximated by one or more simple geometrical forms such as a rectangle, parallelogram, or trapezoid. For each round of estimation of equation (1), reef length along the strike of igneous layering was allowed to vary randomly between minimum and maximum values dictated by the geometrical shape used to approximate the permissive tract. These minimum and maximum possible lengths of the reef were measured on the bedrock map using ArcMAP software (Esri 2009). Reef width was calculated along the dip of igneous layering using the dip angle and simple geometrical relations. Reef width was calculated down to the vertical depth of 1 km unless there was clear evidence that the host intrusion does not extend to that depth. In those cases, the maximum depth of the intrusion was used instead.

Dip angle

For most reef-type tracts, the only dip information available is the average dip of igneous layering in the layered intrusion. In these cases, the dip was estimated by a uniform distribution spanning ±10 degrees around the average dip at 5 degree steps. For the Penikat intrusion, where more dip information was available, a step function was constructed to describe the variability of dip (dip cannot readily be described by a standard distribution). In the step function, the probability of each dip value was based on the frequency with which the dip value was reported.

Reef thickness

Reef thickness variation was estimated using data (376 drill core samples) from the SJ and SK reefs (Halkoaho, unpublished data). Summary statistics for reef thickness are given in Table 3. Reef thickness approximately follows a lognormal distribution with a mean of 2.55 m and standard deviation of 3.37 m, although statistical tests show only a borderline fit (Table 3, Figures 2 and 3).

Table 3. Summary statistics for thickness data from the SJ and SK reefs.

	Thickness
N of Cases	376
Minimum	0.20
Maximum	35.03
Median	1.47
Arithmetic Mean	2.55
Standard Deviation	3.37
Normality tests for log10-transformed data	
Shapiro-Wilk Statistic	0.985
Shapiro-Wilk p-value	0.001
Kolmogorov-Smirnov Test Statistic	0.053
Lilliefors Probability	0.012

Data source: Halkoaho (unpublished data), North American Palladium Ltd. (2006, 2007).

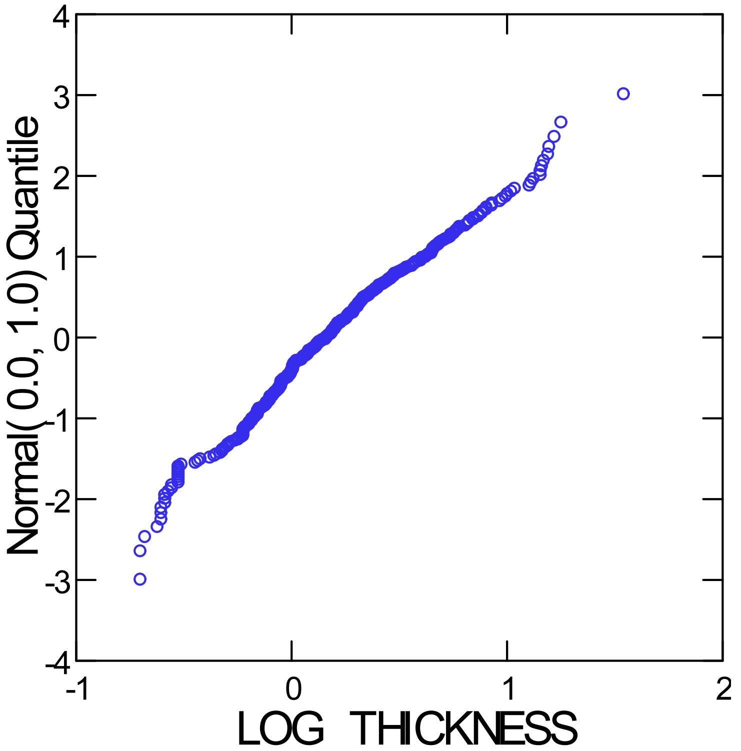

Figure 2. Probability plot for log10-transformed reef thickness data from the SJ and SK reefs.

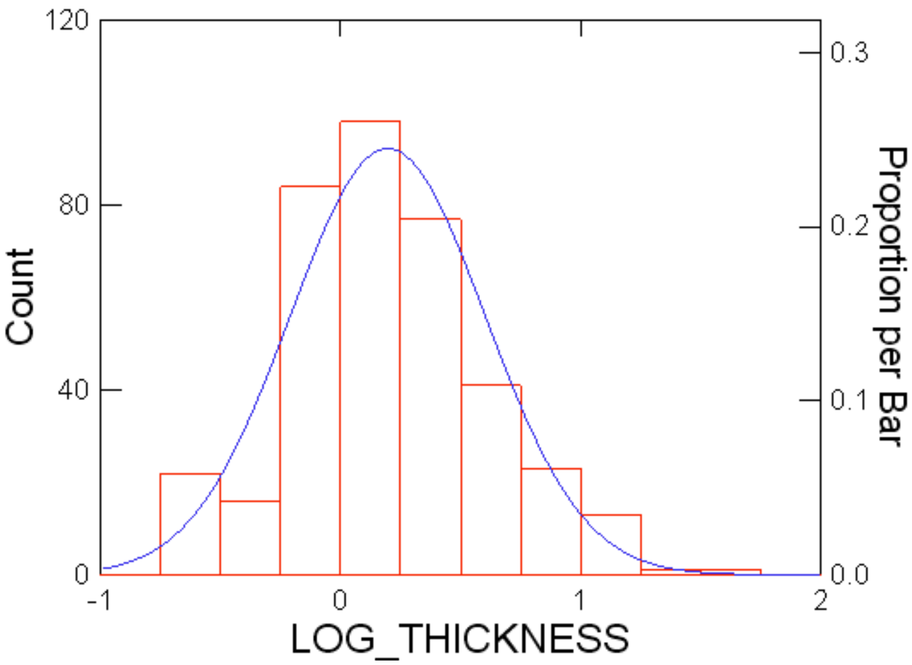

Figure 3. Fitting a normal distribution to log10-transformed reef thickness data from the SJ and SK reefs.

Reef density

Reef density variation was estimated using data from the Suhanko and Konttijärvi intrusions (Table 4). The frequency distribution of density can be described using either a lognormal or normal distribution. A normal distribution was selected since it is less susceptible to giving extremely large values. The density of the Finnish reef deposits is estimated to follow a normal distribution with a mean of 2.94 and standard deviation of 0.03 (Figure 4, Table 5).

Geological loss

The geological loss describes the percentual decrease in the amount of mineralised rock due to discontinuities in the reef caused by geological factors. No geological loss data are available for Finnish reef deposits. A model based on data from 28 deposits/prospects from the Merensky and UG2 reefs (M. Zientek, written comm., 2009) was used. According to the model, the loss function has a normal distribution with mean percent loss of 24% and a standard deviation of 7.8% (Figure 5, Table 6).

Monte Carlo simulation of reef tonnages

The estimation of reef tonnage by Monte Carlo simulation according to equation (1) was repeated 4999 times for each permissive tract. The result of the process was a frequency distribution of reef tonnage for the permissive tract in question (Figures 6 to 26). Due to the requirements of the Eminers software used in the final stage of the assessment, a subset of 26 tonnage values was picked from the estimated frequency distribution at fractions 0.02, 0.04, 0.08, 0.12, …, 0.96, 0.98. The lowest and highest fractions were selected so that the arithmetic mean of the subset is as near as possible to the arithmetic mean of the simulated data of 4999 cases. The 26-sample subsets were input to the Eminers software as the empirical frequency distributions of reef tonnage by editing the empirical distribution model files. For every permissive tract, the subset follows a lognormal distribution with the arithmetic mean within one percent of the mean of the original data (Tables 8-28). The empirical distribution functions for ore tonnage for each permissive tract are tabulated in Table 7 and compared with the simulated tonnages in the following pages.

COMBINATION OF THE TONNAGE AND GRADE MODELS

For each reef-type permissive tract, the tonnage model for the tract was combined with the general grade model for Finnish reef-type deposits. This was done by editing the Eminers model files. In the final grade-tonnage models, there is no dependency between ore tonnage and metal grades. This could not be introduced because of the lack of suitable data. However, dependencies between metal grades exist in the constructed models.

Table 4. Density data from the Suhanko and Konttijärvi intrusions.

Location	Density (g/cm³)
Konttijarvi hanging wall	2.91
Amavaara hanging wall	2.91
Amavaara marginal upper	2.93
Portimo dyke	3.00
Amavaara peridotite marker	2.92
Konttijarvi peridotite marker	2.94
Amavaara upper peridotite	2.95
Ahmavaara pyroxenite	2.95
Konttijarvi pyroxenite	2.99

Data source: Purich et al. 2007.

Table 5. Summary statistics for the density data in Table 4.

	Density
N of Cases	9
Minimum	2.91
Maximum	3
Median	2.94
Arithmetic Mean	2.94
Standard Deviation	0.03
Normality tests for data	
Shapiro-Wilk Statistic	0.894
Shapiro-Wilk p-value	0.219
Kolmogorov-Smirnov Test Statistic	0.206
Lilliefors Probability	0.371

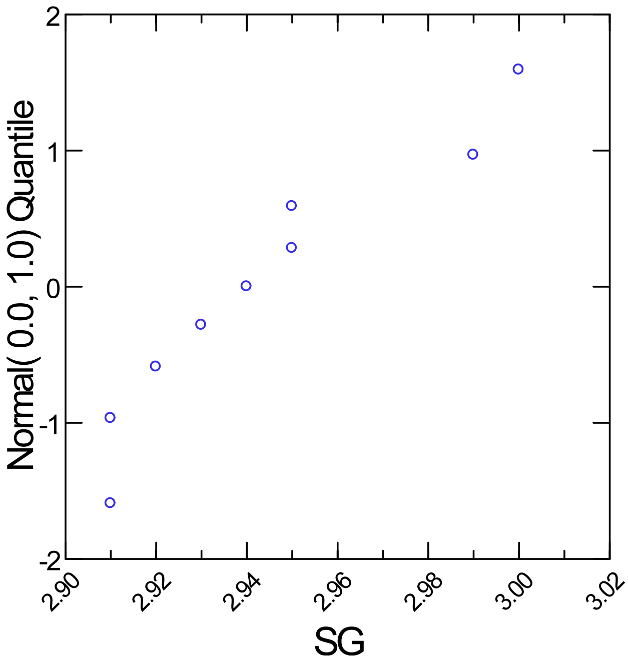

Figure 4. Probability plot for the density data in Table 4.

Table 6. Summary statistics for the geological loss data.

	Loss
N of Cases	36
Minimum	11.5
Maximum	41
Median	24
Arithmetic Mean	24
Standard Deviation	7.8
Normality tests for data	
Shapiro-Wilk Statistic	0.948
Shapiro-Wilk p-value	0.088
Kolmogorov-Smirnov Test Statistic	0.122
Lilliefors Probability	0.185

Data source: M. Zientek (written comm., 2009).

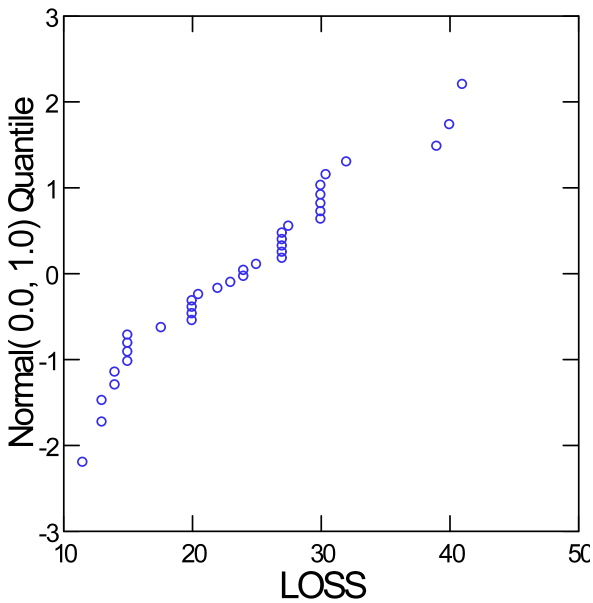

Figure 5. Probability plot for the geological loss data.

Table 7. Empirical cumulative distribution functions for ore tonnage (t) for each reef-type permissive tract.

Akanvaara	Hoikan-vaara	Junttilan-niemi	Kaamajoki	Kaukua	Kemi	Koitelainen	Kouluma-oiva	Kuusijarvi	Lipea-vaara	Murto-lampi
5305134	249182	1308716	841678	358521	7511043	75530643	1852121	6747301	41052	111187
7096632	349196	1819711	1678911	723454	10472141	103455682	2524534	11387365	146543	146498
9718062	478903	2554440	3297605	1442870	15021209	142400296	3352320	17541879	622406	217115
12217751	586970	3259985	4687115	2313344	18349893	183610058	4215460	23630552	1323724	271632
14620032	688981	3814516	6087971	3131676	21645033	225268920	5078186	28281979	2296519	332590
16876080	793388	4405538	7613572	4013639	24831697	263237633	5822679	33002357	3295410	386249
19385914	908127	4950813	9040425	4782790	28079008	304798710	6665406	37854342	4339887	446203
22054074	1017824	5540755	10770560	5664923	31858497	344640276	7540364	42406922	5504253	507253
25077056	1143176	6186063	12396568	6688264	35756982	386881612	8314345	47512152	6681096	573468
27787007	1261587	6900801	14248342	7651546	39613774	436789137	9255514	52882181	7937328	640011
30643760	1411557	7720548	16117680	8787258	43610118	483756576	10305543	58113410	9208704	712057
33729472	1536301	8367900	18200967	10008572	47718517	532647228	11266748	64470888	10635106	794739
37433184	1692162	9265844	20852038	11364021	52776792	592625743	12533244	71118800	12191517	887835
41473490	1873102	10173232	23495292	12631847	57851760	651001651	13977077	78333014	14130618	995448
45263046	2055778	11405509	26011351	14439245	63820540	716762933	15544236	87381270	16083150	1119470
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54572039	2521353	13914726	33160323	18464097	76566040	901004145	19098372	108914050	20579329	1390543
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76963714	3532374	19402494	48101132	26631518	106762250	1346153385	26329015	158038394	30447236	2017287
86594528	4020994	22055122	55549864	30482739	123246844	1549635250	29879286	180848032	35649637	2317543
100071372	4568850	25758469	65381094	35817156	143867388	1801568913	34598071	208707866	42116541	2690872
121018828	5387141	30465238	80761728	44660756	169890337	2177484650	40691818	247503825	51226825	3270323
151983865	6671725	37132907	107945966	55803313	212729630	2834557283	51632324	312714065	65581516	4257011
213827647	9460071	49314248	157228932	83363824	287004033	3994901759	73539282	430095301	91745956	6126368
289179920	12461398	65500494	208188187	112940316	380058623	5426041896	98331485	585870551	123183204	8423094

Naranka-vaara	Narkaus	Penikat	Pintamo	Pirivaara	Porttivaara	Suhanko	Syote	Tilsa	Tornio
8961821	5626267	13198482	11674464	105062	13753085	7669357	14828187	1323527	4975891
12063818	7237963	17263859	16450483	205321	17954804	11196723	19451380	1690711	6512156
16923678	9824458	23426346	23247991	444905	25417816	15599327	28323486	2368040	9173446
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32930160	18368107	43579751	46971842	1422145	49060918	30129036	57056421	4797765	17478273
36871721	20734703	48818498	53073112	1667759	55863620	34140052	64468641	5406434	19781254
41273772	23181619	54479894	58882714	1965863	63473112	38580438	72491794	6031907	21895246
46330839	26043213	59710260	65005936	2266043	70584705	42741367	81255720	6743939	24419108
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68291866	38385078	87065940	97075437	3853833	104481080	63793860	121252380	9808861	35499933
76047992	42139969	94705352	106257994	4357456	115032533	70544550	134621347	10797641	38836396
83667701	46168420	104881113	117805455	4896647	126378520	77077396	146894251	11936445	43318266
93346401	51367735	115021615	131011260	5548282	139432261	85634895	163267868	13159293	47933149
104030122	56564874	125695967	145849907	6307002	155710091	95059579	180328701	14593091	53547130
116078112	63554324	140672075	163004353	7122930	172320028	105280183	203704797	16325956	59310316
129058037	71205892	154579970	182213060	8197870	195655189	118567672	231104232	18354687	67012924
144932179	80321124	175645223	208405856	9499702	223873591	137802056	264193382	20859945	75473524
166936698	95237870	202775572	238887353	11257033	259543991	157796445	310544150	24193786	88680865
199309825	113221558	242712178	277244778	13330196	307460562	189558847	372343174	29444849	104681077
240323280	141835416	300275838	341901098	17057479	387055125	233662848	474495247	37507699	131256819
326549797	195473391	408200639	476862934	24877855	544107957	323645102	639128580	52574461	182873209
428575927	260291568	533275854	660855291	34057041	771470179	440977805	874271988	71107649	242693462

AkanvaaraReefPGE

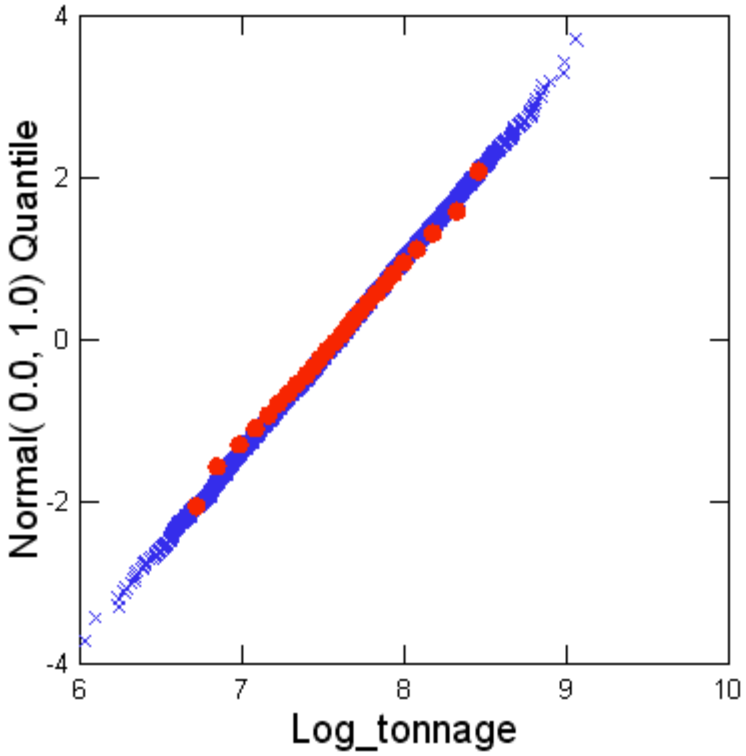

Figure 6. Probability plot comparing the simulated ore tonnage (blue crosses) for the AkanvaaraReefPGE tract with the empirical tonnage model extracted from the simulated data (red dots).

Table 8. Summary statistics for the simulated ore tonnage and empirical distribution function for permissive tract AkanvaaraReefPGE.

	Simulated tonnage		Empirical distribution function	
	Tonnage (t)	Log10(tonnage)	Tonnage (t)	Log10(tonnage)
N of Cases	4999	4999	26	26
Minimum	1083610	6.035	5305130	6.725
Maximum	1147730000	9.060	289180000	8.461
Arithmetic Mean	61991500	7.588	62325800	7.588
Standard Deviation	75670100	0.422	67391000	0.441
Shapiro-Wilk Statistic	0.626	1.000	0.755	0.994
Shapiro-Wilk p-value	0.000	0.879	0.000	1.000
Anderson-Darling Statistic	448.197	0.400	2.109	0.047
Adjusted Anderson-Darling Statistic	448.264	0.400	2.176	0.048
p-value	<0.01	>0.15	<0.01	>0.15

The Shapiro-Wilk and Anderson-Darling statistics test the normality of the distribution.

HoikanvaaraReefPGE

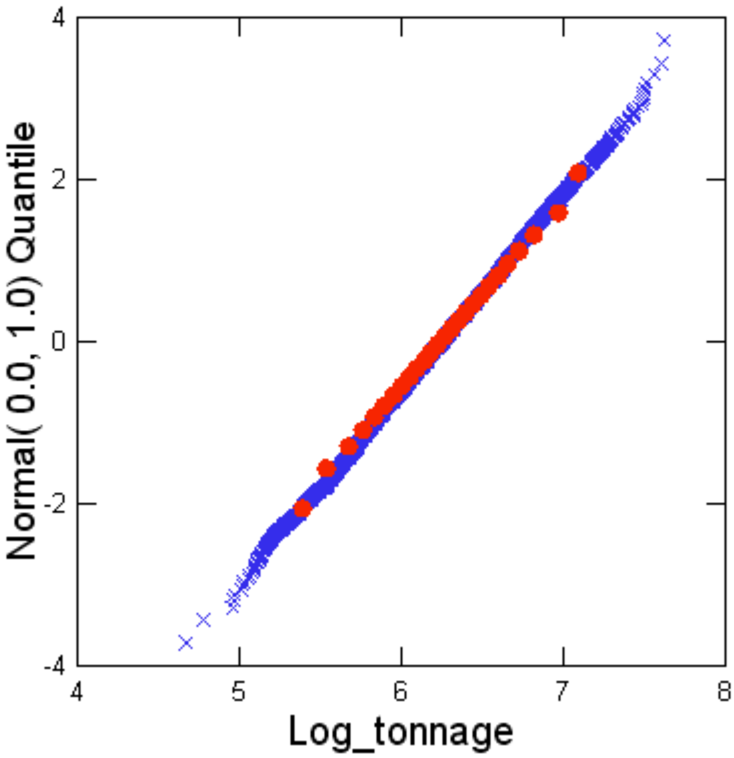

Figure 7. Probability plot comparing the simulated ore tonnage (blue crosses) for the HoikanvaaraReefPGE tract with the empirical tonnage model extracted from the simulated data (red dots).

Table 9. Summary statistics for the simulated ore tonnage and empirical distribution function for permissive tract HoikanvaaraReefPGE.

	Simulated tonnage		Empirical distribution function	
	Tonnage (t)	Log10(tonnage)	Tonnage (t)	Log10(tonnage)
N of Cases	4999	4999	26	26
Minimum	46569	4.668	249182	5.397
Maximum	42111400	7.624	12461400	7.096
Arithmetic Mean	2801960	6.252	2803740	6.252
Standard Deviation	3314450	0.413	2927990	0.430
Shapiro-Wilk Statistic	0.639	1.000	0.769	0.995
Shapiro-Wilk p-value	0.000	0.563	0.000	1.000
Anderson-Darling Statistic	426.828	0.288	1.972	0.044
Adjusted Anderson-Darling Statistic	426.893	0.288	2.036	0.045
p-value	<0.01	>0.15	<0.01	>0.15

The Shapiro-Wilk and Anderson-Darling statistics test the normality of the distribution.

JunttilanniemiReefPGE

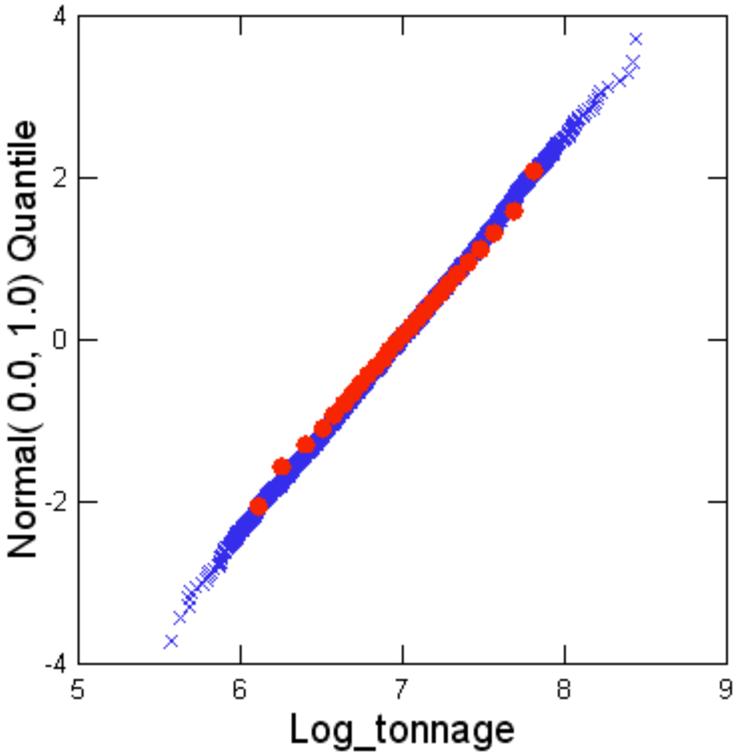

Figure 8. Probability plot comparing the simulated ore tonnage (blue crosses) for the JunttilanniemiReefPGE tract with the empirical tonnage model extracted from the simulated data (red dots).

Table 10. Summary statistics for the simulated ore tonnage and empirical distribution function for permissive tract Junttilanniemi-ReefPGE.

	Simulated tonnage		Empirical distribution function	
	Tonnage (t)	Log10(tonnage)	Tonnage (t)	Log10(tonnage)
N of Cases	4999	4999	26	26
Minimum	374415	5.573	1308720	6.117
Maximum	276054000	8.441	65500500	7.816
Arithmetic Mean	15220700	6.990	15250000	6.989
Standard Deviation	17750700	0.412	15548600	0.432
Shapiro-Wilk Statistic	0.641	1.000	0.786	0.994
Shapiro-Wilk p-value	0.000	0.324	0.000	1.000
Anderson-Darling Statistic	401.006	0.501	1.841	0.046
Adjusted Anderson-Darling Statistic	401.066	0.501	1.900	0.048
p-value	<0.01	>0.15	<0.01	>0.15

The Shapiro-Wilk and Anderson-Darling statistics test the normality of the distribution.

KaamajokiReefPGE

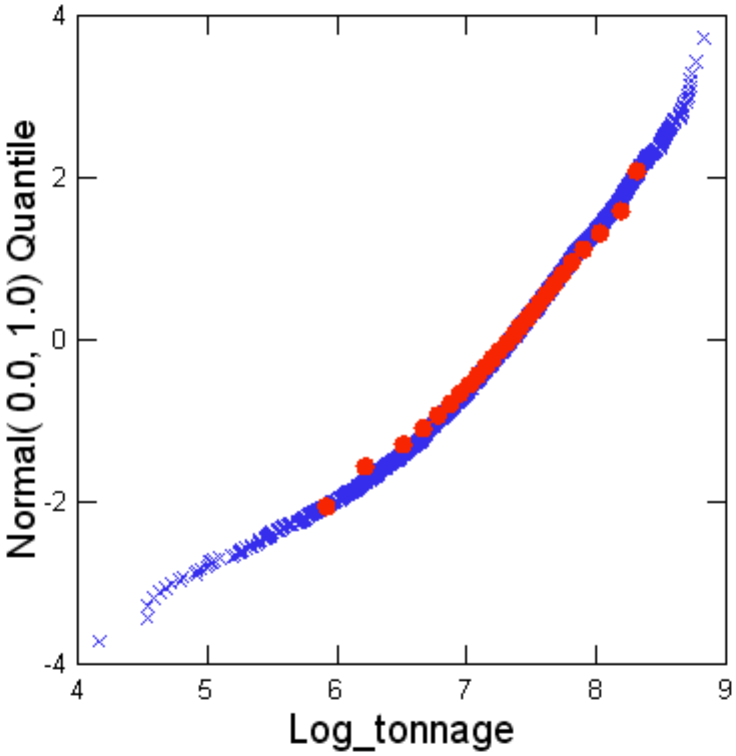

Figure 9. Probability plot comparing the simulated ore tonnage (blue crosses) for the KaamajokiReefPGE tract with the empirical tonnage model extracted from the simulated data (red dots).

Table 11. Summary statistics for the simulated ore tonnage and empirical distribution function for permissive tract KaamajokiReefPGE.

	Simulated tonnage		Empirical distribution function	
	Tonnage (t)	Log10(tonnage)	Tonnage (t)	Log10(tonnage)
N of Cases	4999	4999	26	26
Minimum	14752	4.169	841678	5.925
Maximum	680790000	8.833	208188000	8.318
Arithmetic Mean	39735700	7.297	40015200	7.296
Standard Deviation	55724200	0.565	49937800	0.579
Shapiro-Wilk Statistic	0.611	0.975	0.727	0.985
Shapiro-Wilk p-value	0.000	0.000	0.000	0.955
Anderson-Darling Statistic	508.476	19.745	2.439	0.129
Adjusted Anderson-Darling Statistic	508.553	19.748	2.517	0.133
p-value	<0.01	<0.01	<0.01	>0.15

The Shapiro-Wilk and Anderson-Darling statistics test the normality of the distribution.

KaukuaReefPGE

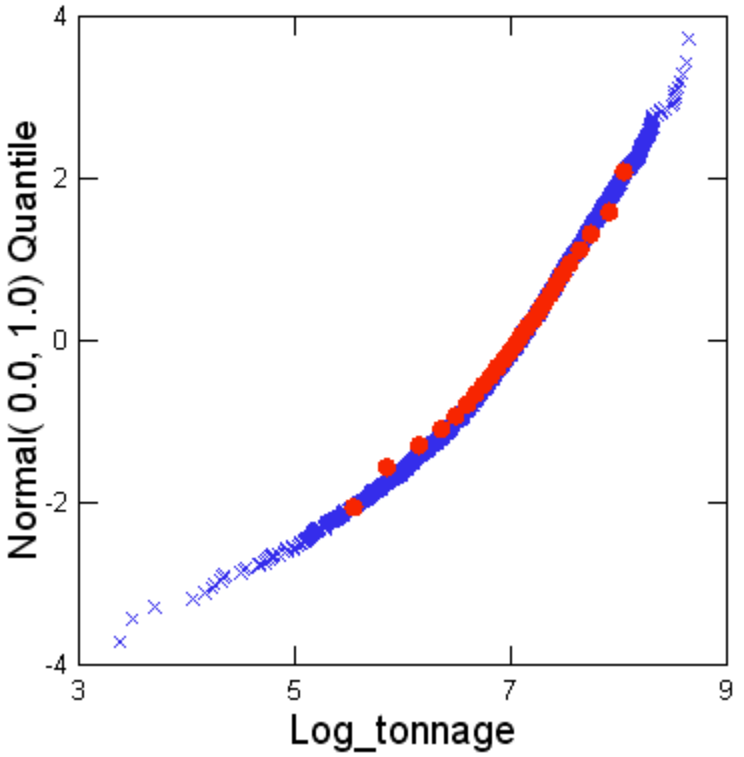

Figure 10. Probability plot comparing the simulated ore tonnage (blue crosses) for the KaukuaReefPGE tract with the empirical tonnage model extracted from the simulated data (red dots).

Table 12. Summary statistics for the simulated ore tonnage and empirical distribution function for permissive tract KaukuaReefPGE.

	Simulated tonnage		Empirical distribution function	
	Tonnage (t)	Log10(tonnage)	Tonnage (t)	Log10(tonnage)
N of Cases	4999	4999	26	26
Minimum	2411	3.382	358521	5.555
Maximum	446629000	8.650	112940000	8.053
Arithmetic Mean	21664100	7.020	21650300	7.017
Standard Deviation	31457300	0.590	26841100	0.606
Shapiro-Wilk Statistic	0.584	0.966	0.735	0.977
Shapiro-Wilk p-value	0.000	0.000	0.000	0.800
Anderson-Darling Statistic	508.493	30.802	2.304	0.195
Adjusted Anderson-Darling Statistic	508.569	30.806	2.378	0.201
p-value	<0.01	<0.01	<0.01	>0.15

The Shapiro-Wilk and Anderson-Darling statistics test the normality of the distribution.

KemiReefPGE

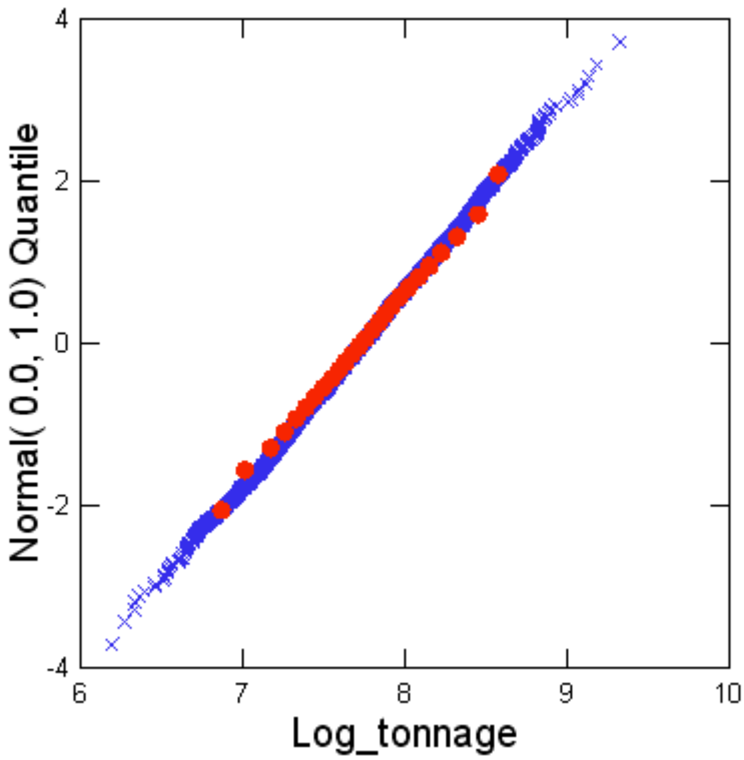

Figure 11. Probability plot comparing the simulated ore tonnage (blue crosses) for the KemiReefPGE tract with the empirical tonnage model extracted from the simulated data (red dots).

Table 13. Summary statistics for the simulated ore tonnage and empirical distribution function for permissive tract KemiReefPGE.

	Simulated tonnage		Empirical distribution function	
	Tonnage (t)	Log10(tonnage)	Tonnage (t)	Log10(tonnage)
N of Cases	4999	4999	26	26
Minimum	1571300	6.196	7511040	6.876
Maximum	2111620000	9.325	380059000	8.580
Arithmetic Mean	86572400	7.742	86430500	7.741
Standard Deviation	105077000	0.413	89782700	0.430
Shapiro-Wilk Statistic	0.611	1.000	0.772	0.995
Shapiro-Wilk p-value	0.000	0.293	0.000	1.000
Anderson-Darling Statistic	440.210	0.463	1.984	0.045
Adjusted Anderson-Darling Statistic	440.276	0.463	2.048	0.047
p-value	<0.01	>0.15	<0.01	>0.15

The Shapiro-Wilk and Anderson-Darling statistics test the normality of the distribution.

KoitelainenReefPGE

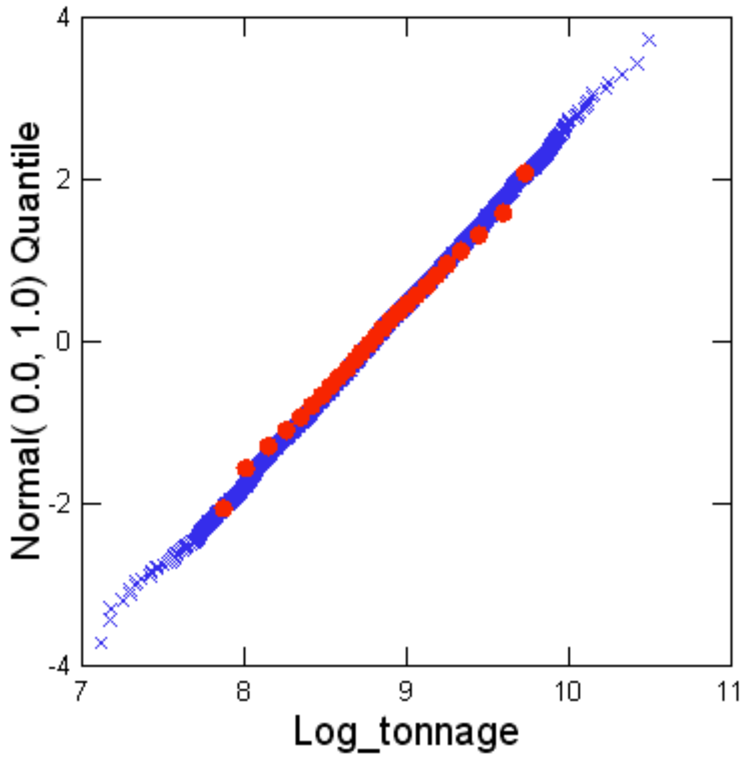

Figure 12. Probability plot comparing the simulated ore tonnage (blue crosses) for the KoitelainenReefPGE tract with the empirical tonnage model extracted from the simulated data (red dots).

Table 14. Summary statistics for the simulated ore tonnage and empirical distribution function for permissive tract KoitelainenReefPGE.

	Simulated tonnage		Empirical distribution function	
	Tonnage (t)	Log10(tonnage)	Tonnage (t)	Log10(tonnage)
N of Cases	4999	4999	26	26
Minimum	13207200	7.121	75530600	7.878
Maximum	31198600000	10.494	5426040000	9.734
Arithmetic Mean	1092500000	8.799	1094540000	8.801
Standard Deviation	1522540000	0.456	1278800000	0.474
Shapiro-Wilk Statistic	0.565	1.000	0.734	0.993
Shapiro-Wilk p-value	0.000	0.445	0.000	1.000
Anderson-Darling Statistic	520.595	0.552	2.368	0.049
Adjusted Anderson-Darling Statistic	520.674	0.552	2.444	0.051
p-value	<0.01	>0.15	<0.01	>0.15

The Shapiro-Wilk and Anderson-Darling statistics test the normality of the distribution.

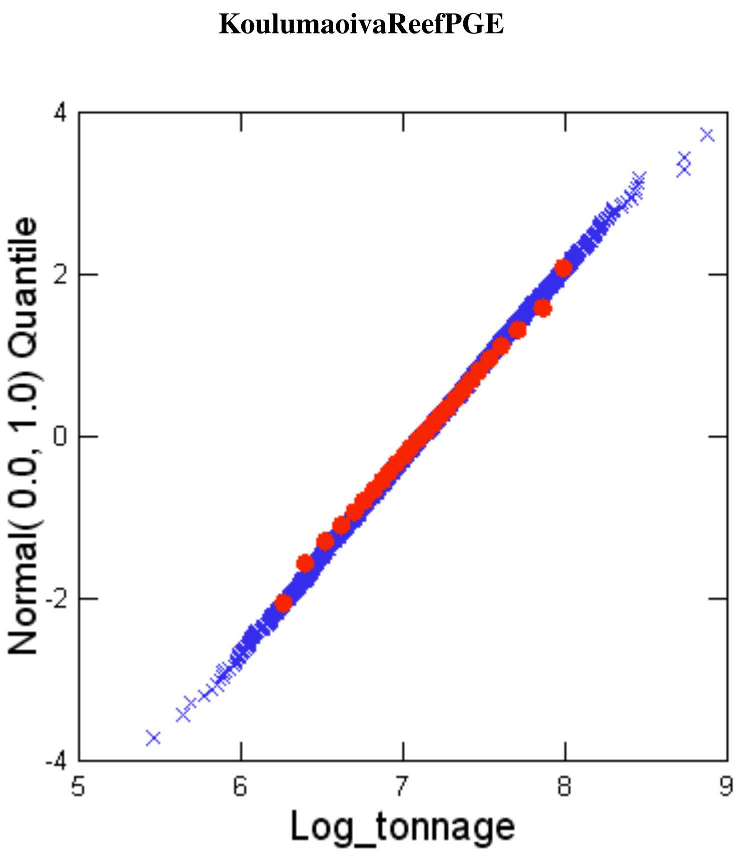

Figure 13. Probability plot comparing the simulated ore tonnage (blue crosses) for the KoulumaoivaReefPGE tract with the empirical tonnage model extracted from the simulated data (red dots).

Table 15. Summary statistics for the simulated ore tonnage and empirical distribution function for permissive tract KoulumaoivaReefPGE.

	Simulated tonnage		Empirical distribution function	
	Tonnage (t)	Log10(tonnage)	Tonnage (t)	Log10(tonnage)
N of Cases	4999	4999	26	26
Minimum	288527	5.460	1852120	6.268
Maximum	749703000	8.875	98331500	7.993
Arithmetic Mean	21420200	7.123	21329000	7.124
Standard Deviation	29000800	0.422	22988400	0.439
Shapiro-Wilk Statistic	0.535	1.000	0.757	0.994
Shapiro-Wilk p-value	0.000	0.668	0.000	1.000
Anderson-Darling Statistic	499.545	0.370	2.082	0.046
Adjusted Anderson-Darling Statistic	499.620	0.370	2.149	0.048
p-value	<0.01	>0.15	<0.01	>0.15

The Shapiro-Wilk and Anderson-Darling statistics test the normality of the distribution.

KuusijärviReefPGE

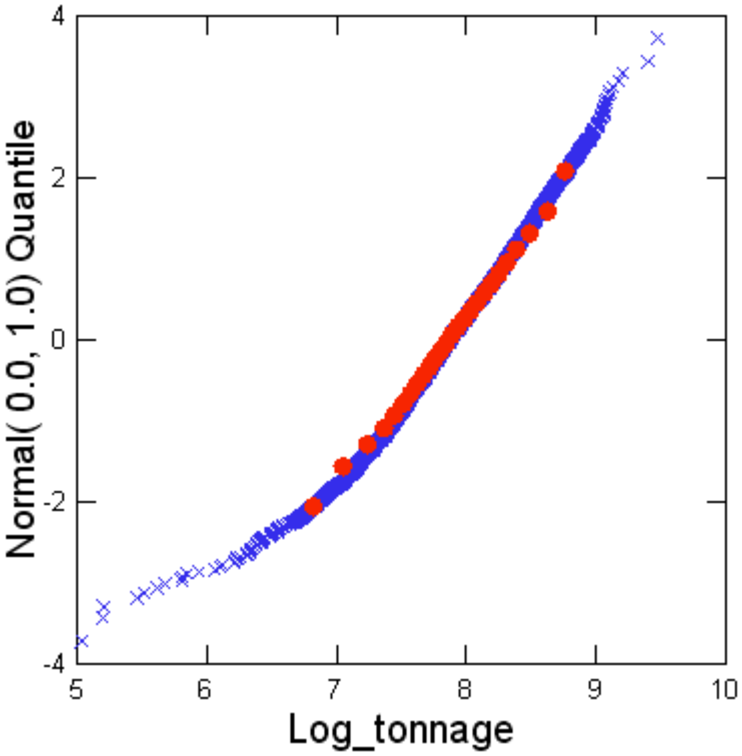

Figure 14. Probability plot comparing the simulated ore tonnage (blue crosses) for the KuusijärviReefPGE tract with the empirical tonnage model extracted from the simulated data (red dots).

Table 16. Summary statistics for the simulated ore tonnage and empirical distribution function for permissive tract KuusijärviReefPGE.

	Simulated tonnage		Empirical distribution function	
	Tonnage (t)	Log10(tonnage)	Tonnage (t)	Log10(tonnage)
N of Cases	4999	4999	26	26
Minimum	109071	5.038	6747300	6.829
Maximum	2991650000	9.476	585871000	8.768
Arithmetic Mean	124293000	7.869	125085000	7.872
Standard Deviation	155456000	0.464	137831000	0.473
Shapiro-Wilk Statistic	0.624	0.985	0.760	0.995
Shapiro-Wilk p-value	0.000	0.000	0.000	1.000
Anderson-Darling Statistic	442.442	6.361	2.079	0.056
Adjusted Anderson-Darling Statistic	442.508	6.362	2.146	0.058
p-value	<0.01	<0.01	<0.01	>0.15

The Shapiro-Wilk and Anderson-Darling statistics test the normality of the distribution.

LipeävaaraReefPGE

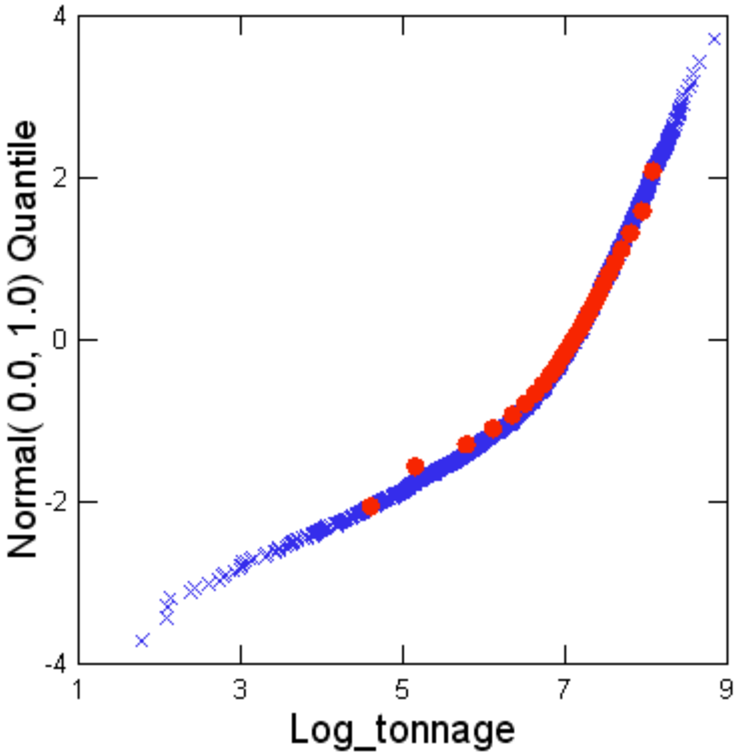

Figure 15. Probability plot comparing the simulated ore tonnage (blue crosses) for the LipeävaaraReefPGE tract with the empirical tonnage model extracted from the simulated data (red dots).

Table 17. Summary statistics for the simulated ore tonnage and empirical distribution function for permissive tract LipeävaaraReefPGE.

	Simulated tonnage		Empirical distribution function	
	Tonnage (t)	Log10(tonnage)	Tonnage (t)	Log10(tonnage)
N of Cases	4999	4999	26	26
Minimum	61	1.788	41052	4.613
Maximum	703871000	8.847	123183000	8.091
Arithmetic Mean	23857200	6.962	23968900	6.951
Standard Deviation	34501000	0.802	30028600	0.822
Shapiro-Wilk Statistic	0.609	0.883	0.754	0.908
Shapiro-Wilk p-value	0.000	0.000	0.000	0.023
Anderson-Darling Statistic	458.938	134.696	2.142	0.751
Adjusted Anderson-Darling Statistic	459.007	134.716	2.211	0.775
p-value	<0.01	<0.01	<0.01	0.04

The Shapiro-Wilk and Anderson-Darling statistics test the normality of the distribution.

MurtolampiReefPGE

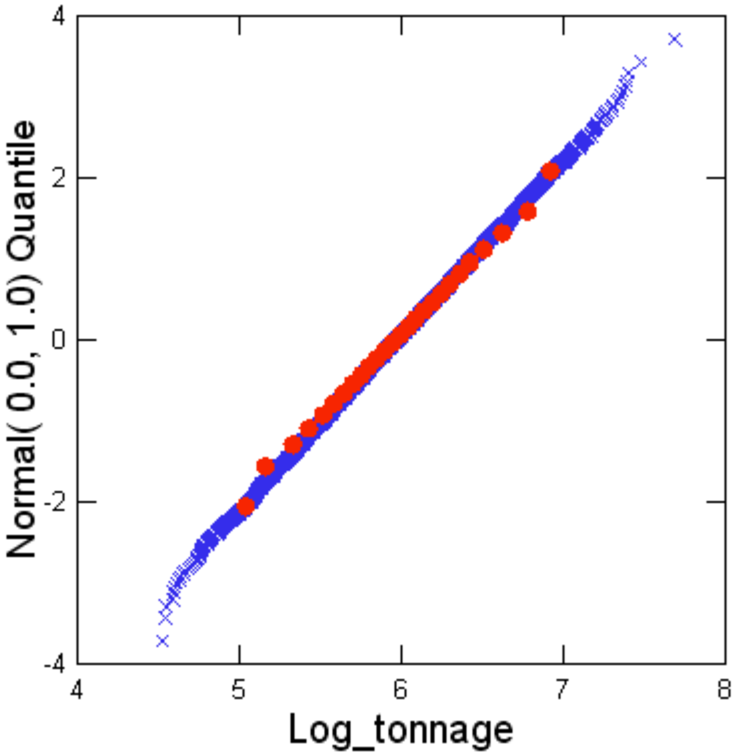

Figure 16. Probability plot comparing the simulated ore tonnage (blue crosses) for the MurtolampiReefPGE tract with the empirical tonnage model extracted from the simulated data (red dots).

Table 18. Summary statistics for the simulated ore tonnage and empirical distribution function for permissive tract MurtolampiReefPGE.

	Simulated tonnage		Empirical distribution function	
	Tonnage (t)	Log10(tonnage)	Tonnage (t)	Log10(tonnage)
N of Cases	4999	4999	26	26
Minimum	33594	4.526	111187	5.046
Maximum	48910300	7.689	8423090	6.925
Arithmetic Mean	1668200	5.977	1662430	5.977
Standard Deviation	2357110	0.461	1969830	0.480
Shapiro-Wilk Statistic	0.564	1.000	0.728	0.993
Shapiro-Wilk p-value	0.000	0.734	0.000	1.000
Anderson-Darling Statistic	532.971	0.190	2.392	0.047
Adjusted Anderson-Darling Statistic	533.051	0.190	2.468	0.049
p-value	<0.01	>0.15	<0.01	>0.15

The Shapiro-Wilk and Anderson-Darling statistics test the normality of the distribution.

NäränkävaaraReefPGE

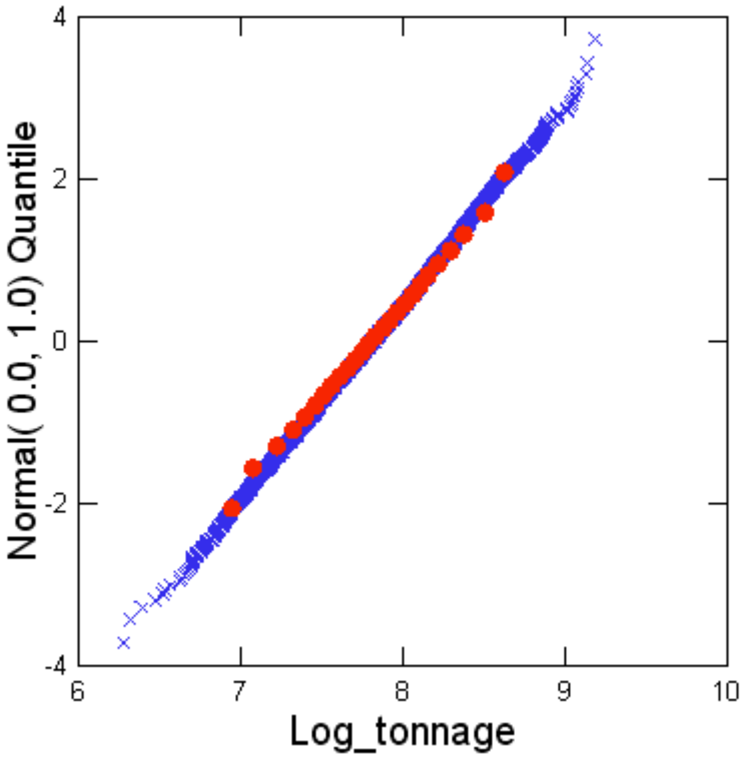

Figure 17. Probability plot comparing the simulated ore tonnage (blue crosses) for the NäränkävaaraReefPGE tract with the empirical tonnage model extracted from the simulated data (red dots).

Table 19. Summary statistics for the simulated ore tonnage and empirical distribution function for permissive tract NäränkävaaraReefPGE.

	Simulated tonnage		Empirical distribution function	
	Tonnage (t)	Log10(tonnage)	Tonnage (t)	Log10(tonnage)
N of Cases	4999	4999	26	26
Minimum	1910370	6.281	8961820	6.952
Maximum	1536580000	9.187	428576000	8.632
Arithmetic Mean	101101000	7.813	100697000	7.811
Standard Deviation	116685000	0.412	101698000	0.429
Shapiro-Wilk Statistic	0.652	1.000	0.789	0.993
Shapiro-Wilk p-value	0.000	0.336	0.000	1.000
Anderson-Darling Statistic	397.757	0.627	1.792	0.048
Adjusted Anderson-Darling Statistic	397.817	0.627	1.850	0.050
p-value	<0.01	0.10	<0.01	>0.15

The Shapiro-Wilk and Anderson-Darling statistics test the normality of the distribution.

NarkausReefPGE

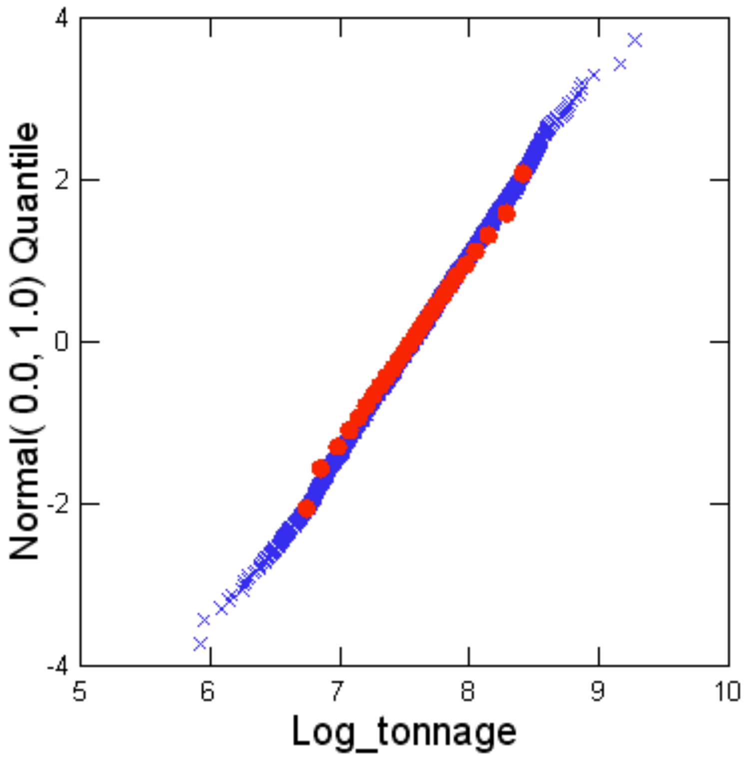

Figure 18. Probability plot comparing the simulated ore tonnage (blue crosses) for the NarkausReefPGE tract with the empirical tonnage model extracted from the simulated data (red dots).

Table 20. Summary statistics for the simulated ore tonnage and empirical distribution function for permissive tract NarkausReefPGE.

	Simulated tonnage		Empirical distribution function	
	Tonnage (t)	Log10(tonnage)	Tonnage (t)	Log10(tonnage)
N of Cases	4999	4999	26	26
Minimum	843637	5.926	5626270	6.750
Maximum	1893220000	9.277	260292000	8.415
Arithmetic Mean	57577800	7.564	57861300	7.565
Standard Deviation	72890500	0.411	61158400	0.428
Shapiro-Wilk Statistic	0.573	1.000	0.762	0.993
Shapiro-Wilk p-value	0.000	0.212	0.000	0.999
Anderson-Darling Statistic	461.184	0.386	2.060	0.050
Adjusted Anderson-Darling Statistic	461.253	0.386	2.126	0.051
p-value	<0.01	>0.15	<0.01	>0.15

The Shapiro-Wilk and Anderson-Darling statistics test the normality of the distribution.

PenikatReefPGE

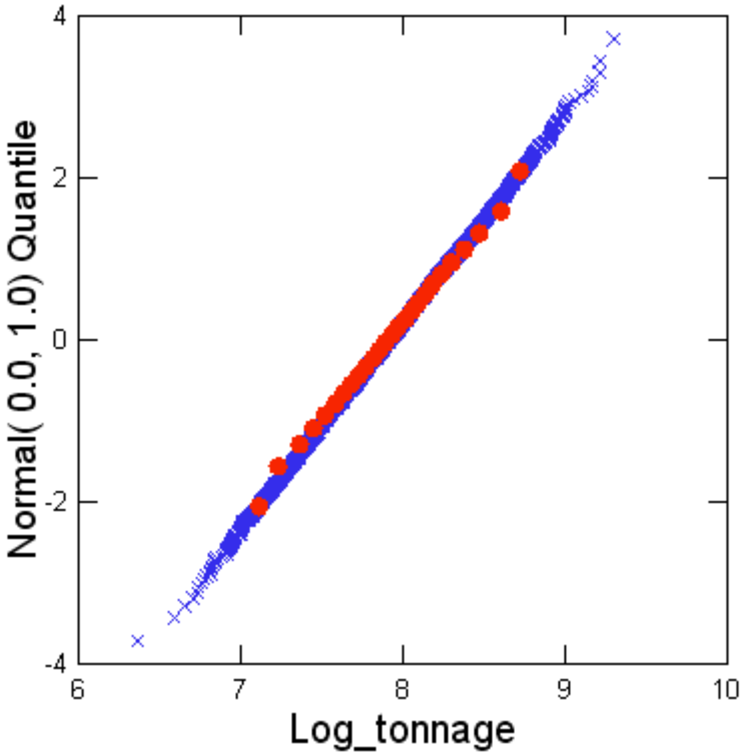

Figure 19. Probability plot comparing the simulated ore tonnage (blue crosses) for the PenikatReefPGE tract with the empirical tonnage model extracted from the simulated data (red dots).

Table 21. Summary statistics for the simulated ore tonnage and empirical distribution function for permissive tract PenikatReefPGE.

	Simulated tonnage		Empirical distribution function	
	Tonnage (t)	Log10(tonnage)	Tonnage (t)	Log10(tonnage)
N of Cases	4999	4999	26	26
Minimum	2335120	6.368	13198500	7.121
Maximum	1990240000	9.299	533276000	8.727
Arithmetic Mean	124688000	7.919	125531000	7.919
Standard Deviation	137267000	0.392	125487000	0.410
Shapiro-Wilk Statistic	0.669	1.000	0.780	0.994
Shapiro-Wilk p-value	0.000	0.986	0.000	1.000
Anderson-Darling Statistic	393.073	0.193	1.890	0.047
Adjusted Anderson-Darling Statistic	393.132	0.193	1.951	0.048
p-value	<0.01	>0.15	<0.01	>0.15

The Shapiro-Wilk and Anderson-Darling statistics test the normality of the distribution.

PintamoReefPGE

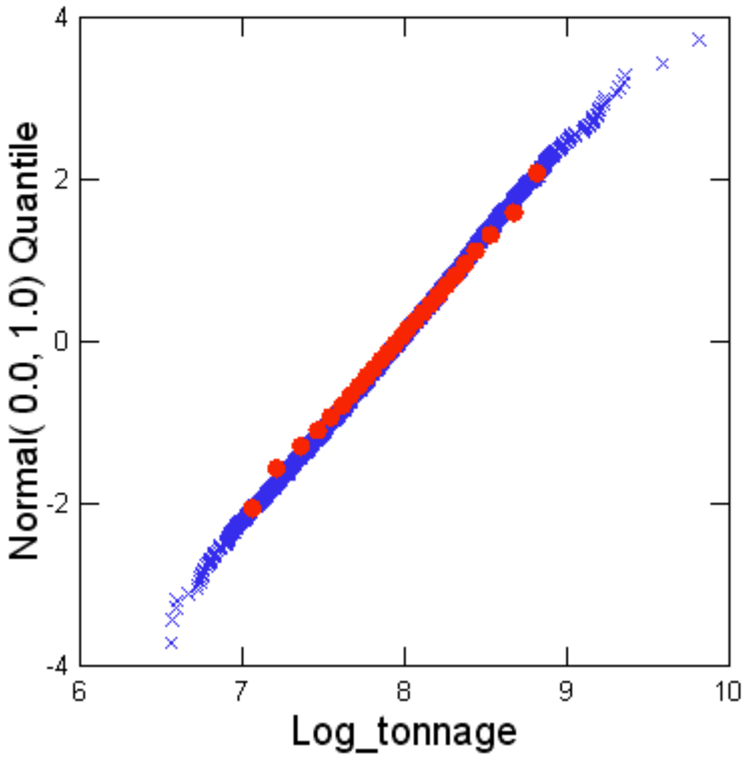

Figure 20. Probability plot comparing the simulated ore tonnage (blue crosses) for the PintamoReefPGE tract with the empirical tonnage model extracted from the simulated data (red dots).

Table 22. Summary statistics for the simulated ore tonnage and empirical distribution function for permissive tract PintamoReefPGE.

	Simulated tonnage		Empirical distribution function	
	Tonnage (t)	Log10(tonnage)	Tonnage (t)	Log10(tonnage)
N of Cases	4999	4999	26	26
Minimum	3667100	6.564	11674500	7.067
Maximum	6514840000	9.814	660855000	8.820
Arithmetic Mean	146385000	7.962	144978000	7.961
Standard Deviation	202150000	0.419	152523000	0.438
Shapiro-Wilk Statistic	0.504	0.999	0.768	0.995
Shapiro-Wilk p-value	0.000	0.067	0.000	1.000
Anderson-Darling Statistic	505.148	0.603	1.944	0.045
Adjusted Anderson-Darling Statistic	505.224	0.604	2.006	0.046
p-value	<0.01	0.12	<0.01	>0.15

The Shapiro-Wilk and Anderson-Darling statistics test the normality of the distribution.

PirivaaraReefPGE

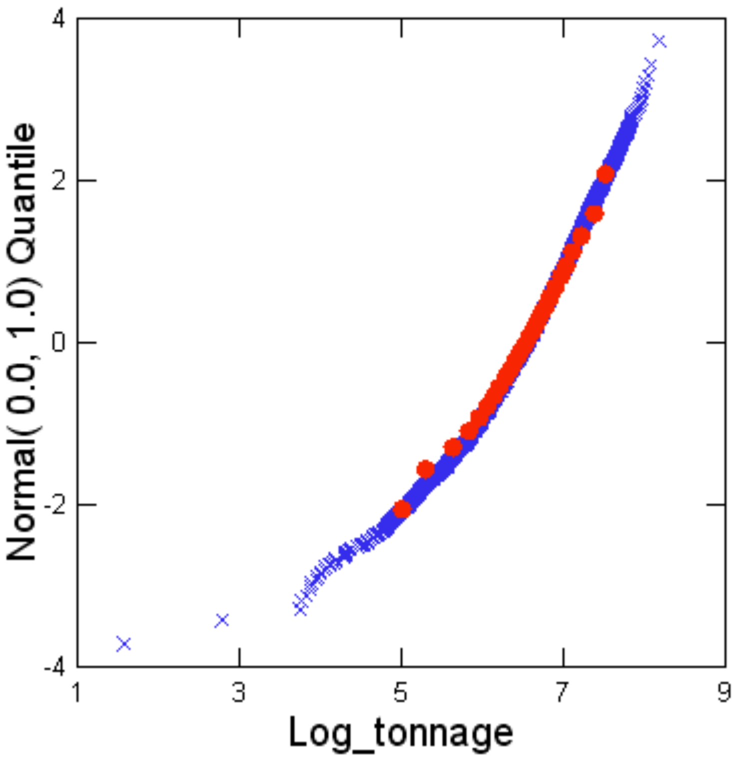

Figure 21. Probability plot comparing the simulated ore tonnage (blue crosses) for the PirivaaraReefPGE tract with the empirical tonnage model extracted from the simulated data (red dots).

Table 23. Summary statistics for the simulated ore tonnage and empirical distribution function for permissive tract PirivaaraReefPGE.

	Simulated tonnage		Empirical distribution function	
	Tonnage (t)	Log10(tonnage)	Tonnage (t)	Log10(tonnage)
N of Cases	4999	4999	26	26
Minimum	37	1.572	105062	5.021
Maximum	153438000	8.186	34057000	7.532
Arithmetic Mean	6537800	6.497	6546610	6.494
Standard Deviation	9436450	0.594	8100110	0.611
Shapiro-Wilk Statistic	0.590	0.966	0.739	0.976
Shapiro-Wilk p-value	0.000	0.000	0.000	0.791
Anderson-Darling Statistic	495.267	28.274	2.260	0.190
Adjusted Anderson-Darling Statistic	495.341	28.278	2.332	0.196
p-value	<0.01	<0.01	<0.01	>0.15

The Shapiro-Wilk and Anderson-Darling statistics test the normality of the distribution.

Porttivaara_PyhitysReefPGE

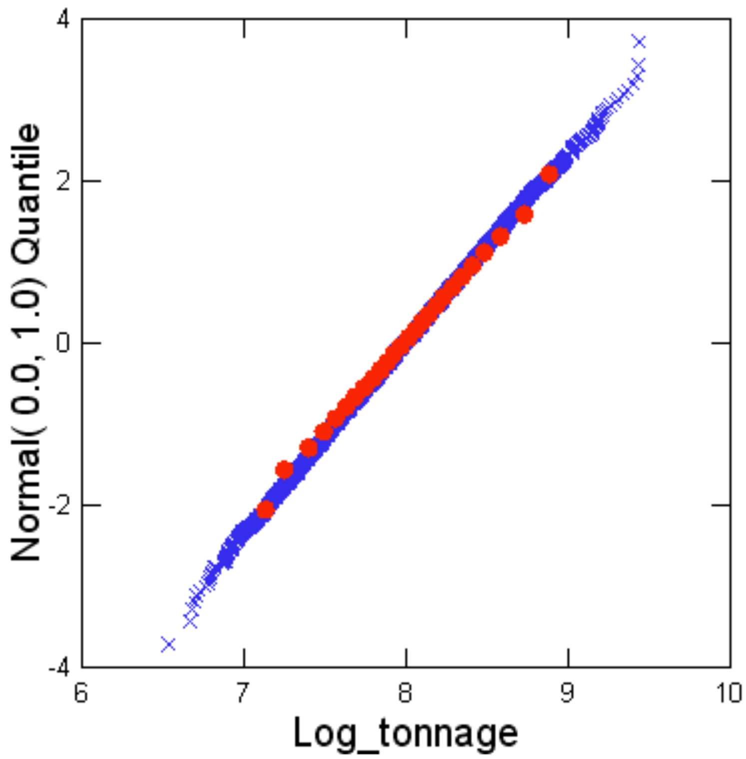

Figure 22. Probability plot comparing the simulated ore tonnage (blue crosses) for the Porttivaara_PyhitysReefPGE tract with the empirical tonnage model extracted from the simulated data (red dots).

Table 24. Summary statistics for the simulated ore tonnage and empirical distribution function for permissive tract Porttivaara_PyhitysReefPGE.

	Simulated tonnage		Empirical distribution function	
	Tonnage (t)	Log10(tonnage)	Tonnage (t)	Log10(tonnage)
N of Cases	4999	4999	26	26
Minimum	3412210	6.533	13753100	7.138
Maximum	2744810000	9.439	771470000	8.887
Arithmetic Mean	159990000	7.996	160261000	7.996
Standard Deviation	204080000	0.423	176526000	0.442
Shapiro-Wilk Statistic	0.597	1.000	0.745	0.994
Shapiro-Wilk p-value	0.000	0.582	0.000	1.000
Anderson-Darling Statistic	477.979	0.231	2.168	0.045
Adjusted Anderson-Darling Statistic	478.051	0.231	2.237	0.046
p-value	<0.01	>0.15	<0.01	>0.15

The Shapiro-Wilk and Anderson-Darling statistics test the normality of the distribution.

SuhankoReefPGE

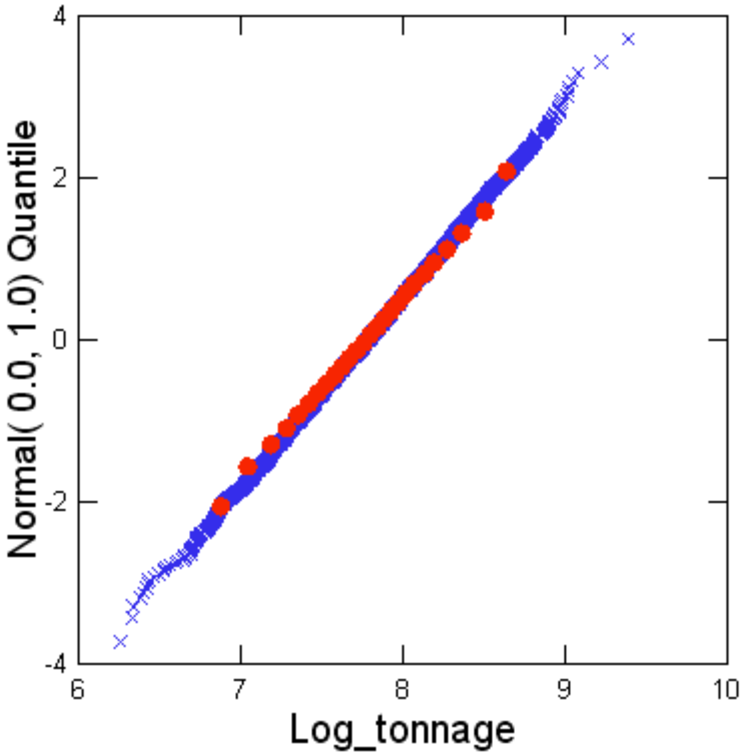

Figure 23. Probability plot comparing the simulated ore tonnage (blue crosses) for the SuhankoReefPGE tract with the empirical tonnage model extracted from the simulated data (red dots).

Table 25. Summary statistics for the simulated ore tonnage and empirical distribution function for permissive tract SuhankoReefPGE.

	Simulated tonnage		Empirical distribution function	
	Tonnage (t)	Log10(tonnage)	Tonnage (t)	Log10(tonnage)
N of Cases	4999	4999	26	26
Minimum	1819290	6.260	7669360	6.885
Maximum	2458680000	9.391	440978000	8.644
Arithmetic Mean	96146900	7.781	96379600	7.780
Standard Deviation	118015000	0.421	102833000	0.441
Shapiro-Wilk Statistic	0.615	1.000	0.763	0.995
Shapiro-Wilk p-value	0.000	0.910	0.000	1.000
Anderson-Darling Statistic	444.926	0.179	2.029	0.042
Adjusted Anderson-Darling Statistic	444.993	0.179	2.094	0.043
p-value	<0.01	>0.15	<0.01	>0.15

The Shapiro-Wilk and Anderson-Darling statistics test the normality of the distribution.

SyöteReefPGE

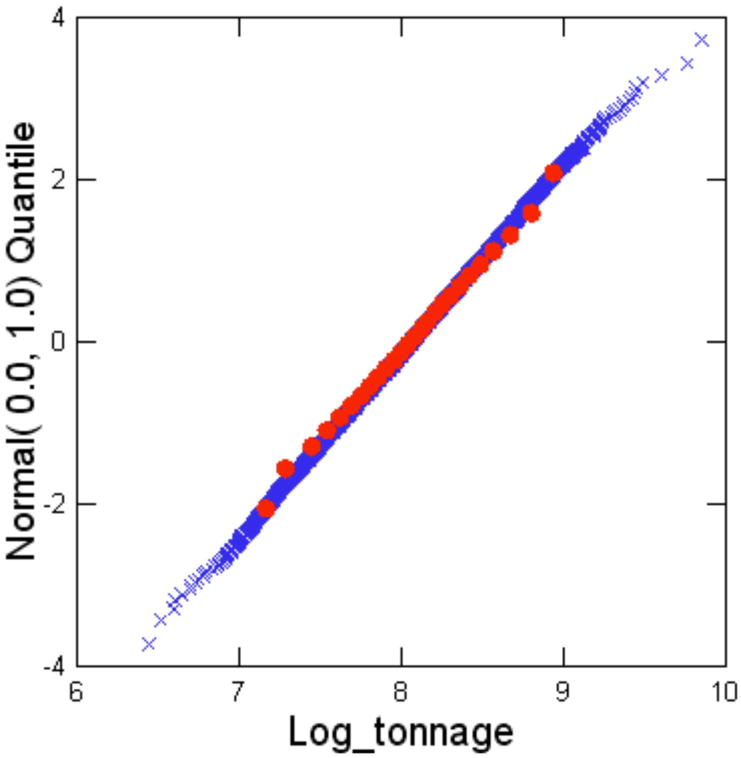

Figure 24. Probability plot comparing the simulated ore tonnage (blue crosses) for the SyöteReefPGE tract with the empirical tonnage model extracted from the simulated data (red dots).

Table 26. Summary statistics for the simulated ore tonnage and empirical distribution function for permissive tract SyöteReefPGE.

	Simulated tonnage		Empirical distribution function	
	Tonnage (t)	Log10(tonnage)	Tonnage (t)	Log10(tonnage)
N of Cases	4999	4999	26	26
Minimum	2781910	6.444	14828200	7.171
Maximum	7129190000	9.853	874272000	8.942
Arithmetic Mean	190248000	8.061	187815000	8.060
Standard Deviation	269504000	0.434	205035000	0.451
Shapiro-Wilk Statistic	0.514	1.000	0.758	0.993
Shapiro-Wilk p-value	0.000	0.812	0.000	1.000
Anderson-Darling Statistic	524.757	0.262	2.108	0.048
Adjusted Anderson-Darling Statistic	524.836	0.262	2.176	0.050
p-value	<0.01	>0.15	<0.01	>0.15

The Shapiro-Wilk and Anderson-Darling statistics test the normality of the distribution.

TilsaReefPGE

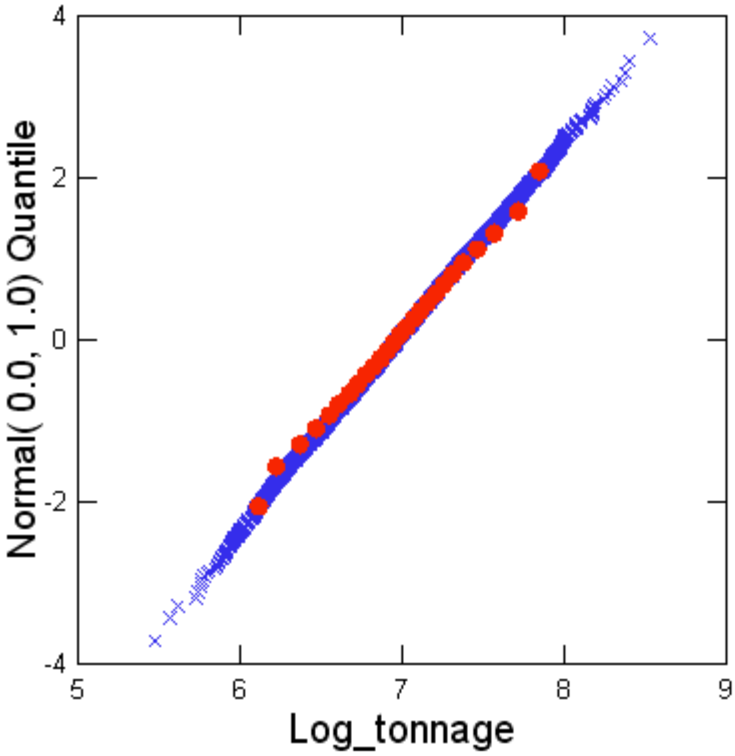

Figure 25. Probability plot comparing the simulated ore tonnage (blue crosses) for the TilsaReefPGE tract with the empirical tonnage model extracted from the simulated data (red dots).

Table 27. Summary statistics for the simulated ore tonnage and empirical distribution function for permissive tract TilsaReefPGE.

	Simulated tonnage		Empirical distribution function	
	Tonnage (t)	Log10(tonnage)	Tonnage (t)	Log10(tonnage)
N of Cases	4999	4999	26	26
Minimum	300703	5.478	1323530	6.122
Maximum	338893000	8.530	71107600	7.852
Arithmetic Mean	15068300	6.974	15171000	6.974
Standard Deviation	18811200	0.419	16568700	0.440
Shapiro-Wilk Statistic	0.608	1.000	0.748	0.993
Shapiro-Wilk p-value	0.000	0.519	0.000	1.000
Anderson-Darling Statistic	467.737	0.409	2.187	0.050
Adjusted Anderson-Darling Statistic	467.807	0.409	2.257	0.051
p-value	<0.01	>0.15	<0.01	>0.15

The Shapiro-Wilk and Anderson-Darling statistics test the normality of the distribution.

TornioReefPGE

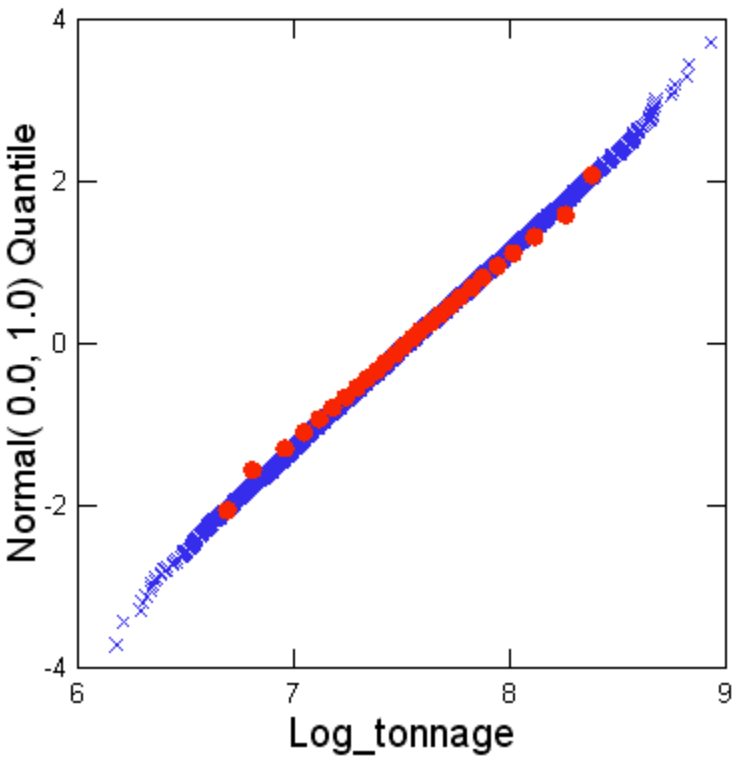

Figure 26. Probability plot comparing the simulated ore tonnage (blue crosses) for the TornioReefPGE tract with the empirical tonnage model extracted from the simulated data (red dots).

Table 28. Summary statistics for the simulated ore tonnage and empirical distribution function for permissive tract TornioReefPGE.

	Simulated tonnage		Empirical distribution function	
	Tonnage (t)	Log10(tonnage)	Tonnage (t)	Log10(tonnage)
N of Cases	4999	4999	26	26
Minimum	1505930	6.178	4975890	6.697
Maximum	856651000	8.933	242693000	8.385
Arithmetic Mean	53392500	7.534	53994900	7.535
Standard Deviation	61216800	0.410	56992600	0.430
Shapiro-Wilk Statistic	0.666	1.000	0.763	0.994
Shapiro-Wilk p-value	0.000	0.591	0.000	1.000
Anderson-Darling Statistic	414.512	0.222	2.046	0.047
Adjusted Anderson-Darling Statistic	414.575	0.222	2.112	0.048
p-value	<0.01	>0.15	<0.01	>0.15

The Shapiro-Wilk and Anderson-Darling statistics test the normality of the distribution.

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APPENDIX 5

ASSESSMENT RESULTS FOR CONTACT-TYPE AND REEF-TYPE PGE PERMISSIVE TRACTS IN FINLAND

AkanvaaraReefPGE
HoikanvaaraContactPGE
HoikanvaaraReefPGE
JunttilanniemiReefPGE
KaamajokiContactPGE
KaamajokiReefPGE
KärppäsuoContactPGE
KärppäsuoReefPGE
KaukuaContactPGE
KaukuaReefPGE
KemiReefPGE
KoitelainenContactPGE
KoitelainenReefPGE
KonttijärviContactPGE
KonttijärviReefPGE
KoulumaoivaContactPGE
KoulumaoivaReefPGE
KuusijärviContactPGE
KuusijärviReefPGE
LipeävaaraContactPGE
LipeävaaraReefPGE
MurtolampiContactPGE
MurtolampiReefPGE001
NäränkävaaraReefPGE001
NarkausContactPGE
NarkausReefPGE
PenikatReefPGE
PintamoContactPGE
PintamoReefPGE
PirivaaraContactPGE
PirivaaraReefPGE
PorttivaaraPyhitysReefPGE
PorttivaaraContactPGE
PyhitysContactPGE
RistijärviContactPGE
RistijärviReefPGE
SuhankoContactPGE
SuhankoReefPGE
SyöteContactPGE
SyöteReefPGE
TilsaContactPGE
TilsaReefPGE
TornioReefPGE

REEF-TYPE PGE ASSESSMENT FOR TRACT AkanvaaraReefPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Reef-type PGE-Ni-Cu
Descriptive model: Finnish reef-type PGE-Ni-Cu (Appendix 3)
Grade-tonnage model: Finnish reef-type PGE-Ni-Cu grade model, AkanvaaraReefPGE tonnage model (Appendix 4)

LOCATION AND RESOURCE SUMMARY

The Akanvaara layered intrusion is located in northern Finland in the municipality of Savukoski, 135 km northeast from Rovaniemi. The 1:100 000 KKJ map sheets are 3644 and 3733. The UTM map sheets containing the intrusion are U5132 and U5141. The PGE resource assessment carried out for this report is summarised in Table 1.

Table 1. Summary of selected resource assessment results for AkanvaaraReefPGE.

Date of assessment	Assessment depth (km)	Tract area (km^2)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
29.08.2008	1	25	Pt	0	Pt	280	Pt	130
			Pd	0	Pd	510	Pd	260
			Au	0	Au	12	Au	7
			Ni	0	Ni	78,000	Ni	58,000
			Cu	0	Cu	98,000	Cu	59,000

t = metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The Akanvaara 2.44 Ga (Mutanen 1998, Mutanen & Huhma 2001) layered intrusion dips to the SE at about 35°, and has a stratigraphic thickness of about 3 km (Mutanen 1997). The upper part of the intrusion at and above the Upper Chromitite layer (UC in Mutanen 1997) is used to determine the permissive tract. Hence, the permissive tract matches with the surface projection of this upper part of the intrusion down to 1 km depth. The NW margin of the tract is defined by information from the bedrock map (Mutanen 1997, Geological Survey of Finland 2008) and diamond drill holes, whereas the SE margin is defined by the projection of the hanging wall contact of the intrusion at 1 km depth to the surface. The intrusion is assumed to extend deeper than 1 km. The chromitite layers within the lower part of the intrusion are weakly PGE-enriched. However, the lower part of the intrusion is excluded from the permissive tract, due to the unfavourable rock type and the fact that drilling has not revealed significant PGE reefs in that part of the intrusion. The sources of information used in the delineation of the tract are summarised in Table 4.

Known deposits

There are no well-explored reef-type PGE deposits within the Akanvaara permissive tract.

Prospects, mineral occurrences, and related deposit types

Two partially explored reef-type PGE occurrences are known within the Akanvaara permissive tract: Upper Chromitite reef in the upper part of the Main Zone, and PGE-Aomalous Anorthosite in the Upper Zone of the intrusion (Table 2 and Figure 1). The Upper Chromitite is known from drill core observations to continue throughout the width and length of the upper part of the Akanvaara intrusion. The horizontal extent of the PGE-Anomalous Anorthosite is not well known, as there only are three drill hole intersections across the zone.

No other types of PGE mineralisation are known at Akanvaara; the intrusion is reasonably well explored, and no indications of contact-type mineralisation have been discovered. The intrusion has only a thin contact zone and the interaction between mafic magma and the footwall country rocks is delimited and diminishes the potential for contact type PGE deposits. The stratigraphically first set of chromitite layers is encountered about 50 m above the footwall contact, directly above the chilled margin rocks.

Table 2. Significant prospects and occurrences in AkanvaaraReefPGE

Name	X coordinate	Y coordinate	Age (Ga)	Comments (grade and tonnage data, if available)	Reference
Upper Chromitite	7454000	3554000	2.43	18.1 Mt @ 22.8 Cr2O3, 0.4% V, 0.912 ppm PGE (Reef thickness 1 m, extent 7.9 km along strike, tonnage down to 300 m vertical depth; occurrence open at depth)	Mutanen (1998)
PGE-Anomalous Anorthosite	7454000	3554000	2.43	Two PGE-enriched sulphide-free layers or zones (14 m and 18-21 m thick); peak grade 1.26 ppm PGE for 1.05 m.	Mutanen (1998)

Exploration history

Geological Survey of Finland (GTK) investigated the occurrence of vanadium in the gabbroic rocks of the Akanvaara intrusion in the early 1970s and also performed till geochemical studies within the area (Mutanen 1998). Rautaruukki Oy carried out exploration in the area in 1973–1974 (Manninen 1981). Exploration for Ni and PGE commenced in the Akanvaara area in 1990 when GTK started bedrock mapping and a geophysical ground survey. Attention was drawn to the area by analogy with the Koitelainen intrusion (Mutanen 1997). During 2002, Outokumpu Mining Oy drilled five diamond drill holes into the Akanvaara layered intrusion. The types of exploration work done in the area, and known to us, are listed in Table 3.

Table 3. Exploration history for the Akanvaara intrusion.

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Bedrock mapping	No	Rautaruukki	1973–1974
	Detailed bedrock mapping, outcrop sampling	Yes	GTK	1990s
Geochemical surveys	Till geochemical survey	No	GTK	1970s
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	1979–1980
Ground geophysical surveys	Electromagnetic, magnetic and gravity surveys covering 97.5 km2; down-hole survey on 5500 m of drill hole		GTK	1990s
Drilling	112 diamond drill holes, total 17369.6 m	Yes	GTK	1994–1997
	Five (SK/AKV-1...5) diamond drill holes, total 700.7 m	Yes	Outokumpu Mining	2002
Other	Ore mineralogical investigations on 700 polished thin sections. Beneficiation studies on chromite.		GTK	1990–1998
	Petrophysical measurements for 4805 drill core samples.			
	Chemical analyses for over 2000 samples; PGE+Au analysed for about 600 samples			
	Re-logging 9 drill holes (1554.2 m).	Yes	Outokumpu Mining	2003

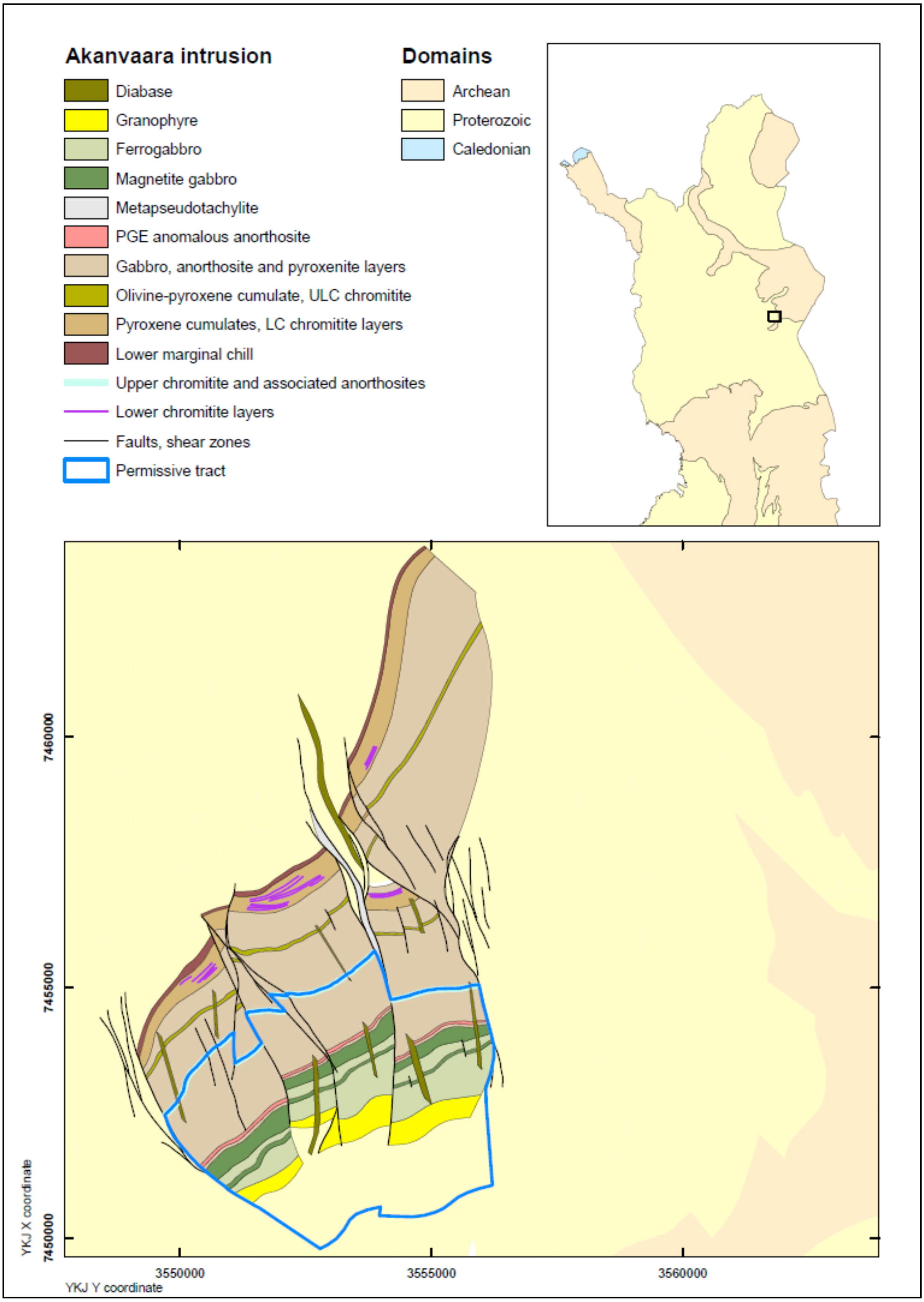

Figure 1. Location of the permissive tract AkanvaaraReefPGE.

Sources of information

Principal sources of information used by the assessment team for delineation of AkanvaaraReefPGE are listed in Table 4.

Table 4. Principal sources of information used by the assessment team for AkanvaaraReefPGE.

Theme	Type of source	Scale	Citation
Geology	PhD thesis on Akanvaara and Koitelainen intrusions Geological map of the Akanvaara intrusion Bedrock Map Database of Finland	 1: 20 000	Mutanen (1997) Mutanen (1997) Geological Survey of Finland (2008)
Mineral occurrences	PhD thesis and exploration report on geology and mineral occurrences of the Akanvaara and Koitelainen intrusions		Mutanen (1997, 1998)
Geochemistry	U-Pb age determination from zircon		Mutanen (1998), Mutanen & Huhma (2001)
Geophysics	Not used		
Exploration	General and detailed descriptions of exploration activities and results in the area		Mutanen (1997, 1998, 1999)

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

Two reef-type occurrences are known within the tract (Table 2). These occurrences are so modest that it was considered possible that neither of them would become an economic deposit, even under the most favourable circumstances. Hence, the minimum number of undiscovered reef-type deposits at Akanvaara can be zero.

The existence of thick PGE-anomalous layers was considered to indicate a potential for at least one undiscovered reef-type deposit. On the other hand, the intrusion is rather extensively drilled, but no significant deposits have been found. The intrusion was not considered as promising as the Koitelainen intrusion. Estimator 3 pointed out that all studies indicate only one significantly critical zone: the PGE-Anomalous Anorthosite about 50 m below the magnetite gabbro. A consensus was not reached in the discussion and means of the numbers given by individual estimators were used as input to the Eminers software (Table 5).

Table 5. Undiscovered deposit estimates, deposit numbers, and tract area for AkanvaaraReefPGE.

Mean undiscovered deposit estimate					Summary statistics					Area (km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}	
1	2	2			1.6	0.46	28	0	1.6	25

Estimator	Estimated number of undiscovered deposits				
	N90	N50	N10	N05	N01
Estimator 1	1	2	2		
Estimator 2	1	2	3		
Estimator 3	0	1	1		
Mean	1	2	2		

Nxx = Estimated number of deposits associated with the xx^th^ percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were calculated by combining the undiscovered deposit estimates with the Finnish reef-type PGE grade model and the AkanvaaraReefPGE tonnage model (Appendix 4) using the EMINERS software (Root et al. 1992, Duval 2004). Results of the Monte Carlo simulation are presented as cumulative frequency plots (Figure 2) and selected simulation results are reported in Table 6. The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralized rock.

Table 6. Results of Monte Carlo simulations of undiscovered resources in AkanvaaraReefPGE.

Material	At least the indicated amount at the probability of					Mean	Probability of mean or greater	Probability of zero
	0.95	0.9	0.5	0.1	0.05			
Pt (t)	0	17	130	650	1,100	280	0.27	0.06
Pd (t)	0	39	260	1,100	1,800	510	0.27	0.06
Au (t)	0	1	7	29	42	12	0.32	0.06
Ni (t)	0	10,000	58,000	170,000	230,000	78,000	0.36	0.06
Cu (t)	0	4,600	59,000	240,000	340,000	98,000	0.34	0.06
Rock (Mt)	0	16	79	220	270	99	0.39	0.06

t – metric tonnes; Mt – millions of tonnes.

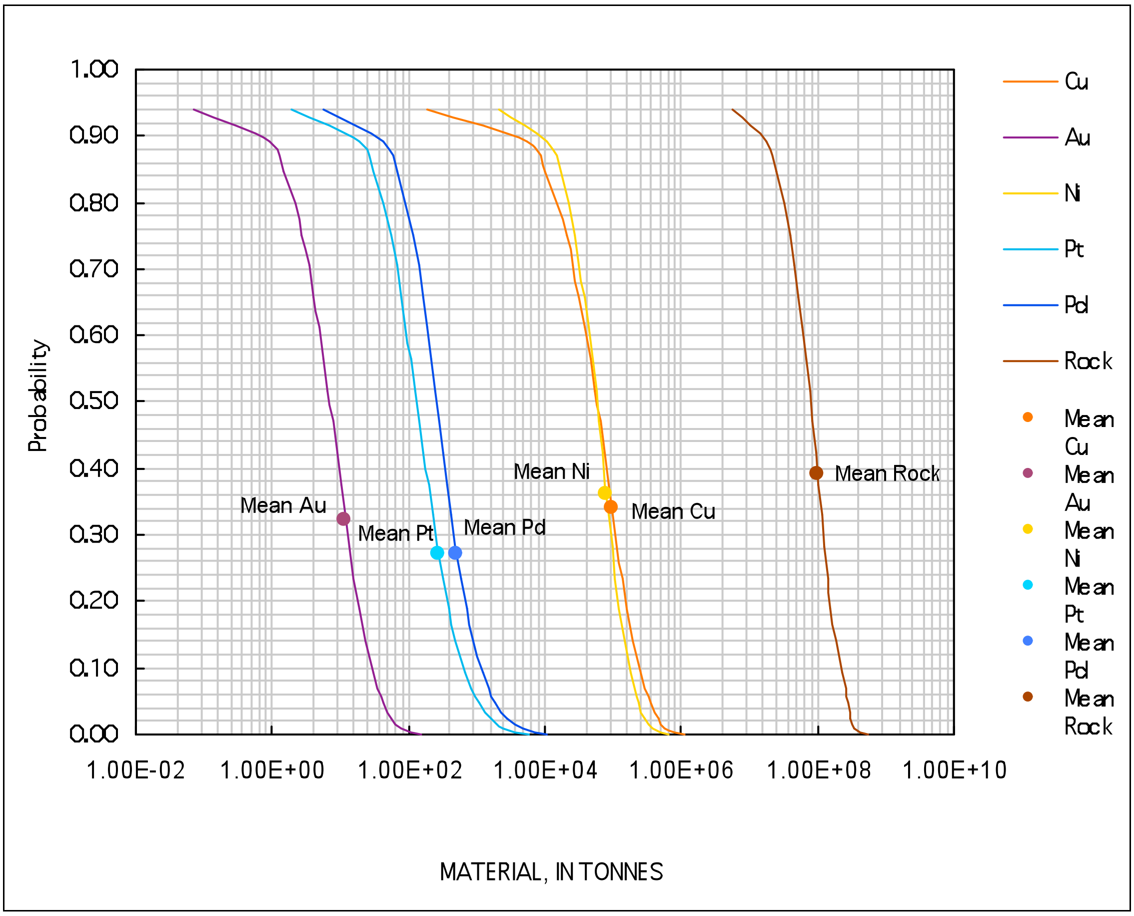

Figure 2. Cumulative frequency plot showing the results of Monte Carlo computer simulation of undiscovered resources in AkanvaaraReefPGE.

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CONTACT-TYPE PGE ASSESSMENT FOR TRACT HoikanvaaraContactPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Contact-type Cu-Ni-PGE
Descriptive model: Fennoscandian contact-type Cu-Ni-PGE (Appendix 1)
Grade and tonnage model: Fennoscandian contact-type Cu-Ni-PGE (Appendix 2)

LOCATION AND RESOURCE SUMMARY

The Hoikanvaara block of the Western intrusion of the Koillismaa Complex is located in northern Finland in the municipality of Taivalkoski, 130 km southeast from the city of Rovaniemi. The 1:100 000 KKJ map sheet is 3543. The UTM map sheet containing the block is S5213. The PGE resource assessment carried out for this report is summarised in Table 1.

Table 1. Summary of selected resource assessment results for HoikanvaaraContactPGE

Date of assessment	Assessment depth (km)	Tract area (km^2)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
27.08–02.10.2008	1	1.6	Pt	0	Pt	0	Pt	0
			Pd	0	Pd	0	Pd	0
			Au	0	Au	0	Au	0
			Ni	0	Ni	0	Ni	0
			Cu	0	Cu	0	Cu	0

t = metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The permissive tract delineated in Figure 1 is a surface projection of the basal contact zone of the Hoikanvaara block. On the surface, the delineation is based on a geological map by Räsänen et al. (2004), and low-altitude airborne magnetic survey data by GTK. Geophysical data imply that Hoikanvaara is a shallow block, which caused us to delineate the permissive tract along the contact between the block and its country rocks on the present erosion surface. The tract delineation at depth is based on drilling (Outokumpu Oy 1965, GTK 1998) and geophysical information (local ground surveys). The sources of information used in the delineation of the tract are summarized in Table 5.

Known deposits

No contact-type PGE deposits are known from Hoikanvaara.

Prospects, mineral occurrences, and related deposit types

One contact-type PGE prospect is known within the tract (Table 2 and Figure 1), the Hoikanvaara PGE prospect exposed at the southern margin of the Hoikanvaara Block.

Table 2. Significant prospects and occurrences in HoikavaaraContactPGE.

Name	X coordinate	Y coordinate	Age (Ma)	Comments (grade and tonnage data, if available)	Reference
Hoikanvaara	7296600	3542400	2.44	Several 1 m sections at 0.3–0.6 g/t Pd, 0.1–0.2 g/t Pt, 0.08–0.13 g/t Au, 0.2–0.3% Ni, 0.2–0.4% Cu	Iljina (2004)

Deposit ages are derived from the assumed age of the Hoikanvaara intrusion based on age data from the Porttivaara Block of the Koillismaa intrusion (Alapieti 1982).

Exploration history

Exploration in the region commenced in 1965 when Outokumpu Oy started to map and drill the marginal series targets in the Koillismaa Intrusion. Types of exploration work carried out in the Hoikanvaara tract area, and known to us, are listed in Table 3.

Table 3. Exploration history for HoikanvaaraContactPGE.

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Detailed bedrock mapping, outcrop sampling	A few cases	Outokumpu Oy,	1960s
	Detailed bedrock mapping, outcrop sampling		Oulu University	1970s
Geochemical surveys	None			
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	1998
Ground geophysical surveys	VLF-R, magnetic and IP surveys		GTK	1998
Drilling	2 diamond-drill holes, total 246.57 m	Yes	Outokumpu Oy	1965
	5 diamond-drill holes, total 623.60 m	Yes	GTK	1998
Other	Regional research and mapping programme in the KLIC region.	No	Univ Oulu	1971–1976
	Regional research and exploration programme in the KLIC region.	Yes	GTK	1996–2000

KLIC = Koillismaa Layered Igneous Complex.

Sources of information

Principal sources of information used by the assessment team for delineation of HoikanvaaraContactPGE are listed in Table 4.

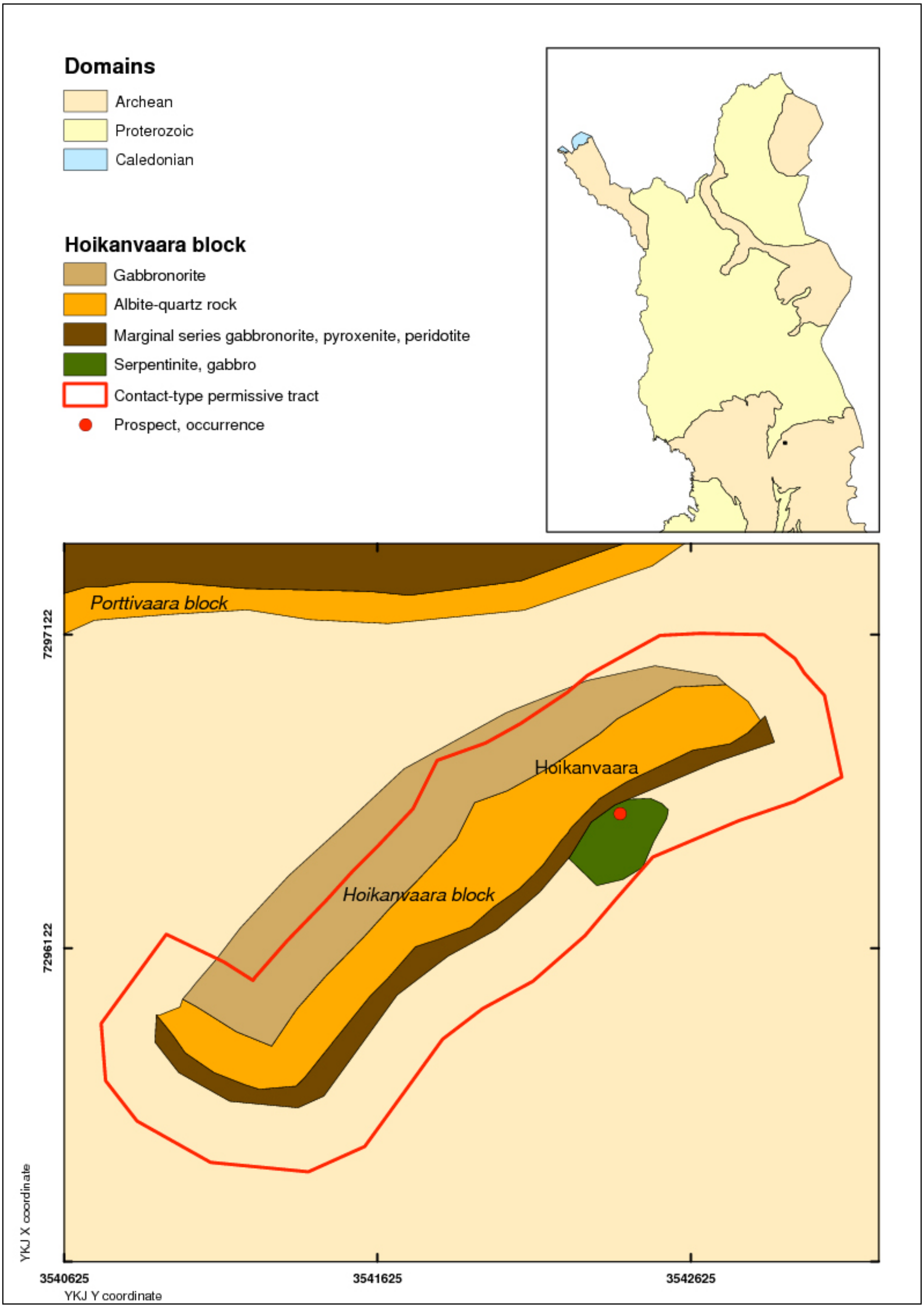

Figure 1. Location of the permissive tract HoikanvaaraContactPGE.

Table 4. Principal sources of information used by the assessment team for HoikanvaaraContactPGE.

Theme	Type of source	Scale	Citation
Geology	Geological description of the KLIC geology and then known mineral occurrences		Alapieti (1982)
	Geological description of the KLIC geology and the known mineral occurrences		Iljina (2004)
	Geological map of the KLIC region	1:200 000	Räsänen et al. (2004)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
	PhD on geology and reef-type mineralisation in the Western Koillismaa Intrusion		Karinen (2010)
Mineral occurrences	Summary report and overview of exploration work in the area		Iljina (2004)
Geochemistry	Not available		
Geophysics	Magnetic and IP survey		Iljina (2004)
Exploration	Detailed description of exploration activities in the area by GTK		Iljina (2004)

KLIC = Koillismaa Layered Igneous Complex.

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

Geological factors that were used to estimate the number of undiscovered deposits included the geology of the intrusion, the distribution of the known deposits, and the available geophysical and drilling data (Tables 3 and 4).

One contact-type prospect (Hoikanvaara) is known within the tract. Since no resource estimate is available, it was not included in the grade and tonnage model. This would mean that the number of undiscovered contact-type deposits within the tract is at least one, but only if that prospect indeed has enough grade and tonnage to possibly be suitable for mining. The extent of the Hoikanvaara permissive tract projected on the surface was calculated to be small, only 0.8 km^2. The known prospect is small and suspected to be uneconomic. Consequently, the minimum number of undiscovered deposits that could exist within the tract is zero deposits.

Estimators 2 and 3 considered that as the tract has been so extensively drilled, there is no room for an undiscovered deposit (of suitable size for mining) even to be listed in the 10th percentile of probability. Estimator 1 was optimistic and believed there is a small probability that a small and rich deposit exists. A consensus was not reached in the discussion and means of the numbers given by individual estimators were used as input to the Eminers software (Table 5).

Table 5. Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for HoikanvaaraContactPGE.

Mean of undiscovered deposit estimate					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
0	0	0			0	0.12	–	0	0	1.6	0

Estimator	N90	N50	N10	N05	N01
	Estimated number of undiscovered deposits				
Estimator 1	0	0	1		
Estimator 2	0	0	0		
Estimator 3	0	0	0		
Mean	0	0	0		

Nxx = Estimated number of deposits associated with the xx^{th} percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; Deposit density = deposit density reported as the total number of deposits per km^2. N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were not estimated, because the result of the assessment workshop suggested a mean probability of less than 10% for at least one deposit to occur within the tract.

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REEF-TYPE PGE ASSESSMENT FOR TRACT HoikanvaaraReefPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Reef-type PGE-Ni-Cu
Descriptive model: Finnish reef-type PGE-Ni-Cu (Appendix 3)
Grade-tonnage model: Finnish reef-type PGE-Ni-Cu grade model, HoikanvaaraReefPGE tonnage model (Appendix 4)

LOCATION AND RESOURCE SUMMARY

The Hoikanvaara block of the Western intrusion of the Koillismaa Complex is located in northern Finland in the municipality of Taivalkoski, 130 km southeast from the city of Rovaniemi. The 1:100 000 KKJ map sheet is 3543. The UTM map sheet containing the block is S5213.

Table 1. Summary of selected resource assessment results for HoikanvaaraReefPGE.

Date of assessment	Assessment depth (km)	Tract area (km²)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
22.09–02.10.2008	1	1.1	Pt	0	Pt	2	Pt	0
			Pd	0	Pd	5	Pd	0
			Au	0	Au	0	Au	0
			Ni	0	Ni	650	Ni	0
			Cu	0	Cu	840	Cu	0

t = metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

Airborne and local ground surveys imply that the Hoikanvaara intrusive block is very small and therefore shallow. The block dips to the NW with an angle of about 50 degrees. The permissive tract matches the surface projection of the layered-series part of the block. The tract delineation at depth is based on drilling by GTK in 1998, and on geophysical information (airborne and grounds surveys). The sources of information used in the delineation of the tract are summarized in Table 3.

Known deposits

No reef-type PGE deposits have been found within the area of Hoikanvaara permissive tract.

Prospects, mineral occurrences, and related deposit types

No obvious reef-type PGE prospects are known from the tract.

Exploration history

Exploration in the region commenced in 1965 when Outokumpu Oy started to map and drill the marginal series targets within the Koillismaa Intrusion. Types of exploration work carries out in the Hoikanvaara tract area, and known to us, are listed in Table 2.

Table 2. Exploration history for HoikanvaaraReefPGE.

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Detailed bedrock mapping, outcrop sampling	A few cases	Outokumpu Oy,	1960s
	Detailed bedrock mapping, outcrop sampling		Oulu University	1970s
Geochemical surveys	None			
Airborne geo-physical surveys	Low-altitude airborne magnetic, electromag-netic and radiometric survey		GTK	1998
Ground geophysi-cal surveys	VLF-R, magnetic and IP surveys		GTK	1998
Drilling	2 diamond-drill holes, total 246.57 m	Yes	Outokumpu Oy	1965
	5 diamond-drill holes, total 623.60 m	Yes	GTK	1998
Other	Regional research and mapping programme in the KLIC region.	No	Univ Oulu	1971–1976
	Regional research and exploration programme in the KLIC region.	Yes	GTK	1996–2000

KLIC = Koillismaa Layered Igneous Complex.

Sources of information

Principal sources of information used by the assessment team for delineation of HoikanvaaraReefPGE are listed in Table 3.

Table 3. Principal sources of information used by the assessment team for HoikanvaaraReefPGE.

Theme	Type of source	Scale	Citation
Geology	Geological description of the KLIC geology and then known mineral occurrences		Alapieti (1982)
	Geological description of the KLIC geology and the known mineral occurrences		Iljina (2004)
	Geological map of the KLIC region	1:200 000	Räsänen et al. (2004)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
	PhD on geology and reef-type mineralisation in the Western Koillismaa Intrusion		Karinen (2010)
Mineral occurrences	Summary report and overview of exploration work in the area		Iljina (2004)
Geochemistry	Not available		
Geophysics	Magnetic and IP survey		Iljina (2004)
Exploration	Detailed description of exploration activities in the area by GTK		Iljina (2004)

KLIC = Koillismaa Layered Igneous Complex.

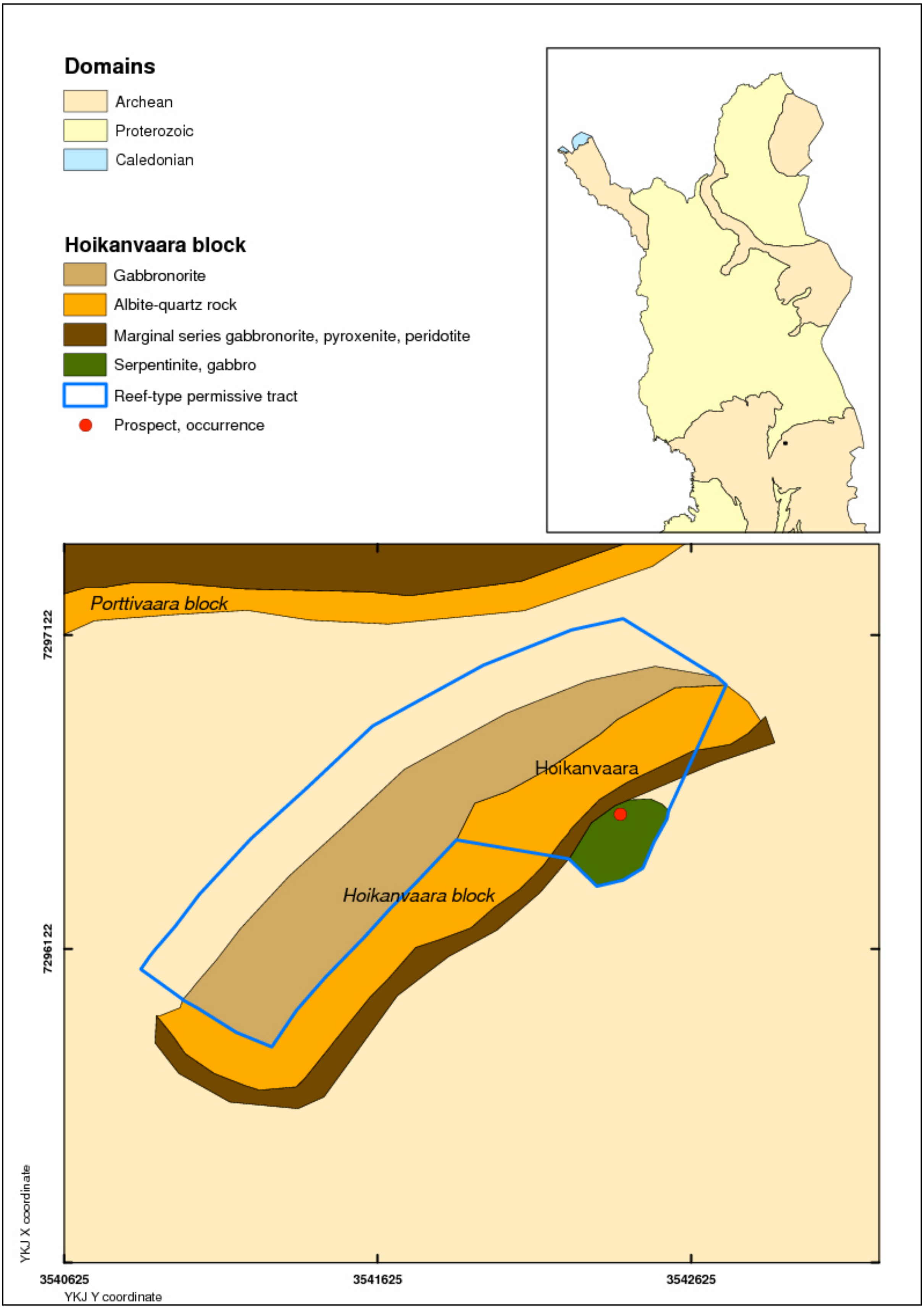

Figure 1. Location of the permissive tract HoikanvaaraReefPGE.

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

Not a single reef-type prospect is known within the tract. This means that the minimum number of undiscovered reef-type deposits within the tract is zero.

Two estimators argued for a small possibility of one reef-type deposit occurring, whereas one estimator insisted that there is no possibility for even one deposit in such a small intrusive block, where most of the volume comprises marginal series rocks (Table 4). Hence, mean values were used in the further assessment.

Table 4. Undiscovered deposit estimates, deposit numbers, and tract area for HoikanvaaraReefPGE.

Mean undiscovered deposit estimate					Summary statistics					Area (km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}	
0	0	1			0.30	0.50	170	0	0.30	1.1

Estimator	Estimated number of undiscovered deposits				
	N90	N50	N10	N05	N01
Estimator 1	0	0	1		
Estimator 2	0	0	0		
Estimator 3	0	0	1		
Mean	0	0	1		

Nxx = Estimated number of deposits associated with the xx^{th} percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were calculated by combining the undiscovered deposit estimates with the Finnish reef-type PGE grade model and the HoikanvaaraReefPGE tonnage model (Appendix 4) using the EMINERS software (Root et. al. 1992, Duval 2004). Results of the Monte Carlo simulation are presented as cumulative frequency plots (Figure 2) and selected simulation results are reported in Table 5. The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralized rock.

Table 5. Results of Monte Carlo simulations of undiscovered resources in HoikanvaaraReefPGE.

Material	At least the indicated amount at the probability of					Mean	Probability of mean or greater	Probability of zero
	0.95	0.9	0.5	0.1	0.05			
Pt (t)	0	0	0	5	11	2	0.16	0.70
Pd (t)	0	0	0	10	21	5	0.17	0.70
Au (t)	0	0	0	0	1	0	0.18	0.70
Ni (t)	0	0	0	2,000	3,600	650	0.22	0.70
Cu (t)	0	0	0	2,200	4,800	840	0.17	0.70
Rock (Mt)	0	0	0	3	5	1	0.24	0.70

t = metric tonnes; Mt = millions of tonnes.

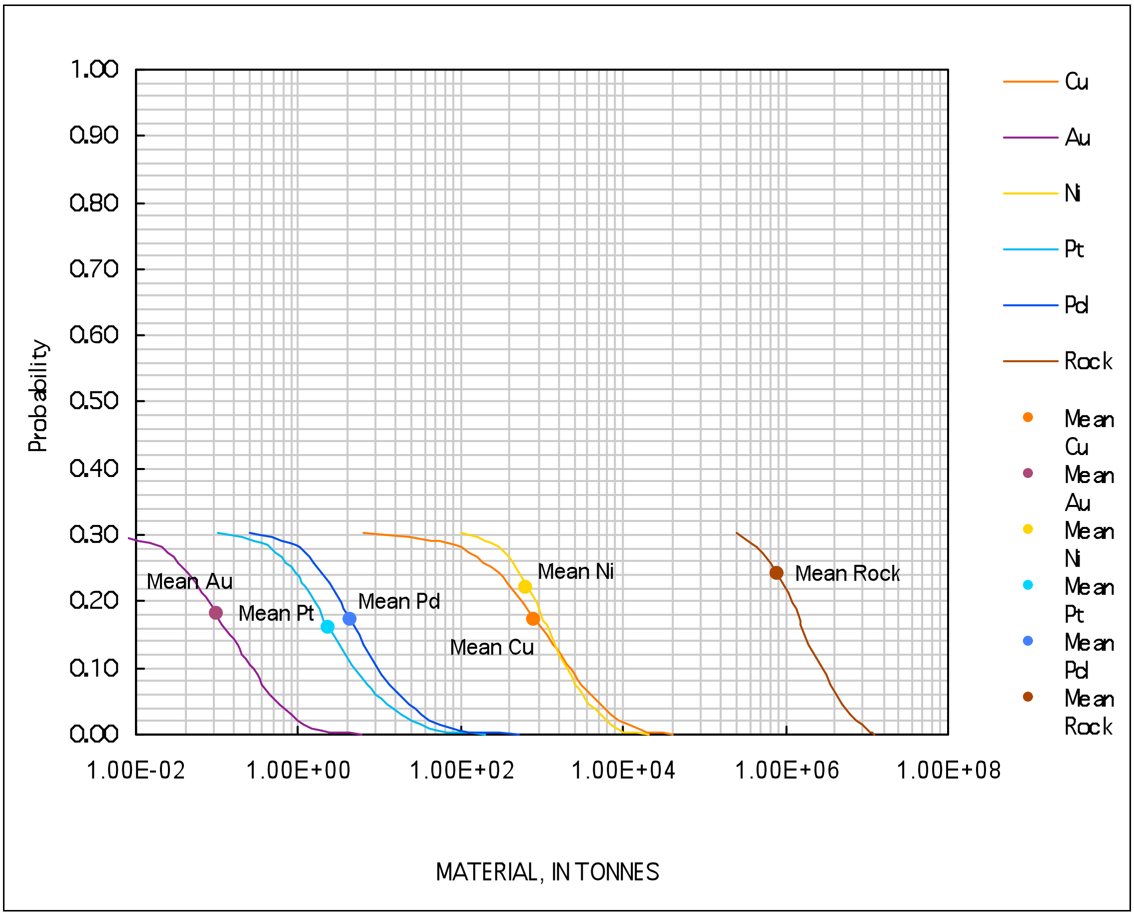

Figure 2. Cumulative frequency plot showing the results of Monte Carlo computer simulation of undiscovered resources in HoikanvaaraReefPGE.

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REEF-TYPE PGE ASSESSMENT FOR TRACT JunttilanniemiReefPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Reef-type PGE-Ni-Cu
Descriptive model: Finnish reef-type PGE-Ni-Cu (Appendix 3)
Grade-tonnage model: Finnish reef-type PGE-Ni-Cu grade model, JunttilanniemiReefPGE tonnage model (Appendix 4)

LOCATION AND RESOURCE SUMMARY

The Junttilanniemi layered intrusion is located in northern Finland in the municipality of Paltamo (Wilkman 1931, Kontinen & Meriläinen 2004), about 250 km S from Rovaniemi and 20 km NW from Kajaani. The 1:100 000 KKJ map sheet is 3432. The UTM map sheet containing the intrusion is Q5224. The PGE resource assessment carried out for this report is summarised in Table 1.

Table 1. Summary of selected resource assessment results for JunttilanniemiReefPGE.

Date of assessment	Assessment depth (km)	Tract area (km^2)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
29.08.2008	1	1.8	Pt	0	Pt	12	Pt	0
			Pd	0	Pd	23	Pd	0
			Au	0	Au	1	Au	0
			Ni	0	Ni	3,300	Ni	0
			Cu	0	Cu	4,100	Cu	0

t = metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The Junttilanniemi intrusion dips SE to S with an angle of about 70 degrees and probably extends to the depth of >1 km. The intrusion is overturned, as the top is to the NW. No marginal series has been encountered at Junttilanniemi. The intrusion has abundant outcrop, except in its southern part with the greatest PGE potential, which is under a lake. On the other hand, very little drilling has been performed in the whole area of the intrusion. The possible undiscovered reef-type PGE deposit in the Junttilanniemi intrusion is located within the lowest part of the intrusion, 200–600 m above its base. This lowermost part of the Junttilanniemi layered intrusion contains the contact between earlier boninitic-like (Cr-rich) and later tholeiitic magma units and it is used to delineate the permissive tract. The delineation is based on the view that no reefs can exist in the magnetite gabbro in the upper, northern part of the intrusion. This idea is supported by the fact that no anomalous PGE concentrations were measured from a series of outcrop and drill core samples from the intrusion (Halkoaho, pers. comm., 2008). Furthermore, rocks having a similar (very low) Cr contents as those in the upper part of the Junttilanniemi intrusion, and yet having high PGE grades have not been encountered anywhere in the Fennoscandian shield. Hence, the permissive tract matches with the surface projection of the southern part of the intrusion down to 1 km depth (Figure 1). The eastern contact is tectonic. The sources of information used in the delineation of the tract are summarised in Table 3.

Known deposits

No reef-type PGE deposits are known within the Junttilanniemi permissive tract.

Prospects, mineral occurrences, and related deposit types

No obvious reef-type PGE prospects are known within the tract.

Exploration history

Exploration commenced in the Junttilanniemi area in 1974 when Rautaruukki Oy drilled three diamond drill holes into the magnetite gabbro unit. Bedrock mapping began at Junttilanniemi at the end of the 1980s, when the Geological Survey of Finland (GTK) started to map the area. During 1992–1993, the Department of Geology of the University of Oulu performed some field work in the area. In 2003, more attention was drawn to the area with the discovery of a glacial erratic boulder containing a sulphide dissemination with significant PGE grades (Pt+Pd = 8.4 ppm, Pd/Pt = 4.4). The boulder was found in the northernmost part of the Nurmes municipality. During 2003–2008, systematic PGE analyses were made on outcrop samples and on a few drill core samples, but the results gave no indications of PGE anomalous zones. The exploration history for the Junttilanniemi intrusion is summarised in Table 2.

Table 2. Exploration history for the Junttilanniemi intrusion.

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Detailed bedrock mapping, outcrop sampling	No	GTK	1987–1991
		No	University of Oulu	1992–1993
		Yes	GTK	2003–2008
Geochemical surveys	None performed			
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric surveys		GTK	1987
Ground geophysical surveys	Not done			
Drilling	Four diamond drill holes, total 242.5 m	No	Rautaruukki	1974
Other	Age determination 2443 ± 7 Ma	No	GTK	2006

Sources of information

Principal sources of information used by the assessment team for the delineation of JunttilanniemiReef-PGE are listed in Table 3.

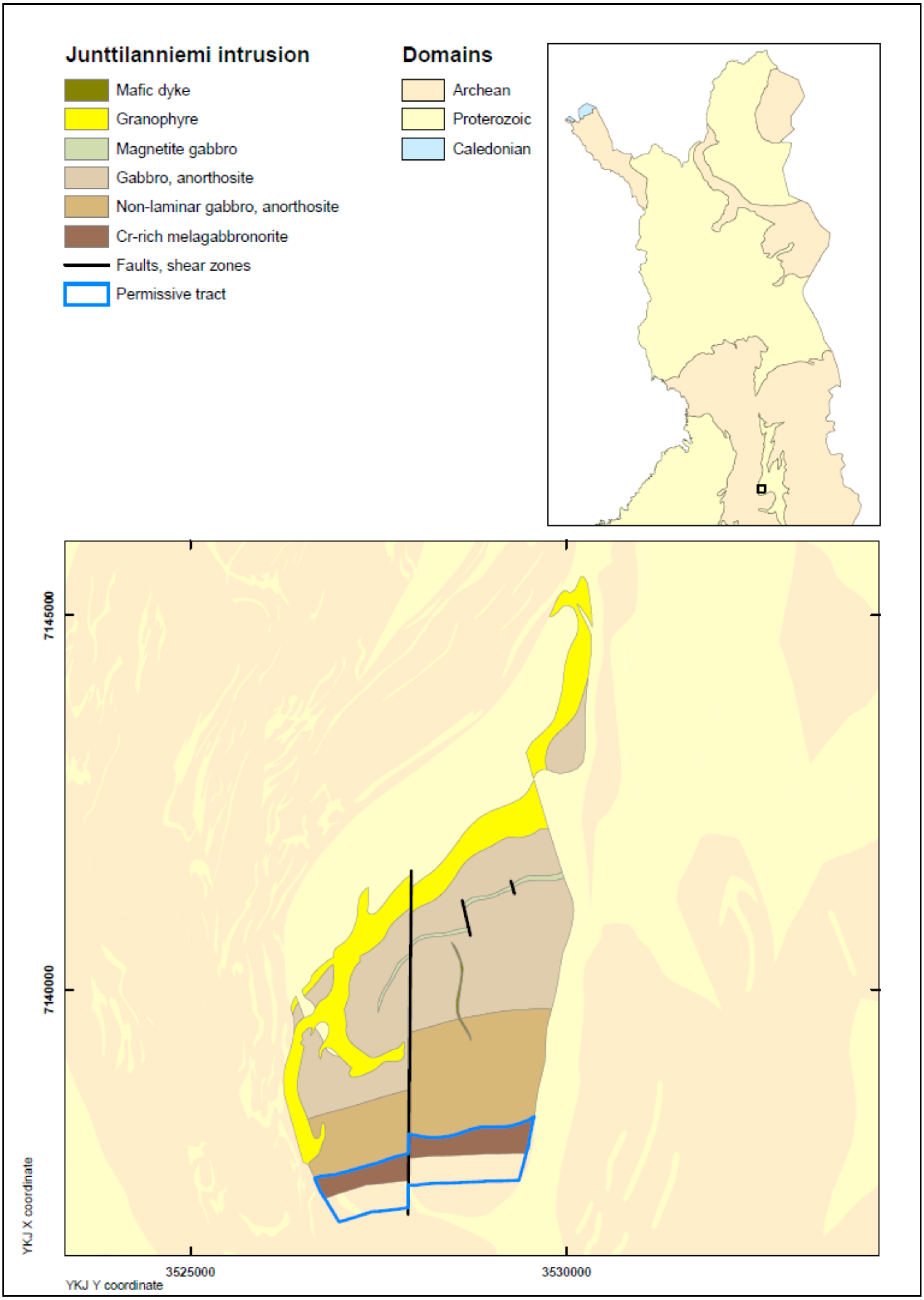

Figure 1. Location of the permissive tract JunttilanniemiReefPGE.

Table 3. Principal sources of information used by the assessment team for JunttilanniemiReefPGE.

Theme	Type of source	Scale	Citation
Geology	Geological map, sheet C 4 Kajaani	1:400 000	Wilkman (1931)
	Geological map, sheet 3234 Paltaniemi	1:100 000	Kontinen & Meriläinen (2004)
	Geological map of the Junttilanniemi intrusion		Halkoaho (2008, unpublished)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
Mineral occurrences	NA		
Geochemistry	NA		
Geophysics	NA		
Exploration	NA		

NA = not available.

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

Factors that were used to estimate the number of undiscovered reef-type deposits included the geology and size of the Junttilanniemi intrusion, and the available geophysical and drilling data (Tables 2 and 3).

No reef-type prospects are known within the tract. This means that the minimum number of undiscovered reef-type deposits within the tract is zero. The intrusion has a relatively extensive outcrop coverage, except for the area with the greatest PGE potential, which is under a lake. Very little drilling has been performed in the whole of the intrusion – all four drill holes were drilled in the magnetite gabbro part of the intrusion. Hence, the existence of a reef-type deposit at the present erosion level was considered possible, but only in the part under the lake.

All estimators emphasized the small size of the Junttilanniemi permissive tract and agreed on the rather small probability for the existence of an undiscovered reef-type deposit. Estimator 3 pointed out that Junttilanniemi could be the source for a PGE-bearing boulder found to the SE of the intrusion, and that the Junttilanniemi intrusion seems to contain the contact zone between earlier Cr-rich and later Cr-poorer magma units. A consensus was reached concerning the probability levels for the existence of undiscovered deposits (Table 4).

Table 4. Undiscovered deposit estimates, deposit numbers, and tract area for JunttilanniemiReefPGE.

Consensus undiscovered deposit estimate					Summary statistics					Area (km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}	
0	0	1			0.30	0.50	170	0	0.30	1.8

	Estimated number of undiscovered deposits				
Estimator	N90	N50	N10	N05	N01
Estimator 1	0	0	1		
Estimator 2	0	0	1		
Estimator 3	0	0	1		
Consensus	0	0	1		

Nxx = Estimated number of deposits associated with the xx^{th} percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were calculated by combining the undiscovered deposit estimates with the Finnish reef-type PGE grade model and the JunttilanniemiReefPGE tonnage model (Appendix 4) using the EMINERS software (Root et al. 1992, Duval 2004). Selected simulation results are reported in Table 5. Results of the Monte Carlo simulation are presented as a cumulative frequency plots (Figure 2). The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralized rock.

Table 5. Results of Monte Carlo simulations of undiscovered resources in JunttilanniemiReefPGE.

Material	At least the indicated amount at the probability of					Mean	Probability of mean or greater	Probability of zero
	0.95	0.9	0.5	0.1	0.05			
Pt (t)	0	0	0	26	58	12	0.16	0.71
Pd (t)	0	0	0	50	110	23	0.16	0.71
Au (t)	0	0	0	1	3	1	0.18	0.71
Ni (t)	0	0	0	11,000	19,000	3,300	0.21	0.71
Cu (t)	0	0	0	11,000	24,000	4,100	0.17	0.71
Rock (Mt)	0	0	0	14	24	4	0.23	0.71

t = metric tonnes; Mt = millions of tonnes.

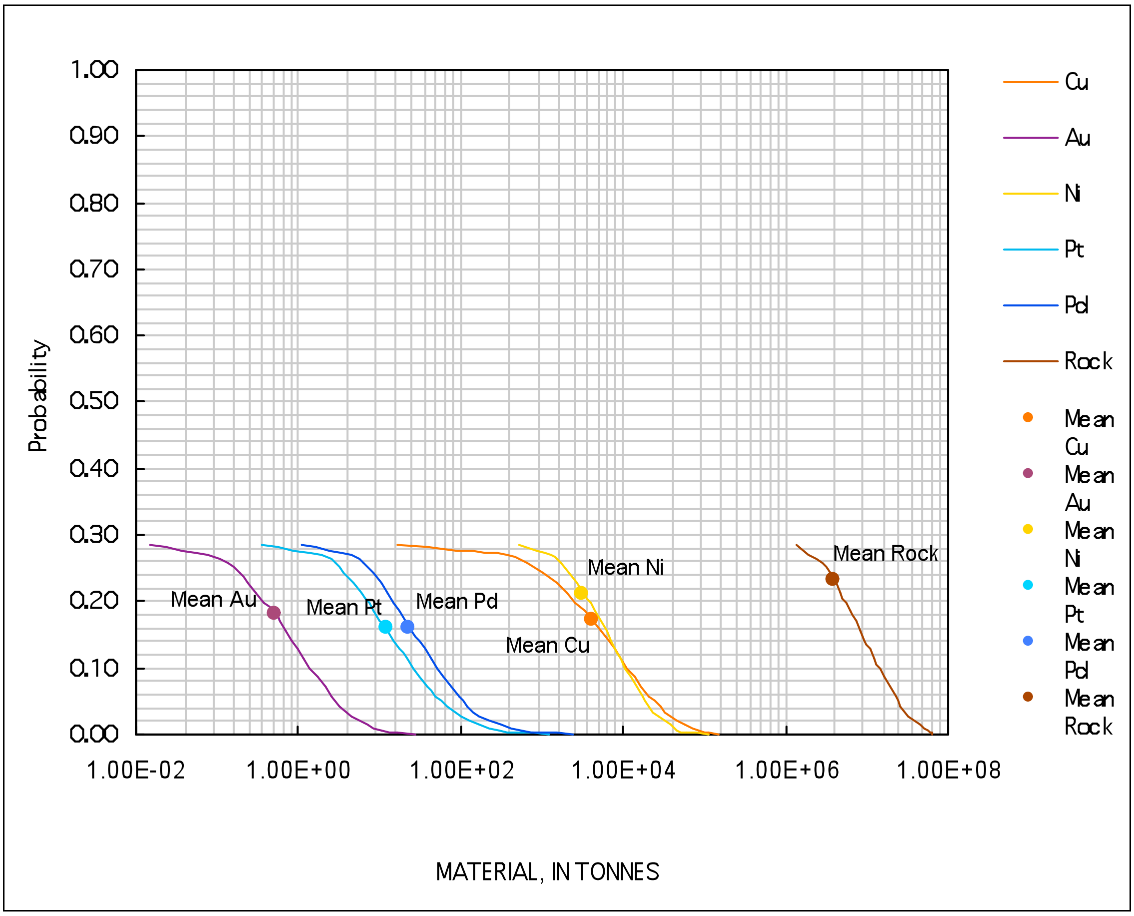

Figure 2. Cumulative frequency plot showing the results of Monte Carlo computer simulation of undiscovered resources in JunttilanniemiReefPGE.

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CONTACT-TYPE PGE ASSESSMENT FOR TRACT KaamajokiContactPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Contact-type Cu-Ni-PGE
Descriptive model: Fennoscandian contact-type Cu-Ni-PGE (Appendix 1)
Grade and tonnage model: Fennoscandian contact-type Cu-Ni-PGE (Appendix 2)

LOCATION AND RESOURCE SUMMARY

The Kaamajoki layered intrusion is located in the northwesternmost Finland, in the municipality of Enontekiö, 280 km NW from Rovaniemi. The 1:100 000 KKJ map sheets are 1832 and 1834. The UTM map sheets containing the intrusion are V3444 and W3333. The PGE resource assessment carried out for this report is summarised in Table 1.

Table 1. Summary of selected resource assessment results for KaamajokiContactPGE

Date of assessment	Assessment depth (km)	Tract area (km²)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
27.08–02.10.2008	1	16	Pt	0	Pt	25	Pt	5
			Pd	0	Pd	100	Pd	14
			Au	0	Au	9	Au	2
			Ni	0	Ni	88,000	Ni	46,000
			Cu	0	Cu	160,000	Cu	64,000

t = metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The eastern and southeastern contacts of the Kaamajoki intrusion dip at 40° to the west, and this also appears to be the dip of the bulk of the intrusion. The intrusion is interpreted to extend to approximately 1 km depth (Lanne 2004). The deepest hole drilled has intercepted the basal contact at the vertical depth of about 400 m. At the west, north and southwest, the contact is steep, probably defined by faults. At the surface, marginal series rocks may be present along the full extent of the eastern and southeastern margin of the intrusion. However, exact data are scarce, as the outcrop and drilling densities are low. Only in the southernmost part of the intrusion, at the Kaamajoki prospect, has drilling intercepted mineralised marginal series rocks.

The permissive tract delineated in Figure 1 is a surface projection of the basal contact zone of the Kaamajoki intrusion. The contact is interpreted to plunge at 40° to the west from the surface at the eastern margin of the intrusion, and to continue horizontally to the west at the depth of 1 km, until it is intersected by near vertical faults at the western margin of the intrusion. Hence, a 200 m wide buffer zone is added only to the eastern margin of the tract to accommodate possible offset-type deposits. On the surface, the delineation is based on the geological map by Kantti (2002) and on the Digital Bedrock Map Database of Geological Survey of Finland. The sources of information used in the delineation of the tract are summarisd in Table 3.

Known deposits

No contact-type PGE deposits are known within the tract.

Prospects, mineral occurrences, and related deposit types

One contact-type PGE occurrence is known within the tract (Table 2and Figure 1), the Kaamajoki PGE prospect at the southeastern margin of the Kaamajoki intrusion. It is incompletely delineated, and no tonnage and little grade data are available.

Table 2. Significant prospects and occurrences in KaamajokiContactPGE.

Name	X coordinate	Y coordinate	Age (Ga)	Comments (grade and tonnage data, if available)	Reference
Kaamajoki	7622040	3295830	2.46	14 m @ 0.55% Cu, 0.21% Ni, Pd low, Pt not analysed	Heikura et al. (2004)

Exploration history

Exploration commenced in the Kaamajoki area in 1970s when University of Turku included the intrusion in its nickel deposit research project. Attention to area was drawn by Ni- and Cu-enriched, sulphidic, glacial erratic boulders found from the area in the 1960s and 1970s. The Geological Survey of Finland (GTK) has performed work the area in several stages during 1987–1989, 1994–1995 and 2003, including bedrock mapping, geophysical field measurements, till geochemical studies and diamond drilling. The first outcrops with contact-type mineralisation features were detected in 1988 (Heikura et al. 2004). GTK claimed areas at the eastern and southeastern margin of the intrusion in 1994–1996 (Kaamajoki and Tsohkkoaivi claims), and these were relinquished in 2002. Table 3 summarises the exploration history of the Kaamajoki intrusion.

Table 3. Exploration history for the permissive track KaamajokiContactPGE.

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Detailed bedrock mapping, outcrop sampling	No	Univ. Turku	1975–1976
	Detailed bedrock mapping, outcrop sampling	Yes*	GTK	1981–1984, 1987, 1994–1996, 2003
Geochemical surveys	Till geochemical survey: six short profiles, mostly close to the E-SE contact of the intrusion	Yes*	GTK	1987–1988
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	1983, 2002
Ground geophysical surveys	Slingram, magnetic, VLF-R, Sampo-EM, and gravity surveys		GTK	1983, 1987, 1994–95
Drilling	9 diamond-drill holes	No	Univ. Turku	1976
	26 diamond-drill holes	Yes*	GTK	1989, 1995, 2003
Other	Ore mineralogy investigations		GTK	2003

* Pt not analysed.

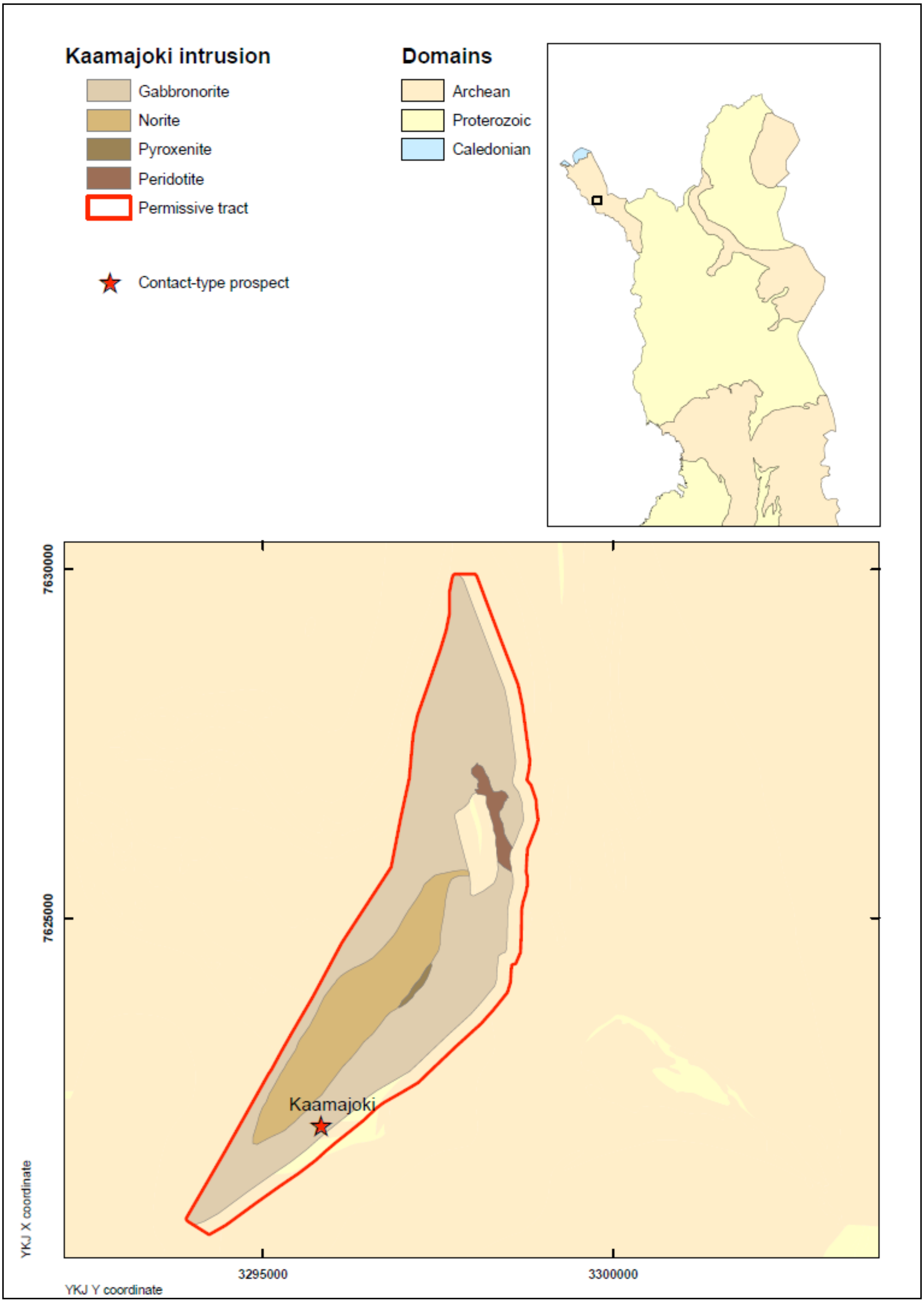

Figure 1. Location of the permissive tract KaamajokiContactPGE and the contact-type Kaamajoki prospect.

Sources of information

Principal sources of information used by the assessment team for the delineation of KaamajokiContactPGE are listed in Table 4.

Table 4 Principal sources of information used by the assessment team for KaamajokiContactPGE.

Theme	Type of source	Scale	Citation
Geology	MSc thesis on the Kaamajoki intrusion and its nickel mineralisation		Kantti (2002)
Geology	Bedrock Map Database of Finland	1:200 000	Geological Survey of Finland (2008)
Mineral occurrences	Summary report and overview of exploration work in the area	1:50 000	Heikura et al. (2004)
Mineral occurrences	MSc thesis on the Kaamajoki intrusion and its nickel mineralisation		Kantti (2002)
Geochemistry	Till geochemical survey	1:50 000	Heikura et al. (2004)
Geophysics	Slingram, magnetic, VLF-R, Sampo-EM, and gravity surveys	1:50 000	Heikura et al. (2004), Lanne (2004)
Exploration	General description of exploration activities in the area.	1:50 000	Heikura et al. (2004)

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

One contact-type prospect (Kaamajoki) is known within the tract. Since no resource estimate is available (Table 2), it was not included in the grade and tonnage model. The Kaamajoki prospect is poorly known, and it is possible that it does not contain enough metal to be economically viable. Hence, the minimum number of undiscovered contact-type deposits within the tract can be zero.

The Kaamajoki intrusion intersects Neoarchaean sulphide-bearing metasedimentary rocks (Tarju-Ruossakero), which increases its potential to host PGE mineralization. On the other hand, the central part of the intrusion, in the vicinity of the Kaamajoki prospect, is rather well drilled and not very promising. Furthermore, it is possible that the Kaamajoki prospect is a remobilised shear zone-controlled occurrence instead of a contact-type occurrence. If this is the case, there is no evidence for intrusive sulphide phase processes.

Although the estimators agreed on the rather poor potential for undiscovered deposits, they disagreed on the exact numbers of undiscovered deposits at different probability levels. Hence, the averages of the numbers given by individual estimators were used as input to the Eminers software. The average undiscovered deposit estimates at various probability levels and the values given by individual estimators are shown in Table 5. The expected number of deposits, standard deviation and the coefficient of variation, which are also given in Table 5, were calculated by the software from the undiscovered deposit estimates using a regression equation (Singer & Menzie 2005).

Table 5. Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for KaamajokiContactPGE.

Mean undiscovered deposit estimate					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
0	1	2			1.0	0.79	79	0	1.0	16	0.062

Estimator	Estimated number of undiscovered deposits				
	N90	N50	N10	N05	N01
Estimator 1	0	1	2		
Estimator 2	1	1	2		
Estimator 3	0	0	1		
Mean	0	1	2		

Nxx = Estimated number of deposits associated with the xxth percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; Deposit density = deposit density reported as the total number of deposits per km^2. N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were estimated by combining the means of estimated numbers of undiscovered contact-type PGE deposits with the Fennoscandian contact-type PGE grade and tonnage model (Appendix 2) using the EMINERS software (Root et al. 1992, Duval 2004). Selected simulation results are reported in Table 6. Results of the Monte Carlo simulation are presented as cumulative frequency plots (Figure 2). The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralized rock.

Table 6. Results of Monte Carlo simulations of undiscovered resources in KaamajokiContactPGE.

Material	At least the indicated amount at the probability of					Mean	Probability of mean or greater	Probability of zero
	0.95	0.90	0.50	0.10	0.05			
Pt (t)	0	0	5	82	120	25	0.25	0.30
Pd (t)	0	0	14	290	570	100	0.23	0.30
Au (t)	0	0	2	25	46	9	0.25	0.30
Ni (t)	0	0	46,000	250,000	330,000	88,000	0.35	0.30
Cu (t)	0	0	64,000	500,000	680,000	160,000	0.31	0.30
Rock (Mt)	0	0	21	320	450	87	0.25	0.30

t – metric tonnes; Mt – millions of tonnes.

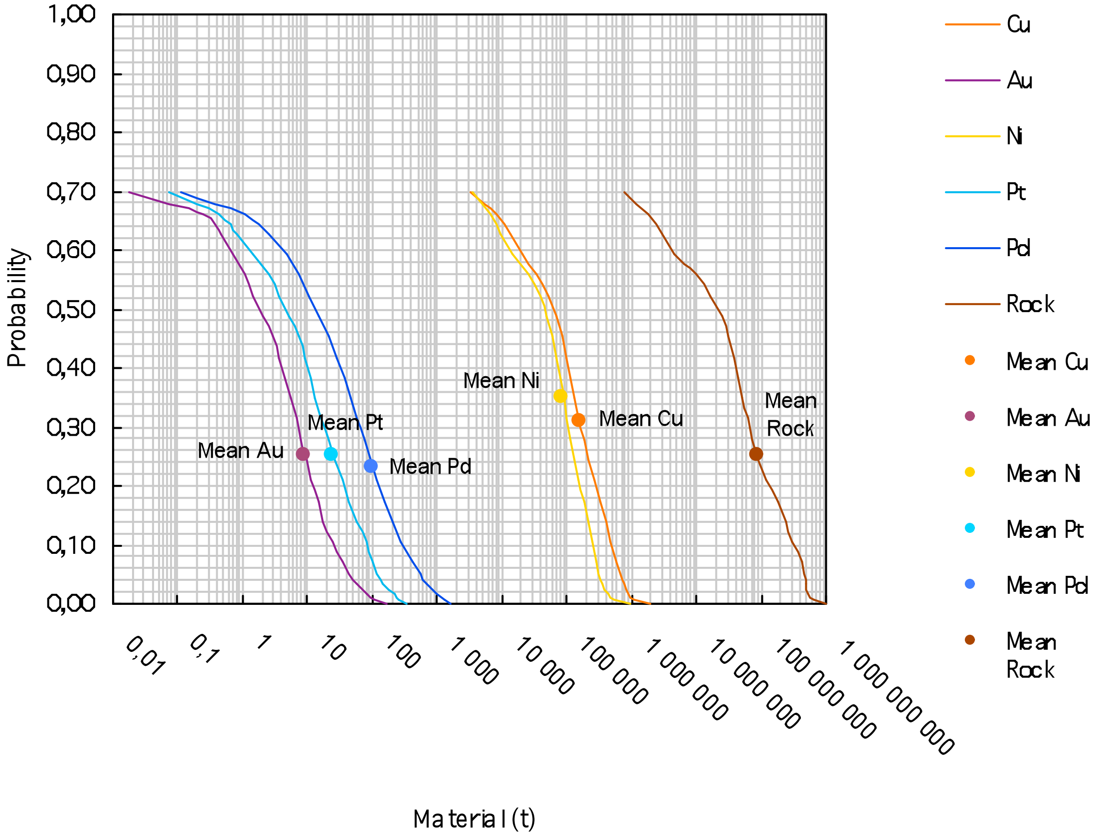

Figure 2. Cumulative frequency plot showing the results of Monte Carlo computer simulation of undiscovered resources in KaamajokiContactPGE.

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REEF-TYPE PGE ASSESSMENT FOR TRACT KaamajokiReefPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Reef-type PGE-Ni-Cu
Descriptive model: Finnish reef-type PGE-Ni-Cu (Appendix 3)
Grade-tonnage model: Finnish reef-type PGE-Ni-Cu grade model, KaamajokiReefPGE tonnage model (Appendix 4)

LOCATION AND RESOURCE SUMMARY

The Kaamajoki layered intrusion is located in northwesternmost Finland, in the municipality of Enontekiö, 280 km NW from Rovaniemi. The 1:100 000 KKJ map sheets are 1832 and 1834. The UTM map sheets containing the intrusion are V3444 and W3333.

Table 1. Summary of selected resource assessment results for KaamajokiReefPGE.

Date of assessment	Assessment depth (km)	Tract area (km^2)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
25.08.–02.10.2008	1	14	Pt	0	Pt	75	Pt	14
			Pd	0	Pd	140	Pd	32
			Au	0	Au	3	Au	1
			Ni	0	Ni	21,000	Ni	7,300
			Cu	0	Cu	26,000	Cu	5,000

t = metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The eastern and southeastern contacts of the Kaamajoki intrusion dip at 40° to the west, and this also appears to be the dip of the bulk of the intrusion. The intrusion is interpreted to extend to approximately 1 km depth (Lanne 2004). The deepest hole drilled has intercepted the basal contact at the vertical depth of about 400 m. At the west, north and southwest, the contact between the intrusion and its country rocks is steep, probably defined by faults. At the surface, marginal series rocks may be present along the full extent of the eastern and southeastern margin of the intrusion. However, exact data are scarce, as the outcrop and drilling densities are low. Only in the southernmost part of the intrusion, at the Kaamajoki prospect, has drilling intercepted mineralised marginal series rocks.

There are no indications of two compositionally distinct magma types in the Kaamajoki intrusion. Geochemical characteristics of cumulates indicate that the parental magma of the intrusion belongs to the Cr-poor type. However, the assessment group believed that the division into the Cr-poor and Cr-rich magma types is a general rule rather than a strict constraint for the assessment and exploration – it is not a necessary rule for a reef-type mineralisation to occur in all intrusions of this age group. Hence, the permissive tract matches the surface projection of the upper part of the intrusion down to 1 kilometre depth. The sources of information used in the delineation of the tract are summarised in Table 3.

Known deposits

No obvious reef-type PGE deposits are known from the Kaamajoki tract.

Prospects, mineral occurrences, and related deposit types

No obvious reef-type PGE prospects or occurrences are known from the Kaamajoki tract.

Exploration history

Exploration commenced in the Kaamajoki area in the 1970s when the Department of Geology of the University of Turku included the intrusion in its nickel deposit research project. Attention was drawn to the area by Ni- and Cu-enriched, sulphidic, glacial erratic boulders found from the area in the 1960s and 1970s. The Geological Survey of Finland (GTK) has explored the area in several stages since 1987. The first outcrops with contact-type mineralisation features were detected in 1988 (Heikura et al. 2004). GTK claimed areas at the eastern and southeastern margin of the intrusion in 1994–1996 (Kaamajoki and Tsohkkoaivi claims), and these were relinquished in 2002. Table 2 summarises the exploration history of the Kaamajoki intrusion.

Table 2. Exploration history for the permissive track KaamajokiReefPG

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Detailed bedrock mapping, outcrop sampling	No	Univ. Turku	1975–1976
	Detailed bedrock mapping, outcrop sampling	Yes*	GTK	1981–1984, 1987, 1994–1996, 2003
Geochemical surveys	Till geochemical survey: six short profiles, mostly close to the E-SE contact of the intrusion	Yes*	GTK	1987–1988
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	1983, 2002
Ground geophysical surveys	Slingram, magnetic, VLF-R, Sampo-EM, and gravity surveys		GTK	1983, 1987, 1994–95
Drilling	9 diamond-drill holes	No	Univ. Turku	1976
	26 diamond-drill holes	Yes*	GTK	1989, 1995, 2003
Other	Ore mineralogy investigations		GTK	2003

* Pt not analysed.

Sources of information

Principal sources of information used by the assessment team for the delineation of KaamajokiReefPGE are listed in Table 3.

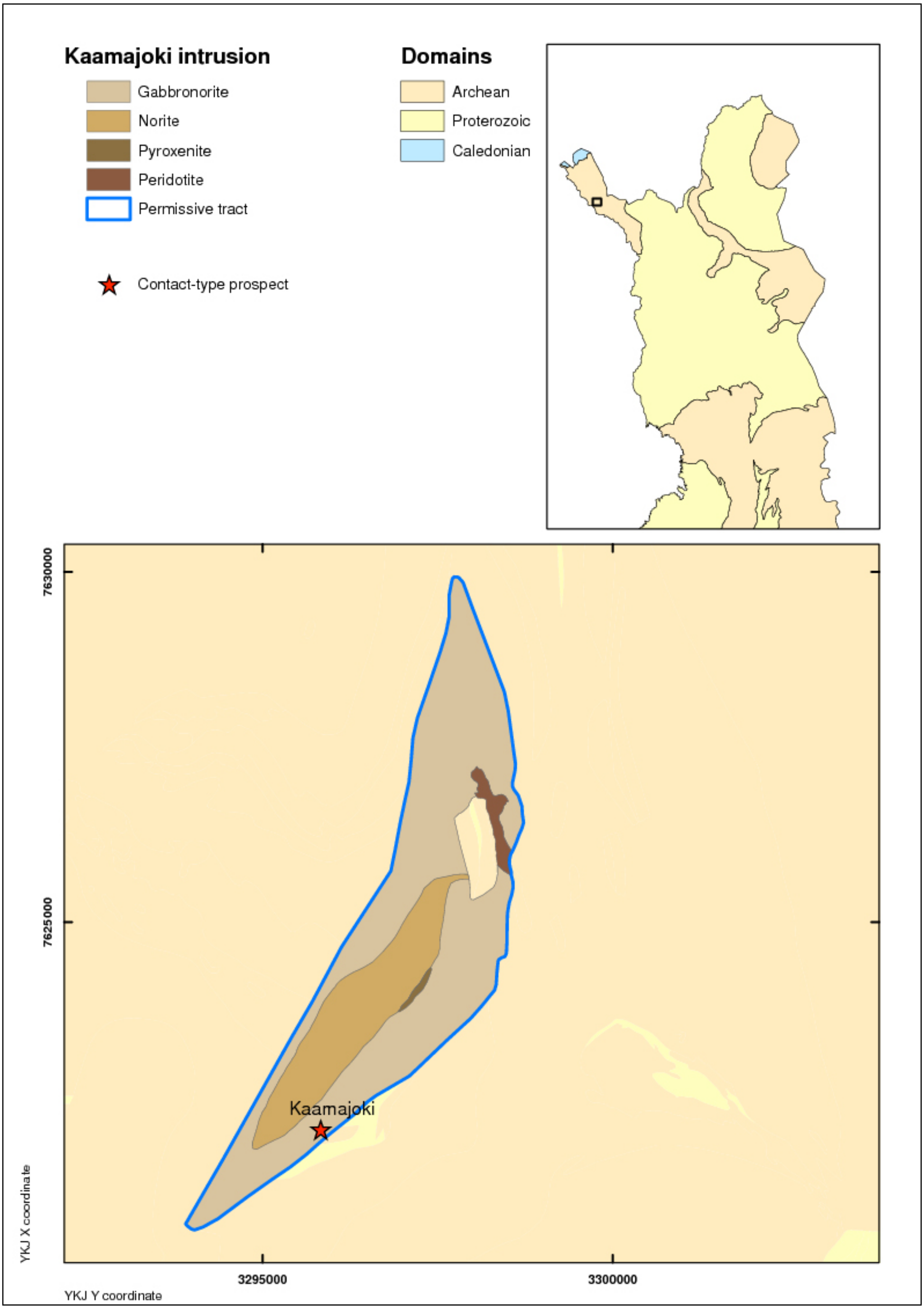

Figure 1. Location of the permissive tract KaamajokiReefPGE.

Table 3. Principal sources of information used by the assessment team for KaamajokiReefPGE.

Theme	Type of source	Scale	Citation
Geology	MSc thesis on the Kaamajoki intrusion and its nickel mineralisation		Kantti (2002)
	Bedrock Map Database of Finland	1:200 000	Geological Survey of Finland (2008)
Mineral occurrences	Summary report and overview of exploration work in the area	1:50 000	Heikura et al. (2004)
	MSc thesis on the Kaamajoki intrusion and its nickel mineralisation		Kantti (2002)
Geochemistry	Till geochemical survey	1:50 000	Heikura et al. (2004)
Geophysics	Slingram, magnetic, VLF-R, Sampo-EM, and gravity surveys	1:50 000	Heikura et al. (2004), Lanne (2004)
Exploration	General description of exploration activities in the area.	1:50 000	Heikura et al. (2004)

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

Geological factors that were used to estimate the number of undiscovered deposits at Kaamajoki included the geology of the intrusion, the distribution of the known indications of mineralisation, and the available geophysical and drilling data (Tables 2 and 3).

No reef-type deposits or prospects are known within the tract. However, there is one location that looks like a reef and has disseminated sulphides, although it apparently does not contain elevated PGE values; only the Cu concentration is locally above the background there. Hence, the minimum number of undiscovered reef-type deposits within the tract is zero. Although the estimators agreed on the rather poor potential for reef-type deposits, they disagreed on the exact numbers of undiscovered deposits at the 10% probability level (Table 4). Hence, the averages of the numbers given by individual estimators were used as input to the Eminers software. The expected number of deposits, its standard deviation, and the coefficient of variation, which are also given in Table 4, are calculated by the software from the undiscovered deposit estimates using a regression equation (Singer & Menzie 2005).

Table 4. Undiscovered deposit estimates, deposit numbers, and tract area for KaamajokiReefPGE.

Mean undiscovered deposit estimate					Summary statistics					Area (km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}	
0	1	1			0.70	0.41	58	0	0.70	14

Estimator	Estimated number of undiscovered deposits				
	N90	N50	N10	N05	N01
Estimator 1	0	1	1		
Estimator 2	0	1	2		
Estimator 3	0	1	1		
Mean	0	1	1		

Nxx = Estimated number of deposits associated with the xxth percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were calculated by combining the undiscovered deposit estimates with the Finnish reef-type PGE grade model and the KaamajokiReefPGE tonnage model (Appendix 4) using the EMINERS software (Root et al. 1992, Duval 2004). Selected simulation results are reported in Table 5. Results of the Monte Carlo simulation are presented as cumulative frequency plots (Figure 2). The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralized rock.

Table 5. Results of Monte Carlo simulations of undiscovered resources in KaamajokiReefPGE.

Material	At least the indicated amount at the probability of					Mean	Probability of mean or greater	Probability of zero
	0.95	0.9	0.5	0.1	0.05			
Pt (t)	0	0	14	170	330	75	0.21	0.30
Pd (t)	0	0	32	310	550	140	0.22	0.30
Au (t)	0	0	1	8	15	3	0.24	0.30
Ni (t)	0	0	7,300	57,000	92,000	21,000	0.29	0.30
Cu (t)	0	0	5,000	70,000	120,000	26,000	0.24	0.30
Rock (Mt)	0	0	11	73	120	26	0.31	0.30

t = metric tonnes; Mt = millions of tonnes.

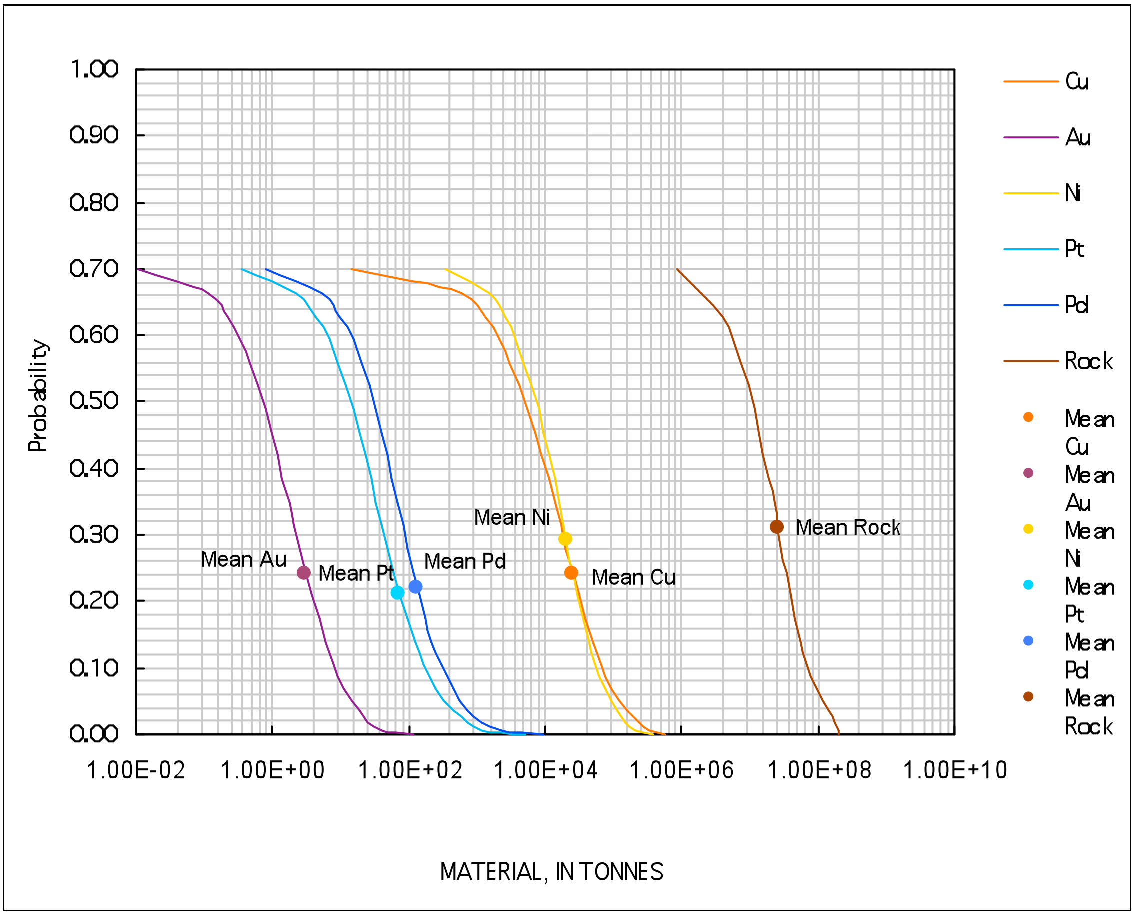

Figure 2. Cumulative frequency plot showing the results of Monte Carlo computer simulation of undiscovered resources in KaamajokiReefPGE.

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CONTACT-TYPE PGE ASSESSMENT FOR TRACT KärppäsuoContactPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Contact-type Cu-Ni-PGE
Descriptive model: Fennoscandian contact-type Cu-Ni-PGE (Appendix 1)
Grade and tonnage model: Fennoscandian contact-type Cu-Ni-PGE (Appendix 2)

LOCATION AND RESOURCE SUMMARY

The Kärppäsuo intrusion is located in northern Finland in the municipalities of Pudasjärvi and Yli-Ii, about 120 km SSE from Rovaniemi and 60 km NE from the city of Oulu. The 1:100 000 KKJ map sheets are 3513 and 3514. The UTM map sheets containing the intrusion are S4332, S4331 and R4442. The PGE resource assessment carries out for this report is summarised in Table 1.

Table 1. Summary of selected resource assessment results for KärppäsuoContactPGE.

Date of assessment	Assessment depth (km)	Tract area (km²)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
02.10.2008	1	21	Pt	0	Pt	32	Pt	10
			Pd	0	Pd	130	Pd	35
			Au	0	Au	12	Au	4
			Ni	0	Ni	110,000	Ni	77,000
			Cu	0	Cu	200,000	Cu	110,000

t = metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The Kärppäsuo intrusion is a N-S trending, about 17 km long and 100 m wide layered dyke dipping to the east with an angle of 45° (Konnunaho & Lahti 2008). The dyke is located along a suture (fault zone) between two Archaean TTG-dominated blocks. Indications of contact-type PGE enrichment have been detected in diamond drilling. The permissive tract for contact-type PGE mineralisation (Figure 1) represents the projection to the surface of the basal contact zone of the intrusion from 1 km depth, plus a 200 m buffer zone. On the surface, the delineation is based on the geological map of Konnunaho and Lahti (2008). Drilling has only extended to the depth of 200 m, but geophysical data (Konnunaho & Lahti 2008) suggest that the Kärppäsuo dyke may well extend beyond the depth of 1 km below the present erosion surface. The sources of information used in the delineation of the tract are summarized in Table 4.

Known deposits

No contact-type PGE deposits are known within the tract.

Prospects, mineral occurrences, and related deposit types

Recent drilling has detected weak indications of one contact-type mineralisation in the Kärppäsuo dyke (Table 2).

Table 2. Significant prospects and occurrences in KärppäsuoContactPGE.

Name	X coordinate	Y coordinate	Age (Ga)	Comments (grade and tonnage data, if available)	Reference
Kärppäsuo	7250700	3472650	2.444±4	1.35 m @ 0.5 ppm Pt+Pd+Au, 0.3% Ni, 0.1% Cu	Konnunaho & Lahti (2008)

Age data: H. Huhma, pers. comm., 2006.

Exploration history

Little detailed exploration has been performed in the Kärppäsuo area. Attention to area was drawn by a distinct, 20 km long, aeromagnetic and gravity anomaly. Most of the work has bgeen recent grass-roots exploration by GTK, reported by Konnunaho & Lahti (2008), and has included bedrock mapping, ground magnetic, electromagnetic and gravity surveys, and drilling of a few profiles across the dyke. It is important to note that only small parts of the potentially mineralised areas have so far been investigated. Types of exploration work carries out in the area, and known to us, are listed in Table 3.

Table 3. Exploration history for KärppäsuoContactPGE.

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Detailed bedrock mapping in the area; the intrusion does not have any outcrops		GTK	2002–2008
Geochemical surveys	Whole-rock geochemical investigations of mineralised and unmineralised parts of the intrusion.	Yes	GTK	2002–2008
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	1977, 2000
Ground geophysical surveys	VLF-R, magnetic, and gravimetric survey		GTK	2004, 2005
Drilling	38 diamond-drill holes, total 3772 m	Yes	GTK	2002–2006
Other	Ore and silicate mineralogical investigations on 154 polished thin sections. Whole-rock geochemical investigations of the intrusion.		GTK	2004–2007

Sources of information

Principal sources of information used by the assessment team for the delineation of KärppäsuoContactPGE are listed in Table 4.

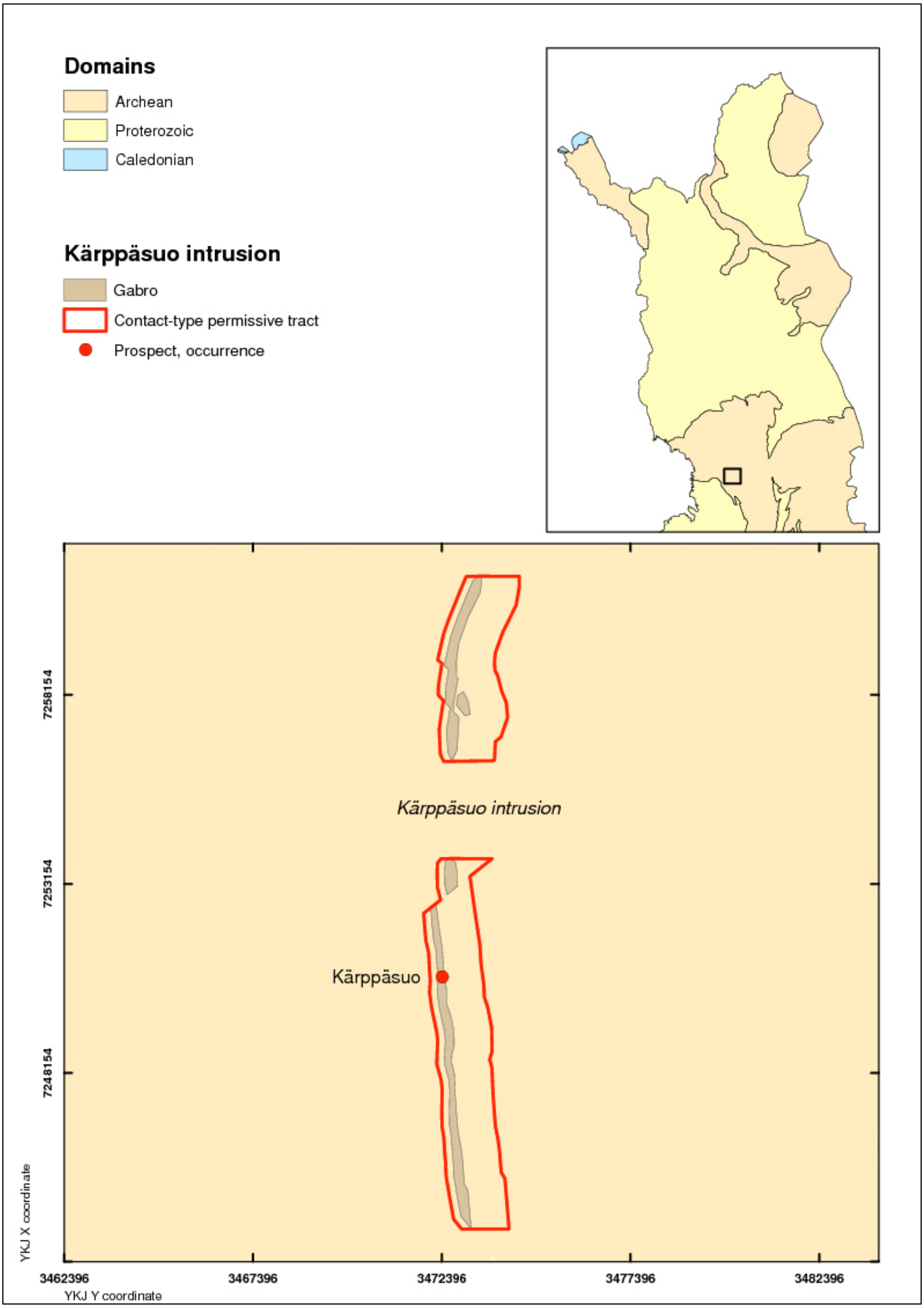

Figure 1. Map showing the location of permissive tract KärppäsuoContactPGE.

Table 4. Principal sources of information used by the assessment team for KärppäsuoContactPGE.

Theme	Type of source	Scale	Citation
Geology	General description of the geology, mineralogy and whole-rock geochemical composition of the intrusion.	1:20 000	Konnunaho & Lahti (2008)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
Mineral occurrences	MSc thesis on the intrusion geology and its mineral occurrences		T. Aalto, under preparation
	Preliminary assessment of mineralised locations found by drilling in 2002–2003, ore and silicate mineralogical, and geochemical investigations.		Konnunaho & Lahti (2008)
Geochemistry	Whole-rock geochemical composition of the intrusion.		Konnunaho & Lahti (2008)
Geophysics	Results of electrical, electromagnetic and gravimetric measurements in the area		Konnunaho & Lahti (2008)
Exploration	General description of exploration activities in the area.		Konnunaho & Lahti (2008)

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

Geological factors that were used to estimate the number of undiscovered deposits included the geology of the intrusion, the distribution of the known indications of mineralisation, the available geophysical and drilling data, and the fact that only very small parts of the potentially mineralised areas have been drilled (Table 4).

One contact-type occurrence, but no deposits, are known within the tract. This means that the number of undiscovered contact-type deposits within the tract can be zero or larger. The layered Kärppäsuo dyke is relatively narrow but very long. Two estimators assumed that there is most probably one deposit (Table 5). One estimator argued for a somewhat lower probability for an economic deposit to occur. In addition, all estimators thought that there is a small potential for another deposit. As a full consensus was not reached, the mean values (Table 5) were used in the statistical simulations.

Table 5. Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for KärppäsuoContactPGE.

Mean undiscovered deposit estimate					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
1	1	2			1.2	0.55	45	0	1.2	21	0.058

Estimator	Estimated number of undiscovered deposits				
	N90	N50	N10	N05	N01
Estimator 1	0	1	2		
Estimator 2	1	1	2		
Estimator 3	1	2	3		
Mean	1	1	2		

Nxx = Estimated number of deposits associated with the xxth percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; Deposit density = deposit density reported as the total number of deposits per km^2. N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

Quantitative assessment simulation results

Undiscovered resources for the tract were estimated by combining the means of estimated numbers of undiscovered contact-type PGE deposits with the Fennoscandian contact-type PGE grade and tonnage model (Appendix 2) using the EMINERS software (Root et al. 1992, Duval 2004). Selected simulation results are reported in Table 6. Results of the Monte Carlo simulation are presented as cumulative frequency plots (Figure 2). The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralized rock.

Table 6. Results of Monte Carlo simulations of undiscovered resources in KärppäsuoContactPGE.

Material	At least the indicated amount at the probability of					Mean	Probability of mean or greater	Probability of zero
	0.95	0.90	0.50	0.10	0.05			
Pt (t)	0	0	10	98	140	32	0.27	0.07
Pd (t)	0	1	35	400	680	130	0.25	0.07
Au (t)	0	0	4	32	52	12	0.27	0.07
Ni (t)	0	5,400	77,000	280,000	350,000	110,000	0.37	0.07
Cu (t)	0	6,800	110,000	560,000	710,000	200,000	0.32	0.07
Rock (Mt)	0	1	42	400	470	110	0.28	0.07

t = metric tonnes; Mt = millions of tonnes.

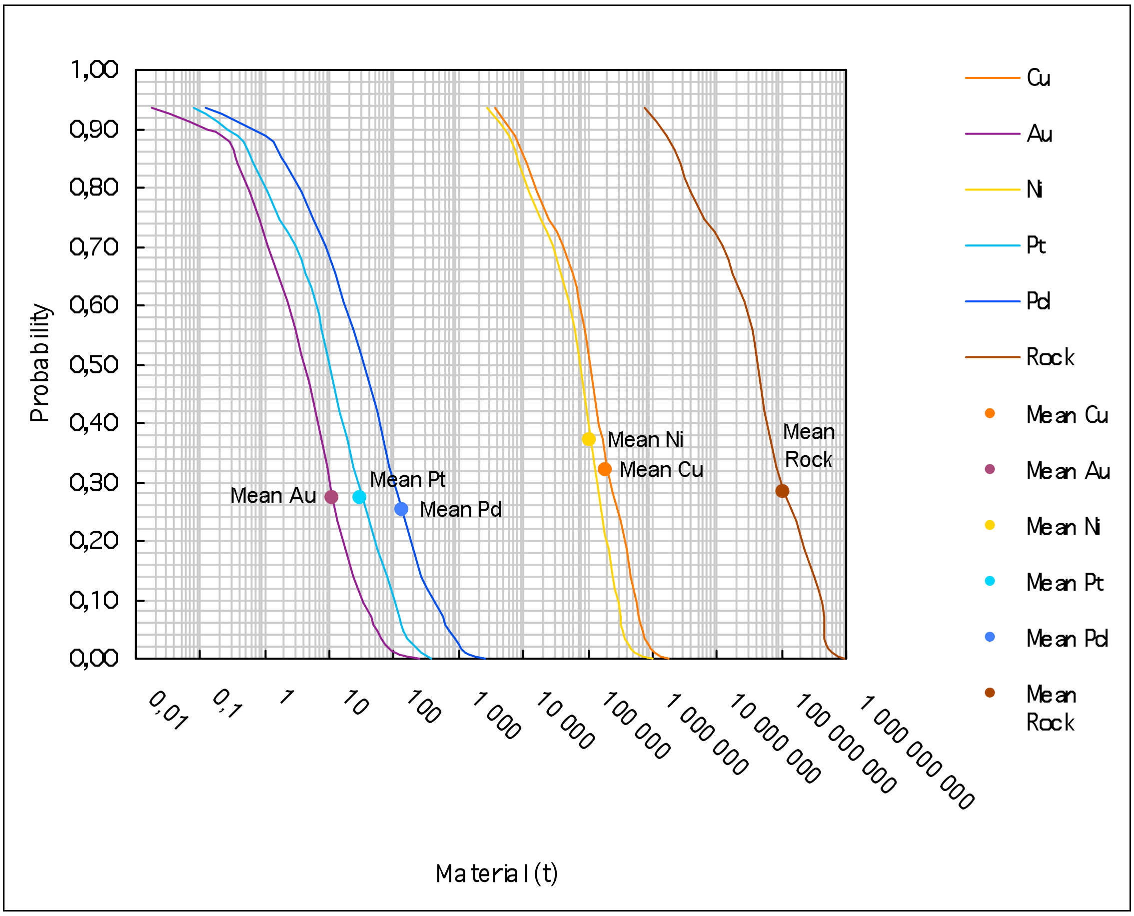

Figure 2. Cumulative frequency plot showing the results of Monte Carlo computer simulation of undiscovered resources in KärppäsuoContactPGE.

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REEF-TYPE PGE ASSESSMENT FOR TRACT KärppäsuoReefPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Reef-type PGE-Ni-Cu
Descriptive model: Finnish reef-type PGE-Ni-Cu (Appendix 3)
Grade-tonnage model: Finnish reef-type PGE-Ni-Cu grade model, KärppäsuoReefPGE tonnage model (Appendix 4)

LOCATION AND RESOURCE SUMMARY

The 2.45 Ga Kärppäsuo intrusion is located in northern Finland in the municipalities of Pudasjärvi and Yli-Ii, about 120 km SSE from Rovaniemi and 60 km NE from the city of Oulu. The 1:100 000 KKJ map sheets are 3513 and 3514. The UTM map sheets containing the intrusion are S4332, S4331 and R4442.

Table 1. Summary of selected resource assessment results for KärppäsuoReefPGE. Only well-delineated deposits are included.

Date of assessment	Assessment depth (km)	Tract area (km²)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
02.10.2008	1	18	Pt	0	Pt	0	Pt	0
			Pd	0	Pd	0	Pd	0
			Au	0	Au	0	Au	0
			Ni	0	Ni	0	Ni	0
			Cu	0	Cu	0	Cu	0

t = metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The Kärppäsuo intrusion is a dyke that probably extends to >1 km depth. It is N-S trending, about 17 km long, 100 m wide, layered, and dips to the east at 45° (Konnunaho & Lahti 2008). Due to the limited work on the area, there is no opinion on which part of the intrusion could represent the earlier Cr-rich and which the later Cr-poor magma unit. However, the assessment group believed that the division into Cr-poor and Cr-rich magma types is a general rule rather than a strict constraint for the assessment and exploration – it is not a necessary rule for a reef-type mineralisation to occur in all intrusions of this age group. Hence, the permissive tract for PGE reef in the intrusion matches the surface projection of the intrusion down to 1 kilometre depth. The sources of information used in the delineation of the tract are summarised in Table 3.

Known deposits

There are no well-explored reef-type PGE deposits within the Kärppäsuo permissive tract.

Prospects, mineral occurrences, and related deposit types

No obvious reef-type PGE prospects are known from the tract.

Exploration history

Little detailed exploration has been performed in the Kärppäsuo area. Attention was drawn to the area by a distinct, 20 km long, aeromagnetic and gravity anomaly. Most of the work has been recent GTK grass-roots exploration reported by Konnunaho and Lahti (2008), and has included bedrock mapping, ground magnetic, electromagnetic and gravity surveys, and drilling of a few profiles across the dyke. It is important to note that only small parts of the potentially mineralised areas have so far been investigated. Types of exploration work carries out in the area, and known to us, are listed in Table 2.

Table 2. Exploration history for Kärppäsuo Reef.

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Detailed bedrock mapping in the area; the intrusion does not have any outcrops		GTK	2002–2008
Geochemical surveys	Whole-rock geochemical investigations of mineralised and unmineralised parts of the intrusion.	Yes	GTK	2002–2008
Airborne geophysical surveys	Low-altitude airborne magnetic, electro-magnetic and radiometric survey		GTK	1977, 2000
Ground geophysical surveys	VLF-R, magnetic, and gravimetric survey		GTK	2004, 2005
Drilling	38 diamond-drill holes, total 3548 m	Yes	GTK	2002–2006
Other	Ore and silicate mineralogical investigation on 154 polished thin sections. Whole-rock geochemical investigations of the intrusion.		GTK	2004–2007

Sources of information

Principal sources of information used by the assessment team for the delineation of KärppäsuoReefPGE are listed in Table 3.

Table 3. Principal sources of information used by the assessment team for KärppäsuoReefPGE.

Theme	Type of source	Scale	Citation
Geology	General description of the geology, mineralogy and whole-rock geochemical composition of the intrusion	1:20 000	Konnunaho & Lahti (2008)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
Mineral occurrences	Preliminary assessment of mineralised locations found by drilling in 2002–2003, ore and silicate mineralogical, and geochemical investigations		Konnunaho & Lahti (2008)
Geochemistry	Whole-rock geochemical composition of the intrusion		Konnunaho & Lahti (2008)
Geophysics	Results of electrical, electromagnetic and gravimetric measurements in the area		Konnunaho & Lahti (2008)
Exploration	General description of exploration activities in the area		Konnunaho & Lahti (2008)

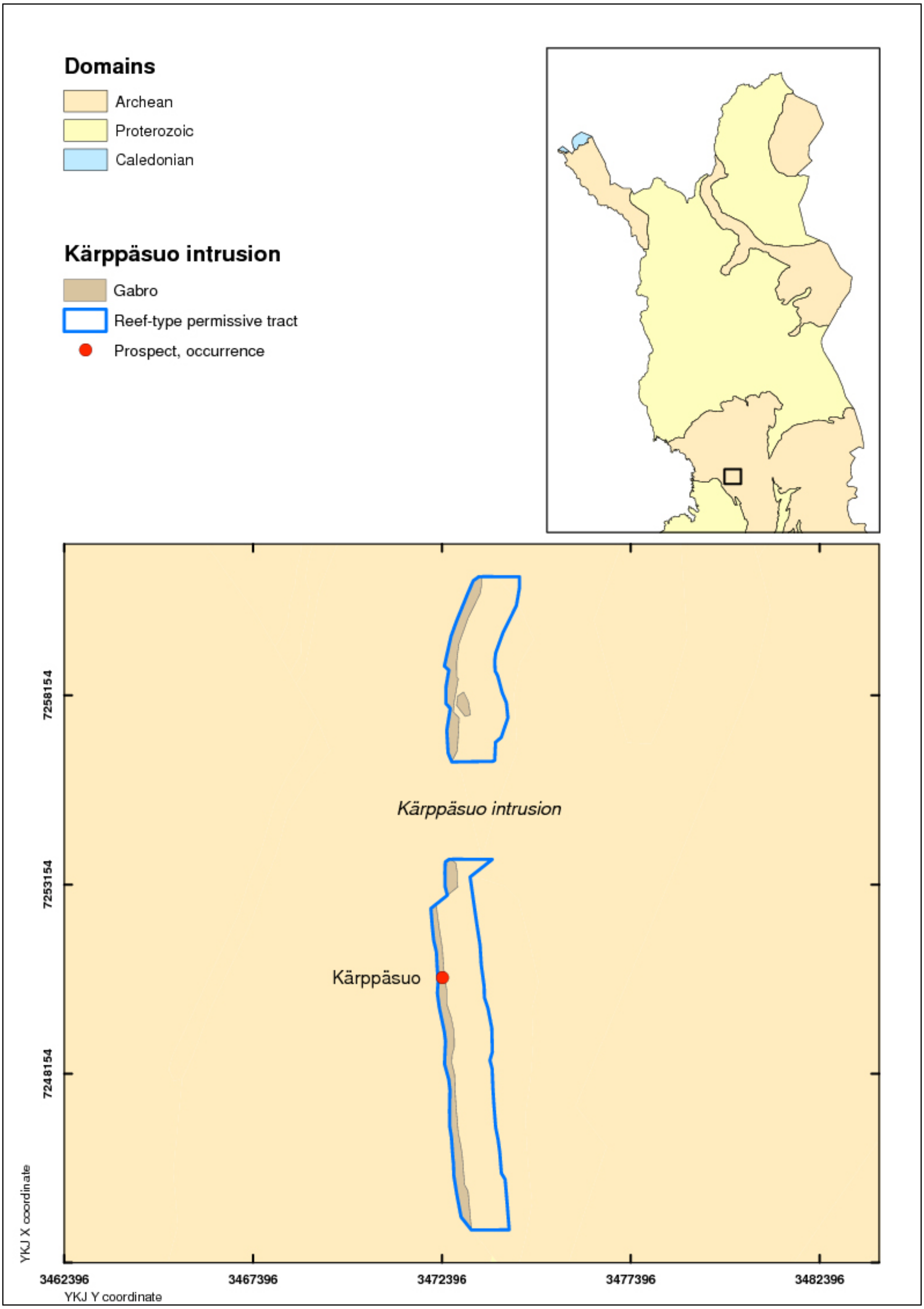

Figure 1. Location of the permissive tract KärppäsuoReefPGE.

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

Not a single reef-type prospect is known within the tract. This means that the minimum number of undiscovered reef-type deposits within the tract is zero. All estimators assumed that there is not much potential for economically viable reef-type deposits at Kärppäsuo. One estimator was slightly more optimistic than the others, seeing a small possibility for a deposit to occur. Since no consensus was reached for the 10% probability, the mean value was used instead. The deposit number estimation results are listed in Table 4.

Table 4. Undiscovered deposit estimates, deposit numbers, and tract area for KärppäsuoReefPGE.

Mean undiscovered deposit estimate					Summary statistics					Area (km2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}	
0	0	0			0	0		0	0	18

	Estimated number of undiscovered deposits				
Estimator	N90	N50	N10	N05	N01
Estimator 1	0	0	0		
Estimator 2	0	0	1		
Estimator 3	0	0	0		
Mean	0	0	0		

Nxx = Estimated number of deposits associated with the xx^{th} percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were not estimated, because the result of the assessment workshop suggested a mean probability of less than 10% for at least one deposit to occur within the tract.

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Duval, J. S. 2004. Version 2.0 of EMINERS – Economic Mineral Resource Simulator. U.S. Geological Survey, Open-File Report 2004-1344.

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Konnunaho, J. & Lahti, I. 2008. Tutkimustyöselostus Pudasjärven kaupungissa ja Yli-Iin kunnassa sijaitsevasta Kärppäsuon gabrosta sekä valtausalueilla Vengasoja 1 ja Sarvensuo 1 (kaivosrekisterinumerot 7974/2 ja 7974/1) tehdyistä malmitutkimuksista vuosina 2002–2008. Geological Survey of Finland, unpublished report M06/3513, 3514/2008/12. 37 p. (in Finnish, English summary)

Singer, D. A. & Menzie, W. D. 2005. Statistical guides to estimating the number of undiscovered mineral deposits: an example with porphyry copper deposits. In: Cheng, Q. & Bonham-Carter, G. (eds.) Proceedings of IAMG – The annual conference of the International Assoc. for Mathematical Geology. Toronto: Geomatics Research Laboratory, York University, 1028–1033.

CONTACT-TYPE PGE ASSESSMENT FOR TRACT KaukuaContactPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Contact-type Cu-Ni-PGE
Descriptive model: Fennoscandian contact-type Cu-Ni-PGE (Appendix 1)
Grade and tonnage model: Fennoscandian contact-type Cu-Ni-PGE (Appendix 2)

LOCATION AND RESOURCE SUMMARY

The Kaukua block of the Western Intrusion of the Koillismaa Complex is located in northern Finland in the municipality of Posio, 125 km southeast from the town of Rovaniemi. The 1:100 000 KKJ map sheet is 3544. The UTM map sheets containing the block are S5232 and S5241. The PGE resource assessment carried out for this report is summarised in Table 1.

Table 1. Summary of selected resource assessment results for KaukuaContactPG

Date of assessment	Assessment depth (km)	Tract area (km²)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
26.08.–02.10.2008	1	9.6	Pt	0	Pt	50	Pt	22
			Pd	0	Pd	220	Pd	78
			Au	0	Au	19	Au	9
			Ni	0	Ni	170,000	Ni	130,000
			Cu	0	Cu	320,000	Cu	200,000

t = metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The permissive tract delineated in Figure 2 is a surface projection of the basal contact zone of the E-W trending Kaukua intrusive block of the Koillismaa intrusion. The northern margin of the block, where the marginal series crops out, has a 20–30° dip to the south, whereas the southern boundary of the intrusion block is a subvertical fault. The maximum estimated depth of the basal contact of the Kaukua block is estimated to be about 300 m. Hence, Kaukua permissive tract roughly matches to the extent of the intrusion at the surface. The surface extent of the intrusive block is based on a geological map by Räsänen et al. (2004), drilling (by GTK and a joint venture between Akkerman Exploration BV and Nortec Ventures), geophysical information (local magnetic survey by GTK), structural modelling by Karinen and Salmirinne (2001) and diamond drilling (Nortec Ventures 2008c). The sources of information used in the delineation of the tract are summarized in Tables 3 and 4.

Known deposits

No contact-type PGE deposits are known within the tract.

Prospects, mineral occurrences, and related deposit types

One contact-type PGE prospect is known within the tract (Table 2 and Figure 2), the Kaukua occurrence in the central part of the intrusive block, where structure of the basal part of the intrusion is the most complicated. The occurrence is incompletely delineated and no representative grade or tonnage information is available. Kaukua is the most PGE-enriched prospect in the whole Koillismaa Complex area. A characteristic feature of the Kaukua contact type mineralisation is the low volume of the disseminated sulphides (generally <2 vol-%), ratios Cu/Ni > 1, Pd/Pt >1, the presence of magmatic breccia, evidence of multiple influxes of magma, and features of extensive partial melting implying high temperature and dynamic flow conditions. The principal sulphide phases are chalcopyrite, pyrrhotite and pentlandite. The dominant PGE phases are tellurides (kotulskite, moncheite) and a Pt-As phase (sperrylite). (Iljina et al. 2005). One reef-type occurrence is also known in the layered series, where erratic and low-grade base metal and PGE enrichments are found in an approximately 20 m thick zone.

Table 2. Significant prospects and occurrences in KaukuaContactPGE

Name	X coordinate	Y coordinate	Age (Ga)	Comments (grade and tonnage data, if available)	Reference
Kaukua	7317050	3553800	2.44	5.5 m @ 6.26 g/t Pd+Pt+Au, 0.53% Cu, 0.22% Ni (drill hole KAU08-13). In total, the mineralised zone is 15-40 m thick.	Nortec Ventures (2008a, 2008b, 2008c)

Deposit age is derived from the assumed age of the Kaukua block based on age data from the Koillismaa Complex (Alapieti 1982).

Exploration history

Attention was drawn to the Koillismaa Complex Western Intrusion area by the discovery of Ni- and Cu-rich sulphide-bearing glacial erratic boulders in the 1960s. The first indications on contact-type deposits in the Kaukua area were detected from outcrops by Outokumpu in the late 1980s (Iljina et al. 2005). GTK explored the area in 1996–2000 and 2004 (Figure 2), and NAN in 2000–2002. A joint venture between Akkerman Exploration B.V. and Nortec Ventures commenced exploration in the area in year 2007 (Nortec Ventures 2007, 2008a, 2008b, 2008c, 2009). The exploration work carries out in the area is listed in Table 3.

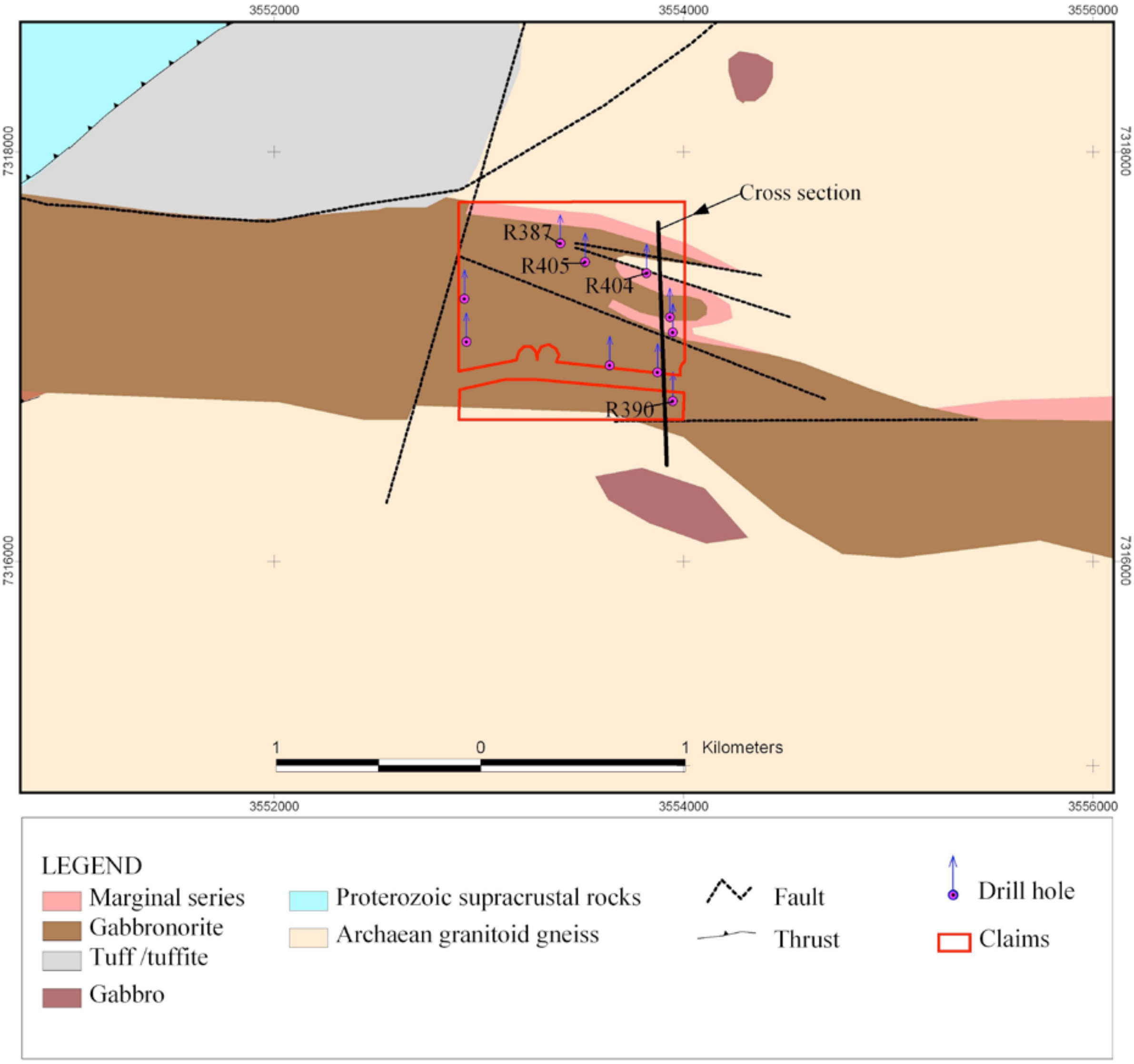

Figure 1. GTK drilling sites at Kaukua (Iljina et al. 2005). North up.

Table 3. Exploration history for KaukuaContactPGE

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Detailed bedrock mapping, outcrop sampling	Yes	Outokumpu Oy	1980s, 1990s
Geochemical surveys	None has been performed			
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	1995
	Low-altitude airborne magnetic and electromagnetic survey		NAN	2001
Ground geophysical surveys	Gravity survey line		Univ. Oulu	1971
	Magnetic and VLF survey		GTK	1999
	Regional gravity survey		GTK	1999–2004
	Magnetic and IP survey		NAN	2001
	3D IP survey covering 3 km^2		A-N	2008
Drilling	10 diamond-drill holes, total 1650 m	Yes	GTK	1999, 2004
	34 diamond-drill holes, total 4569 m	Yes	A-N	2007–2009
Other	Regional research and mapping programme in the KLIC region	No	Univ. Oulu	1971–1976
	Regional research and exploration programme in the KLIC region	Yes	GTK	1996–2000

NAN = North Atlantic Natural Resources.
A-N = Joint Venture between Akkerman Exploration B.V. and Nortec Ventures.
KLIC = Kollismaa Layered Igneous Complex.

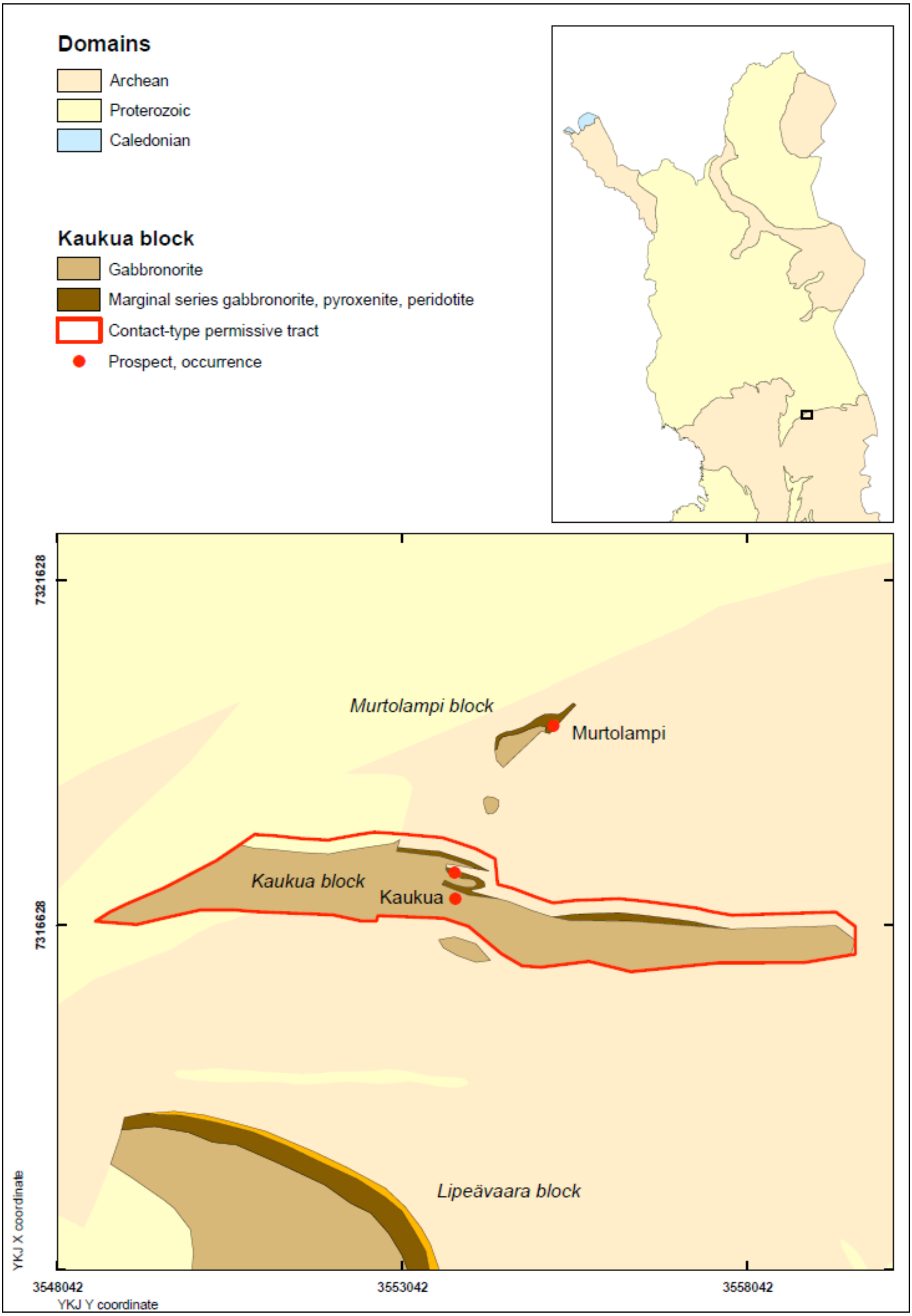

Figure 2. Location of the permissive tract KaukuaContactPGE. The Kaukua contact-type prospect (southernmost red dot) and the reef-type occurrence within the tract are also shown.

Sources of information

Principal sources of information used by the assessment team for the delineation of KaukuaContactPGE are listed in Table 4.

Table 4. Principal sources of information used by the assessment team for KaukuaContactPGE.

Theme	Type of source	Scale	Citation
Geology	Geological description of the KLIC geology and then known mineral occurrences	1:150 000	Piirainen et al. (1974, 1978), Juopperi (1977), Alapieti (1982)
	Geological description of the KLIC geology and then known mineral occurrences		Lahtinen (1985)
	Geological description of the KLIC geology and the known mineral occurrences		Iljina (2004)
	Geological map of the KLIC region	1:200 000	Räsänen et al. (2004)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
	PhD on geology and reef-type mineralisation in the Western Koillismaa Intrusion		Karinen (2010)
Mineral occurrences	Description of the Kaukua PGE occurrence and its geological setting	1:4000	Iljina et al. (2005)
Geochemistry	Not available		
Geophysics	Magnetic and VLF survey, IP survey		Iljina et al. (2005)
Exploration	Summary report on exploration activities by Outokumpu		Lahtinen (1983)
	Detailed description of exploration activities in the area by GTK and NAN, and a brief summary of the activities by Outokumpu		Iljina et al. (2005)
	Description on exploration activities by Akkerman-Nortec		Nortec Ventures (2007, 2008a, 2008b, 2008c, 2009)

KLIC = Kollismaa Layered Igneous Complex.
NAN = North Atlantic Natural Resources.
Akkerman-Nortec = Joint Venture between Akkerman Exploration B. V. and Nortec Ventures.

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

Geological factors that were used to estimate the number of undiscovered deposits at Kaukua included the geology of the intrusion, the distribution of the known deposits, and the available geophysical and drilling data (Table 4).

One contact-type prospect is known within the tract. Since no resource estimate is available, it was not included in the grade and tonnage model. It is noteworthy that in the Koillismaa Complex Western Intrusion area the contact-type deposits of highest PGE concentrations (Kaukua and Haukiaho) are furthest from the regional positive gravity anomaly, which has been interpreted as an indication of a feeder channel for the entire intrusion (Alapieti 1982). This may indicate magma dynamics powerful enough to produce contact-type deposits in the distal rather than proximal parts of the magma chamber of the intrusion. Hence, the largest potential for contact-type deposits at Koillismaa would be in those intrusive blocks that are tens of kilometres away from the supposed feeder channel.

A near consensus was reached between the estimators for the number of undiscovered contact-type PGE deposit at Kaukua; the mean only had to be used for the percentile N10 in the Monte Carlo simulations (Table 5). The expected number of deposits, its standard deviation, and the coefficient of variation, which are given in Table 5, are calculated by the software from the undiscovered deposit estimates using a regression equation (Singer & Menzie 2005).

Table 5. Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for KaukuaContactPGE

Consenus of undiscovered deposit estimate					Summary statistics					Area (km2)	Deposit density (N/km2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
1	2	3			1.9	0.84	43		1.9	9.6	0.20

Estimator	Estimated number of undiscovered deposits				
	N90	N50	N10	N05	N01
Estimator 1	1	2	3		
Estimator 2	1	2	2		
Estimator 3	1	2	3		
Consensus	1	2	3		

Nxx = Estimated number of deposits associated with the xxth percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; Deposit density = deposit density reported as the total number of deposits per km^2. N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were estimated by combining the means of estimated numbers of undiscovered contact-type PGE deposits with the Fennoscandian contact-type PGE grade and tonnage model (Appendix 2) using the EMINERS software (Root et al. 1992, Duval 2004). Selected simulation results are reported in Table 6. Results of the Monte Carlo simulation are presented as cumulative frequency plots (Figure 3). The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralized rock.

Table 6. Results of Monte Carlo simulations of undiscovered resources in KaukuaContactPGE.

Material	At least the indicated amount at the probability of					Mean	Probability of mean or greater	Probability of zero
	0.95	0.90	0.50	0.10	0.05			
Pt (t)	0	1	22	140	190	50	0.32	0.07
Pd (t)	0	2	78	650	970	220	0.28	0.07
Au (t)	0	0	9	55	79	19	0.29	0.07
Ni (t)	0	8,300	130,000	390,000	480,000	170,000	0.40	0.07
Cu (t)	0	10,000	200,000	780,000	970,000	320,000	0.37	0.07
Rock (Mt)	0	3	80	490	570	180	0.34	0.07

t = metric tonnes; Mt = millions of tonnes.

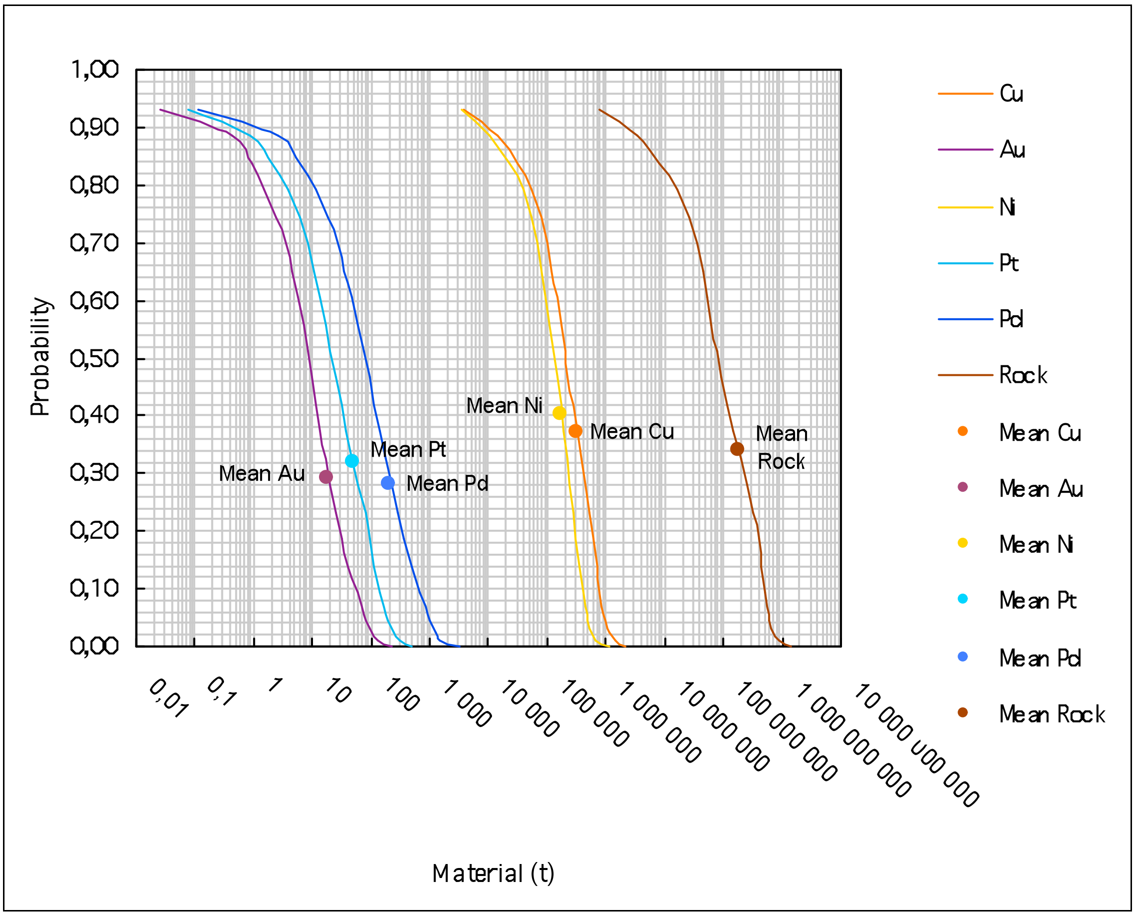

Figure 1. Cumulative frequency plot showing the results of Monte Carlo computer simulation of undiscovered resources in KaukuaContactPGE.

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REEF-TYPE PGE ASSESSMENT FOR TRACT KaukuaReefPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Reef-type PGE-Ni-Cu
Descriptive model: Finnish reef-type PGE-Ni-Cu (Appendix 3)
Grade-tonnage model: Finnish reef-type PGE-Ni-Cu grade model, AkanvaaraReefPGE tonnage model (Appendix 4)

LOCATION AND RESOURCE SUMMARY

The Kaukua block of the Western Intrusion of the Koillismaa Layered Igneous Complex (KLIC) is located in northern Finland in the municipality of Posio, 125 km southeast from the town of Rovaniemi. The 1:100 000 KKJ map sheet is 3544. The UTM map sheets containing the block are S5232 and S5241.

Table 1. Summary of selected resource assessment results for KaukuaReefPGE.

Date of assessment	Assessment depth (km)	Tract area (km²)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
26.08.–02.10. 2008	1	7.5	Pt	0	Pt	57	Pt	17
			Pd	0	Pd	100	Pd	35
			Au	0	Au	2	Au	1
			Ni	0	Ni	15,000	Ni	8,000
			Cu	0	Cu	19,000	Cu	6,300

t = metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The Kaukua block is E-W trending. It dips to the south at 20–30° and ends into a subvertical fault in the south, where the maximum depth of the intrusion is about 300 m. Hence, the permissive tract roughly matches the surface projection of the intrusion block. The location of the northern margin of the tract is defined by information from diamond drill holes and the southern margin by outcrop and geophysical surveys. The sources of information used in the delineation of the tract are summarized in Table 4.

Known deposits

There are no well-explored reef-type PGE deposits within the Kaukua permissive tract.

Prospects, mineral occurrences, and related deposit types

One reef-type occurrence is known in the layered series (Table 2), where erratic and low-grade base metal and PGE enrichments are found in an approximately 20 m thick zone. (Iljina et al. 2005). In addition, one contact-type PGE prospect is known in the central part of the intrusive block, where structure of the basal part of the intrusion is the most complicated (Figure 1).

Table 2. Significant prospects and occurrences in KaukuaReefPGE.

Name	X coordinate	Y coordinate	Age (Ga)	Comments (grade and tonnage data, if available)	Reference
Kaukua	7317400	3553800	2.44	Approximately 20 m thick zone of erratic, low-grade PGE, Ni, Cu mineralisation	Iljina et al. (2005)

Deposit age is derived from the assumed age of the Kaukua block based on age data from the Koillismaa Complex (Alapieti 1982).

Exploration history

Attention was drawn to the Koillismaa Complex Western Intrusion area by Ni- and Cu-rich sulphide-bearing glacial erratic boulders found in the 1960s. The first indications of reef-type deposits in the Kaukua area were discovered by Outokumpu in a small outcrop south of Lake Tölväänlampi in the late 1980s (Iljina et al. 2005). The area was explored by GTK in 1996–2000 and 2004 and by North Atlantic Natural Resources (NAN) in 2000–2002. A joint venture between Akkerman Exploration B.V. and Nortec Ventures commenced exploration in the area in 2007 and has been operating in the area since then (Nortec Ventures 2007, 2008a, 2008b, 2008c, 2009). The exploration work carries out in the area is listed in Table 3.

Table 3. Exploration history for KaukuaReefPGE.

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Detailed bedrock mapping, outcrop sampling	Yes	Outokumpu Oy	1980s, 1990s
Geochemical surveys	None has been performed			
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	1995
	Low-altitude airborne magnetic and electromagnetic survey		NAN	2001
Ground geophysical surveys	Gravity survey line		Univ. Oulu	1971
	Magnetic and VLF survey		GTK	1999
	Regional gravity survey		GTK	1999–2004
	Magnetic and IP survey		NAN	2001
	3D IP survey covering 3 km2		A-N	2008
Drilling	10 diamond-drill holes, total 1650 m	Yes	GTK	1999, 2004
	34 diamond-drill holes, total 4569 m	Yes	A-N	2007–2009
Other	Regional research and mapping programme in the KLIC region	No	Univ. Oulu	1971–1976
	Regional research and exploration programme in the KLIC region	Yes	GTK	1996–2000

NAN = North Atlantic Natural Resources.
A-N = Joint Venture between Akkerman Exploration B.V. and Nortec Ventures.
KLIC = Kollismaa Layered Igneous Complex.

Sources of information

Principal sources of information used by the assessment team for the delineation of KaukuaReefPGE are listed in Table 4.

Table 4. Principal sources of information used by the assessment team for KaukuaReefPGE.

Theme	Type of source	Scale	Citation
Geology	Geological description of the KLIC geology and then known mineral occurrences	1:150 000	Piirainen et al. (1974, 1978), Juopperi (1977), Alapieti (1982)
	Geological description of the KLIC geology and then known mineral occurrences		Lahtinen (1985)
	Geological description of the KLIC geology and the known mineral occurrences		Iljina (2004)
	Geological map of the KLIC region	1:200 000	Räsänen et al. (2004)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
	PhD on geology and reef-type mineralisation in the Western Koillismaa Intrusion		Karinen (2010)
Mineral occurrences	Description of the Kaukua PGE occurrence and its geological setting	1:4000	Iljina et al. (2005)
Geochemistry	Not available		
Geophysics	Magnetic and VLF survey, IP survey		Iljina et al. (2005)
Exploration	Summary report on exploration activities by Outokumpu		Lahtinen (1983)
Exploration	Detailed description of exploration activities in the area by GTK and NAN, and a brief summary of the activities by Outokumpu		Iljina et al. (2005)
Exploration	Description on exploration activities by Akkerman-Nortec		Nortec Ventures (2007, 2008a, 2008b, 2008c, 2009)

KLIC = Koillismaa Layered Igneous Complex.
NAN = North Atlantic Natural Resources.
Akkerman-Nortec = Joint Venture between Akkerman Exploration B. V. and Nortec Ventures.

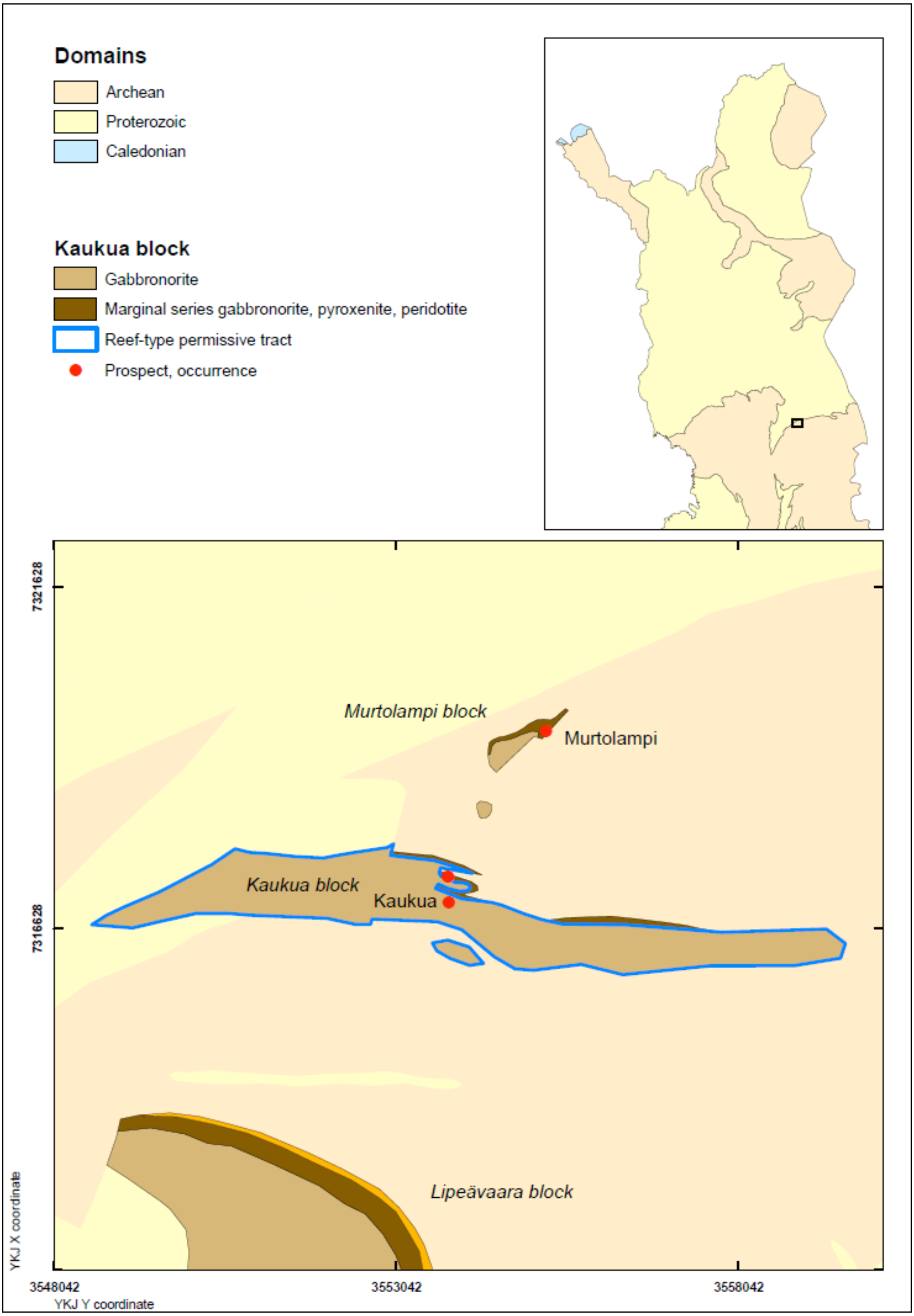

Figure 1. Location of the permissive tract KaukuaReefPGE. The Kaukua contact-type prospect (southernmost red dot) and the reef-type occurrence within the tract are also shown.

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

One reef-type prospect is known within the tract. This means that the minimum number of undiscovered reef-type deposits within the tract is one. Two estimators assumed that there is no space for another reef to exist within the Kaukua Block (Table 5). Also, there are no indications of megacycle boundaries within the block, pointing against the possibility for more than one reef. However, one estimator saw a small possibility for another reef to occur. Since no consensus was reached, mean values of the individual estimates were used in the quantitative assessment.

Table 5. Undiscovered deposit estimates, deposit numbers, and tract area for KaukuaReefPGE.

Mean undiscovered deposit estimate					Summary statistics					Area (km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}	
1	1	1			0.93	0.17	18	0	0.93	7.5

Estimator	Estimated number of undiscovered deposits N90	N50	N10	N05	N01
Estimator 1	1	1	2		
Estimator 2	1	1	1		
Estimator 3	1	1	1		
Mean	1	1	1		

Nxx = Estimated number of deposits associated with the xxth percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were calculated by combining the undiscovered deposit estimates with the Finnish reef-type PGE grade model and the KaukuaReefPGE tonnage model (Appendix 4) using the EMINERS software (Root et al. 1992, Duval 2004). Results of the Monte Carlo simulation are presented as cumulative frequency plots (Figure 2) and selected simulation results are reported in Table 6. The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralized rock.

Table 6. Results of Monte Carlo simulations of undiscovered resources in KaukuaReefPGE.

Material	At least the indicated amount at the probability of 0.95	0.9	0.5	0.1	0.05	Mean	Probability of mean or greater	Probability of zero
Pt (t)	0	1	17	130	230	57	0.22	0.07
Pd (t)	0	2	35	220	390	100	0.23	0.07
Au (t)	0	0	1	6	10	2	0.26	0.07
Ni (t)	0	480	8,000	38,000	57,000	15,000	0.31	0.07
Cu (t)	0	210	6,300	50,000	84,000	19,000	0.27	0.07
Rock (Mt)	0	1	11	47	74	19	0.33	0.07

t = metric tonnes; Mt = millions of tonnes.

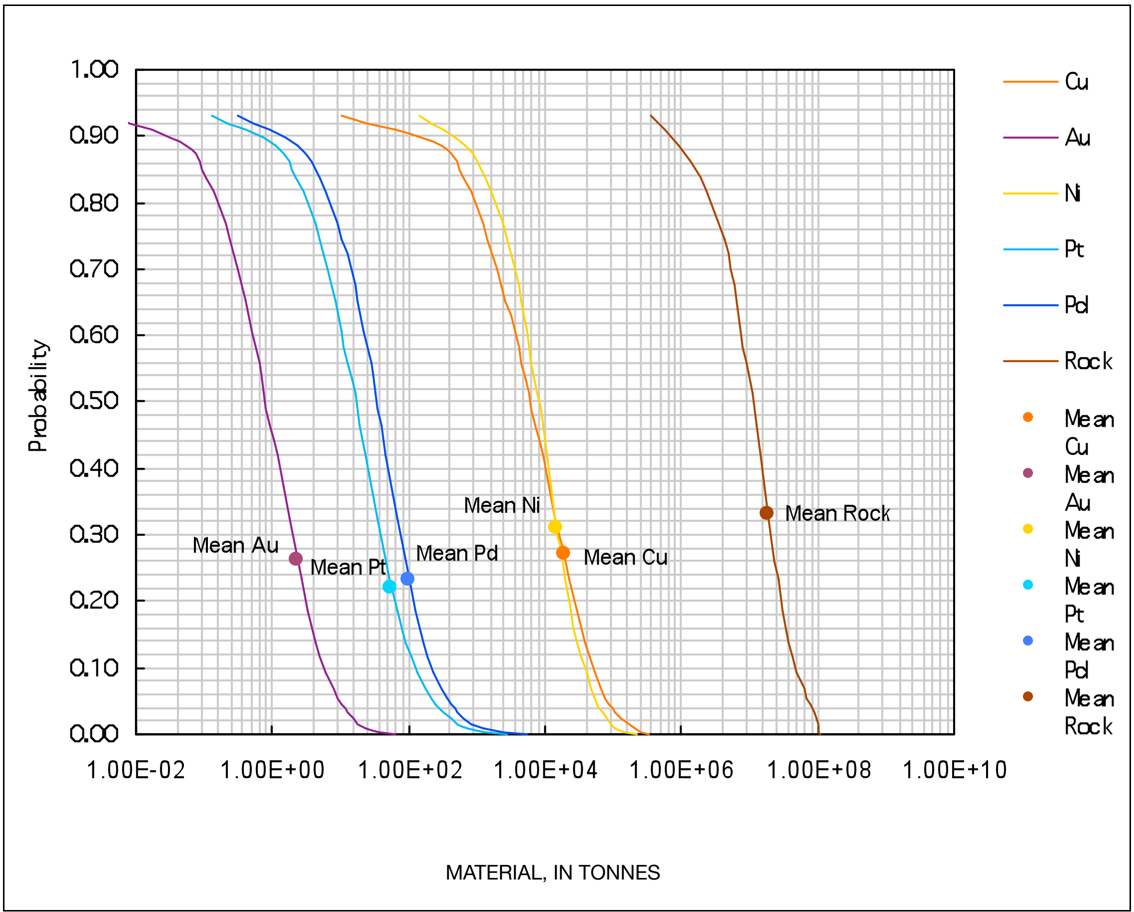

Figure 2. Cumulative frequency plot showing the results of Monte Carlo computer simulation of undiscovered resources in KaukuaReefPGE.

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REEF-TYPE PGE ASSESSMENT FOR TRACT KemiReefPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Reef-type PGE-Ni-Cu
Descriptive model: Finnish reef-type PGE-Ni-Cu (Appendix 3)
Grade-tonnage model: Finnish reef-type PGE-Ni-Cu grade model, KemiReefPGE tonnage model (Appendix 4)

LOCATION AND RESOURCE SUMMARY

The Kemi layered intrusion is located in northern Finland in the municipalities of Kemi and Keminmaa (Figure 1), about 100 km SW from Rovaniemi. The 1:100 000 KKJ map sheet is 2541. The UTM map sheet containing the intrusion is S4233. The PGE resource assessment carries out for this report is summarised in Table 1.

Table 1. Summary of selected resource assessment results for KemiReefPGE. Only well-delineated deposits are included.

Date of assessment	Assessment depth (km)	Tract area (km²)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
			Pt	0	Pt	240	Pt	69
			Pd	0	Pd	440	Pd	140
01.09.2008	1	8.3	Au	0	Au	10	Au	4
			Ni	0	Ni	66,000	Ni	34,000
			Cu	0	Cu	83,000	Cu	26,000

t = metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The age of the Kemi layered intrusion is 2433 ± 4 Ma (Perttunen & Vaasjoki 2001). The intrusion dips to the NW with an angle of about 65° into a depth of well beyond 1 km. The extension of the intrusion to a great depth is indicated by a gravity survey performed by GTK. There is a weakly PGE-anomalous zone at the contact between an earlier Cr-rich and a later Cr-poorer unit (Figure 2). The upper part of the intrusion at and above this contact is used to define the permissive tract. Hence, the permissive tract matches the surface projection of this upper part of the intrusion from 1 km depth to the surface. The SE margin of the tract is defined by information from drilling and the NW margin by the projection of the hanging wall contact of the intrusion at 1 km depth to the surface. The sources of information used in the delineation of the tract are summarised in Table 4.

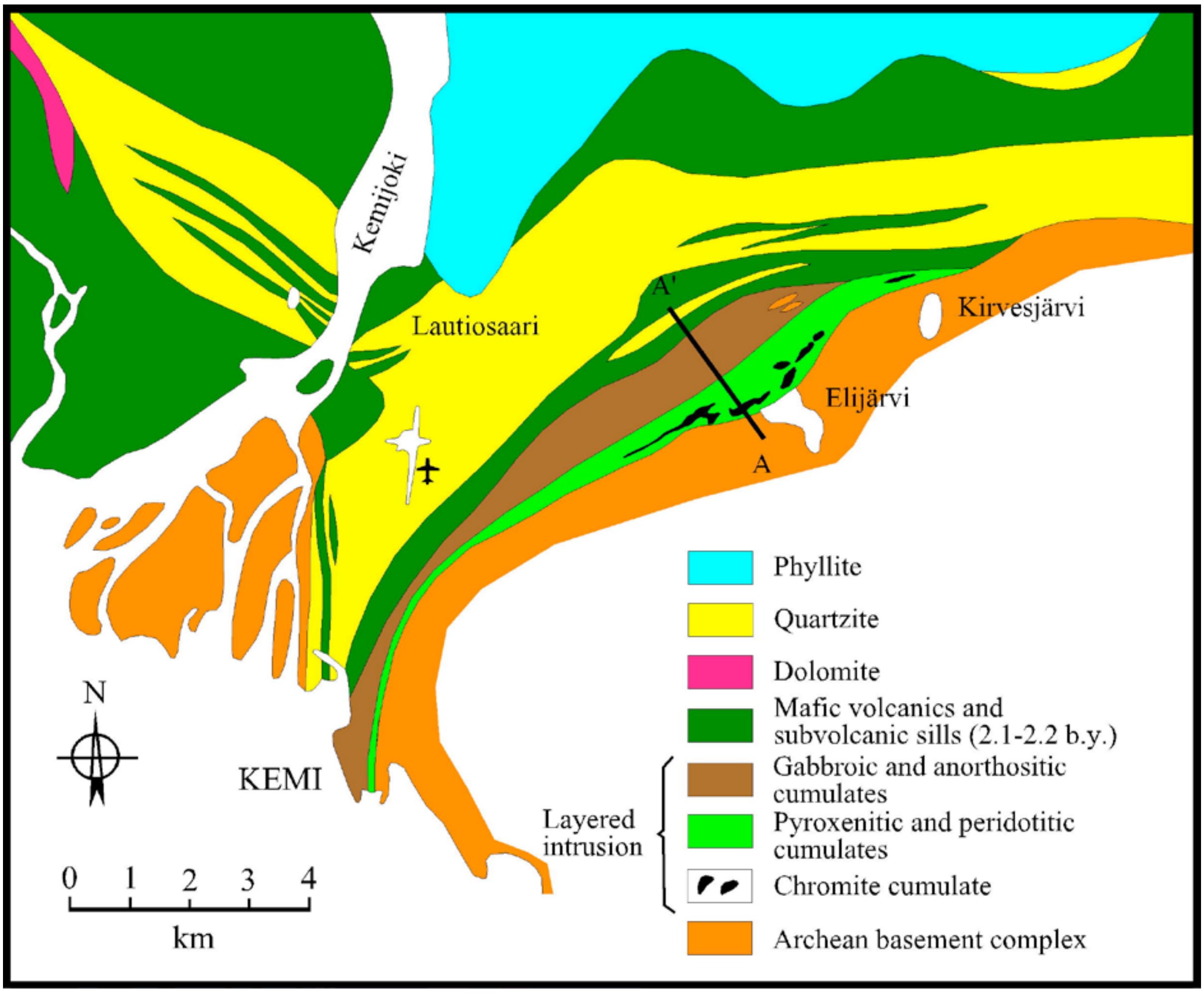

Figure 1. Generalised geological map of the Kemi Layered Intrusion. Modified after Alapieti et al. (1989). The line A – A' indicates the location of the profile shown in Figure 2.

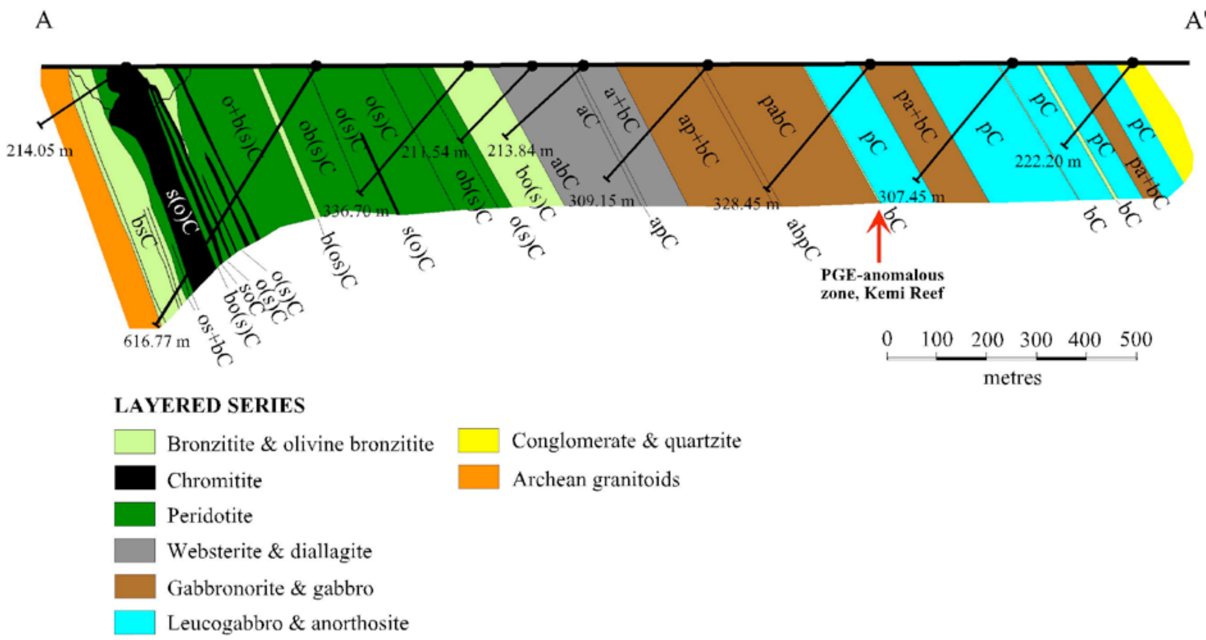

Figure 2. Cross-section of the Kemi Layered Intrusion (see Figure 1 for the location of line A – A'). The location of the PGE-anomalous zone is indicated by the red arrow. Modified after Alapieti et al. (1989).

Known deposits

There are no well-explored reef-type PGE deposits within the Kemi permissive tract.

Prospects, mineral occurrences, and related deposit types

One weakly PGE-enriched reef-type occurrence has been detected from the Kemi permissive tract. This reef is intercepted by just one drill hole forming part of the sole profile drilled across the entire intrusion (Figure 2). The extensively drilled lower chromitite units of the intrusion are also weakly PGE-enriched. However, the PGE grades in the latter are consistently below 0.5 ppm (Kojonen et al. 2005).

Table 2. Significant prospects and occurrences in KemiReefPGE.

Name	X coordinate	Y coordinate	Age (Ga)	Comments (grade and tonnage data, if available)	Reference
Kemi Reef	7301850	3394400	2.43	PGE-anomalous zone	Halkoaho, pers. comm. (2008)

Exploration history

The Kemi chrome ore was discovered in 1959 when a layman brought a dark, nonmagnetic outcrop sample to a GTK geologist. The sample was identified in by laboratory examination as chromitite. Detailed gravimetric, magnetic and electromagnetic surveys were conducted during the autumn of 1959 and diamond drilling was carried out between 25 October 1959 and 30 April 1960. Altogether, 34 diamond drill holes were made during this period. In May 1960, Outokumpu Co. was given the task to further explore the chromite occurrence (Kahma et al. 1962), which later resulted in the opening of the Kemi chromite mine. During 1983, Lapin Malmi drilled five diamond drill holes to check the PGE potential of the Kemi layered intrusion. In 2003, Outokumpu Mining Oy re-logged and analysed three of the Lapin Malmi cores for PGE. The exploration history for the Kemi intrusion is summarised in Table 3.

Table 3. Exploration history for the Kemi intrusion.

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Bedrock mapping	No	GTK	1940s & 1960s
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	1982
Ground geophysical surveys	Electromagnetic, magnetic and gravity surveys covering 7 km2. Number of observation points about 5000. 375 susceptibility determinations from 4 drill holes (total length 387 m). Density determinations from 6 drill holes (total length 1040 m)	No	GTK	1959
Drilling	34 diamond-drill holes	One sample	GTK	1959–1960
	About 250 diamond drill holes		Outokumpu	1960s
	Five diamond drill holes, total 1503.95 m	Yes	Lapin Malm	1983
Other	Re-logging drill holes	Yes	Lapin Malmi	1980s
	Re-logging 3 drill holes	Yes	Outokumpu	2003

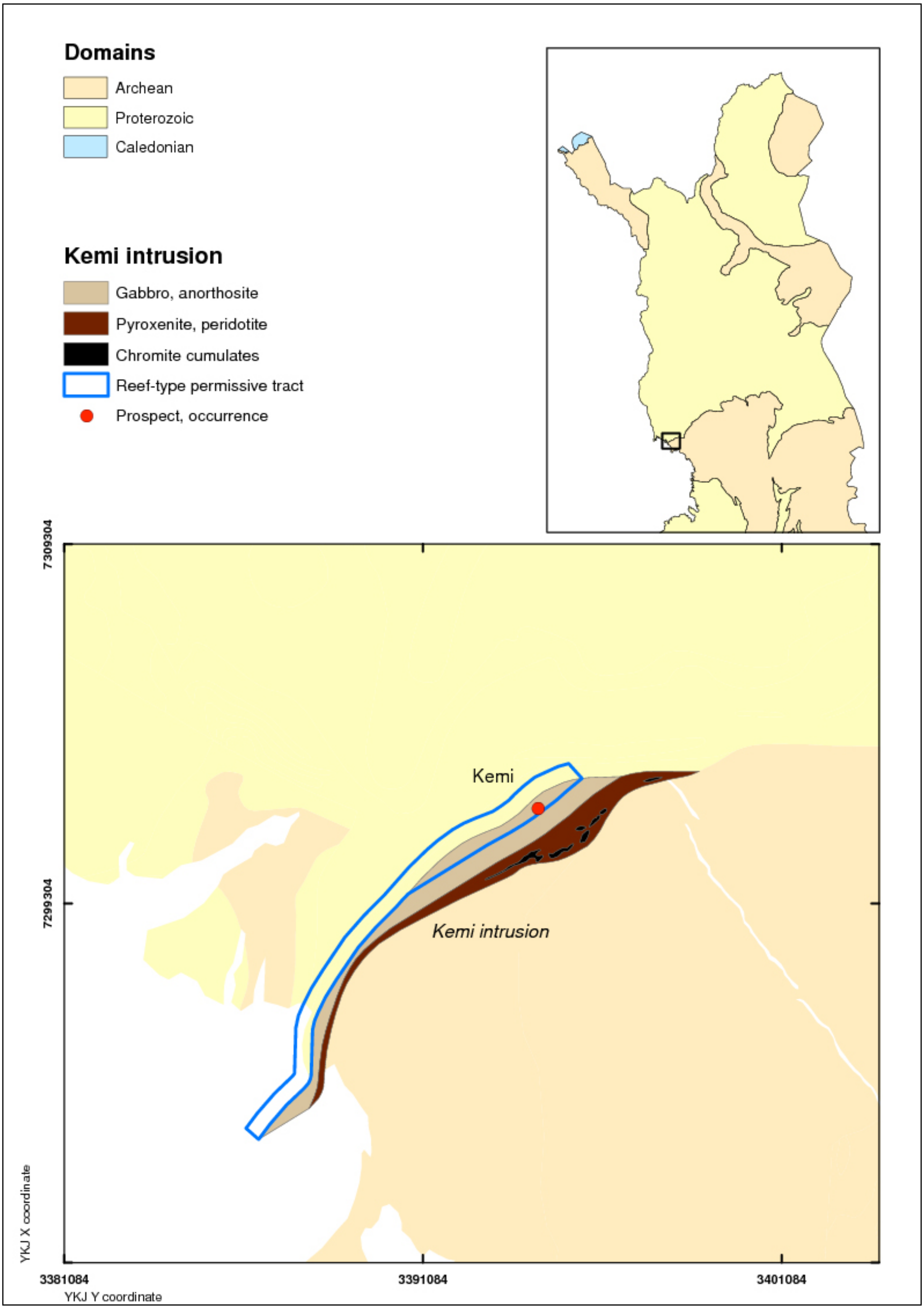

Figure 3. Location of the permissive tract KemiReefPGE.

Sources of information

Principal sources of information used by the assessment team for the delineation of KemiReefPGE are listed in Table 4.

Table 4. Principal sources of information used by the assessment team for KemiReefPGE.

Theme	Type of source	Scale	Citation
Geology	Stratigraphic and structural geology of the region	1:100000	Härme (1949)
	Regional bedrock mapping		Perttunen (1971, 1991)
	Kemi intrusion		Alapieti et al. (1989), Huhtelin & Alapieti (2005)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
Mineral occurrences	Exploration and mapping of the Kemi chromite deposit		Kahma et al. (1962)
	Kemi chromitite deposit investigations		Alapieti et al. (1989), Huhtelin & Alapieti (2005)
Geochemistry	U-Pb age determination from zircon		Perttunen & Vaasjoki (2001)
Geophysics	Exploration and mapping of the Kemi chromite deposit		Kahma et al. (1962)
Exploration	Exploration of the Kemi chromite deposit		Kahma et al. (1962)

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

Only one poorly known reef-type prospect occurs within the tract (Table 2). This means that the minimum number of undiscovered reef-type deposits within the tract is one. The reef-critical part of the intrusion was regarded in our work as quite poorly surveyed and drilled; actually, only one drill hole intersects the PGE anomalous zone (Figure 2). However, it was considered probable that a potentially mineable reef-type deposit exists at the present erosion level. Two of the estimators considered that the geological similarity of the intrusion with the Penikat and Tornio layered intrusions means that there is possibility for another reef deposit to occur within the Kemi tract (Table 5). The calculated mean values of undiscovered deposits at 90th, 50th and 10th percentiles were used in the Monte Carlo simulations.

Table 5. Undiscovered deposit estimates, deposit numbers, and tract area for KemiReefPGE.

Mean undiscovered deposit estimate					Summary statistics					Area (km2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}	
0	1	2			1.0	0.79	79	0	1.0	8.3

Estimator	N90	N50	N10	N05	N01
	Estimated number of undiscovered deposits				
Estimator 1	0	1	1		
Estimator 2	0	1	2		
Estimator 3	0	1	2		
Mean	0	1	2		

Nxx = Estimated number of deposits associated with the xxth percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were calculated by combining the undiscovered deposit estimates with the Finnish reef-type PGE grade model and the KemiReefPGE tonnage model (Appendix 4) using the EMINERS software (Root et al. 1992, Duval 2004). Selected simulation results are reported in Table 5.

Results of the Monte Carlo simulation are presented as a cumulative frequency plots (Figure 4). The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralized rock.

Table 6. Results of Monte Carlo simulations of undiscovered resources in KemiReefPGE.

Material	At least the indicated amount at the probability of					Mean	Probability of mean or greater	Probability of zero
	0.95	0.9	0.5	0.1	0.05			
Pt (t)	0	0	69	600	1,000	240	0.25	0.30
Pd (t)	0	0	140	1,100	1,800	440	0.26	0.30
Au (t)	0	0	4	29	42	10	0.29	0.30
Ni (t)	0	0	34,000	180,000	260,000	66,000	0.33	0.30
Cu (t)	0	0	26,000	240,000	360,000	83,000	0.29	0.30
Rock (Mt)	0	0	49	230	310	83	0.36	0.30

t = metric tonnes; Mt = millions of tonnes.

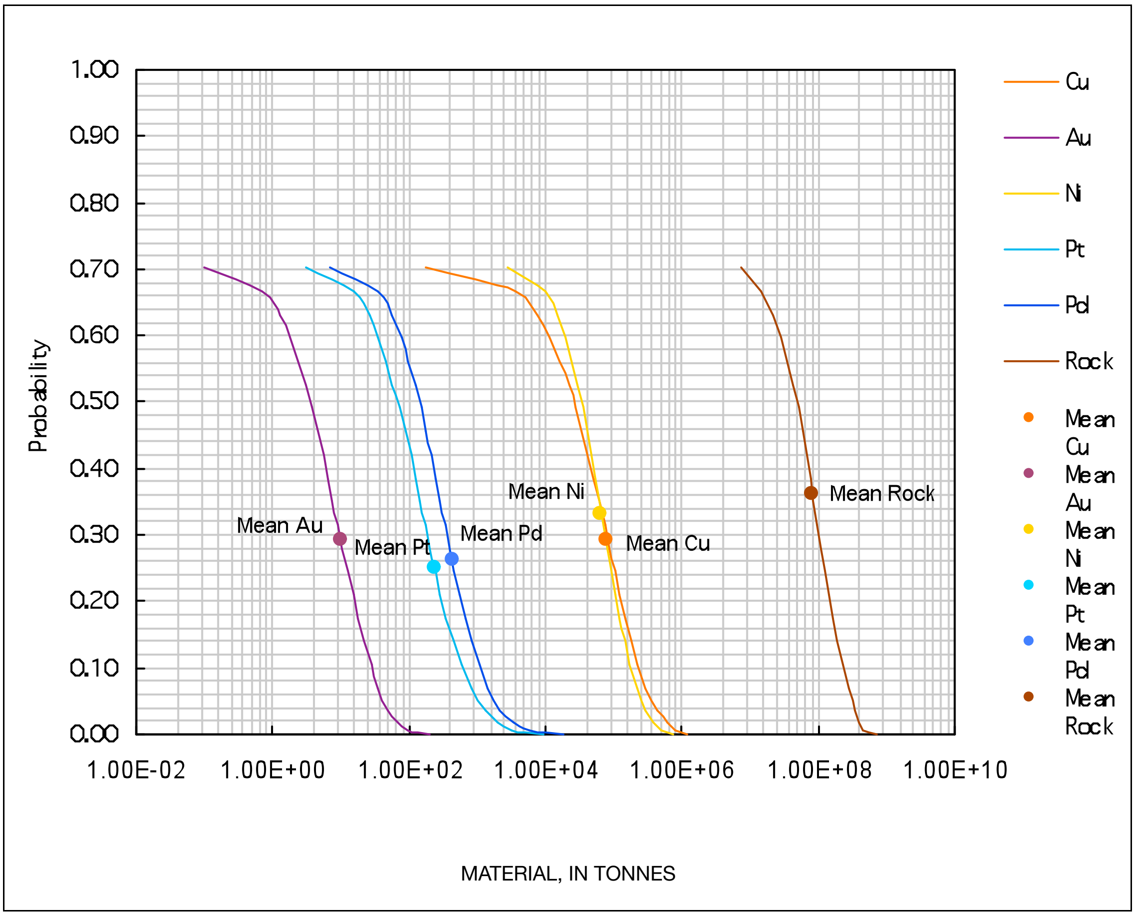

Figure 4. Cumulative frequency plot showing the results of Monte Carlo computer simulation of undiscovered resources in KemiReefPGE.

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CONTACT-TYPE PGE ASSESSMENT FOR TRACT KoitelainenContactPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Contact-type Cu-Ni-PGE
Descriptive model: Fennoscandian contact-type Cu-Ni-PGE deposits (Appendix 1)
Grade and tonnage model: Fennoscandian contact-type Cu-Ni-PGE deposits (Appendix 2)

LOCATION AND RESOURCE SUMMARY

The Koitelainen layered intrusion is located in northern Finland in the municipality of Sodankylä, 200 km NNE from Rovaniemi. The 1:100 000 KKJ map sheets are 3714, 3723, 3732 and 3741. The UTM map sheets containing the intrusion are U4443, U4444, U5221, U5222, and V5111. The PGE resource assessment carried out for this report is summarised in Table 1.

Table 1. Summary of selected resource assessment results for KoitelainenContactPGE.

Date of assessment	Assessment depth (km)	Tract area (km^2)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
			Pt	0	Pt	8	Pt	0
			Pd	0	Pd	31	Pd	0
01.10.2008	1	14	Au	0	Au	3	Au	0
			Ni	0	Ni	27,000	Ni	0
			Cu	0	Cu	49,000	Cu	0

t – metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The permissive tract for contact-type PGE mineralisation within the Koitelainen intrusion was only defined for that part of the intrusion where the marginal series is not boninitic and contains no Cr-rich units, but indicates less-peaceful intrusive conditions. There also is a weakly sulphide-bearing unit in the lowest part of the intrusion (unless this is related to Sattasvaara komatiites, and not a part of Koitelainen intrusion). The part of the Koitelainen layered intrusion assessed is subhorizontal with a 5–10° dip to the south. The sources of information used in the delineation of the tract are summarised in Table 3.

Known deposits

No contact-type PGE deposits are known within the tract.

Prospects, mineral occurrences, and related deposit types

No obvious contact-type PGE prospects are known from the tract. On the other hand, there are two extensive reef-type PGE occurrences within the Koitelainen intrusion (Mutanen 1997), as described in the KoitelainenReefPGE tract report.

Exploration history

Exploration commenced in the Koitelainen area in late 1960s by GTK, and the chromitite reefs of the intrusion were soon detected (Mutanen 1974, 1997). Attention was drawn to the area of the intrusion by the presence of the Keivitsa intrusion which was already detected in the 1920s. Extensive metal exploration was performed in the area in the 1970s and 1980s. Reef-type PGE mineralisation was discovered in the 1970s (Mutanen 1997). However, within the area of possible contact-type mineralisation, very little work has been done. Types of exploration work carried out in the Koitelainen intrusion, and known to us, are listed in Table 2.

Table 2. Exploration history for the Koitelainen intrusion.

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Detailed bedrock mapping, outcrop sampling	Yes	GTK	1970s, 1990s
Geochemical surveys	Till geochemical surveys for the entire area of the intrusion	Yes	GTK	1970s
	Till geochemical survey for SW part of the intrusion	No	Outokumpu	2000
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	1973
Ground geophysical surveys	Electromagnetic (slingram, VLF), magnetic and gravity surveys covering parts of the intrusion down-hole survey on drill holes		GTK	1970s, 1990s
Drilling	Tens of diamond-drill holes	Yes	GTK	1973–1995
Other	Ore mineralogical investigations on 700 polished thin sections.	Yes	GTK	1990–1998

Sources of information

Principal sources of information used by the assessment team for the delineation of KoitelainenContact-PGE are listed in Table 3.

Table 3. Principal sources of information used by the assessment team for KoitelainenContactPGE.

Theme	Type of source	Scale	Citation
Geology	PhD thesis on Akanvaara and Koitelainen intrusions		Mutanen (1997)
	Geological map of the Koitelainen intrusion Radiometric age for the intrusion		Mutanen (1997) Mutanen & Huhma (2001)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
Mineral occurrences	PhD thesis and exploration report on Akanvaara and Koitelainen intrusions geology and mineral occurrences		Mutanen (1997)
Geochemistry	Reports on till geochemical surveys		Kontas & Niskavaara (1989)
Geophysics	Interpretations of ground-geophysical surveys		Mutanen (1974, 1997, 2002)
Exploration	General and detailed descriptions of exploration activities and results in the area of the intrusion		Puustinen (1977), Mutanen (1974, 1997, 2002), Vihreäpuu (2001)

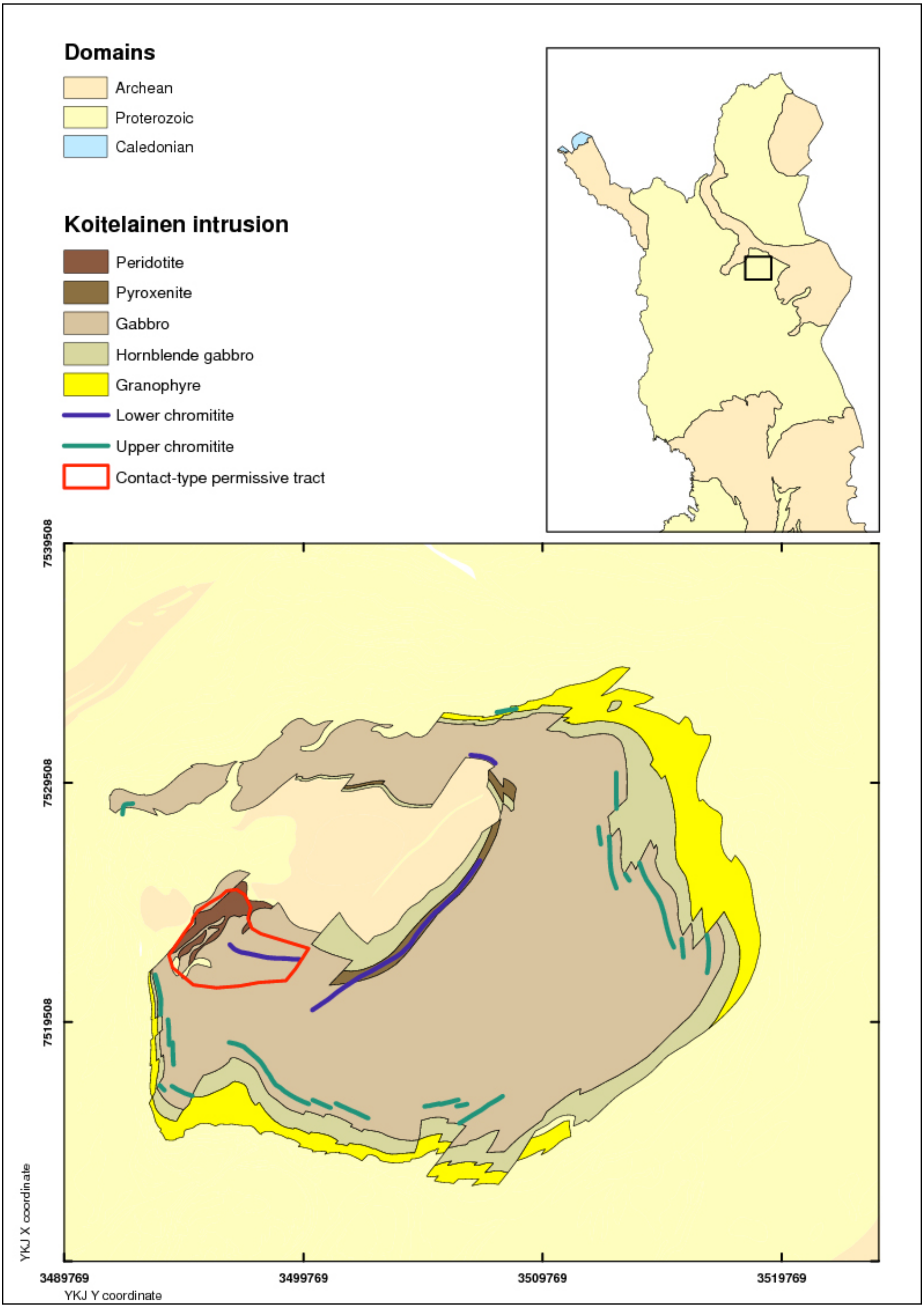

Figure 1. Location of the permissive tract KoitelainenContactPGE.

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

Geological factors that were used to estimate the number of undiscovered deposits within the Koitelainen contact-type tract included the geology of the intrusion, the distribution of the known mineralised locations, and the available geophysical and drilling data (Tables 2 and 3).

No contact-type deposits or prospects are known within the tract. This means that the number of undiscovered contact-type deposits within the tract can be zero or larger. All estimators thought that the potential for a contact-type deposit at Koitelainen is low or very low. A near consensus was reached between the estimators for the number of undiscovered contact-type PGE deposit at Koitelainen; the mean only had to be used for the percentile N10 in the Monte Carlo simulations (Table 4).

Table 4. Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for KoitelainenContactPGE.

Mean undiscovered deposit estimate					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
0	0	1			0.30	0.50	170	0	0.30	14	0.022

Estimator	N90	N50	N10	N05	N01
	Estimated number of undiscovered deposits				
Estimator 1	0	0	1		
Estimator 2	0	0	1		
Estimator 3	0	0	0		
Mean	0	0	1		

Nxx = Estimated number of deposits associated with the xxth percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; Deposit density = deposit density reported as the total number of deposits per km^2. N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

Quantitative assessment simulation results

Undiscovered resources for the tract were estimated by combining the means of estimated numbers of undiscovered contact-type PGE deposits with the Fennoscandian contact-type PGE grade and tonnage model (Appendix 2) using the EMINERS software (Root et al. 1992, Duval 2004). Selected simulation results are reported in Table 5. Results of the Monte Carlo simulation are presented as a cumulative frequency plots (Figure 2). The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralized rock.

Table 5. Results of Monte Carlo simulations of undiscovered resources in KoitelainenContactPGE.

Material	At least the indicated amount at the probability of					Mean	Probability of mean or greater	Probability of zero
	0.95	0.90	0.50	0.10	0.05			
Pt (t)	0	0	0	16	46	8	0.16	0.70
Pd (t)	0	0	0	57	160	31	0.13	0.70
Au (t)	0	0	0	7	15	3	0.15	0.70
Ni (t)	0	0	0	94,000	180,000	27,000	0.21	0.70
Cu (t)	0	0	0	140,000	320,000	49,000	0.19	0.70
Rock (Mt)	0	0	0	59	210	27	0.17	0.70

t = metric tonnes; Mt = millions of tonnes.

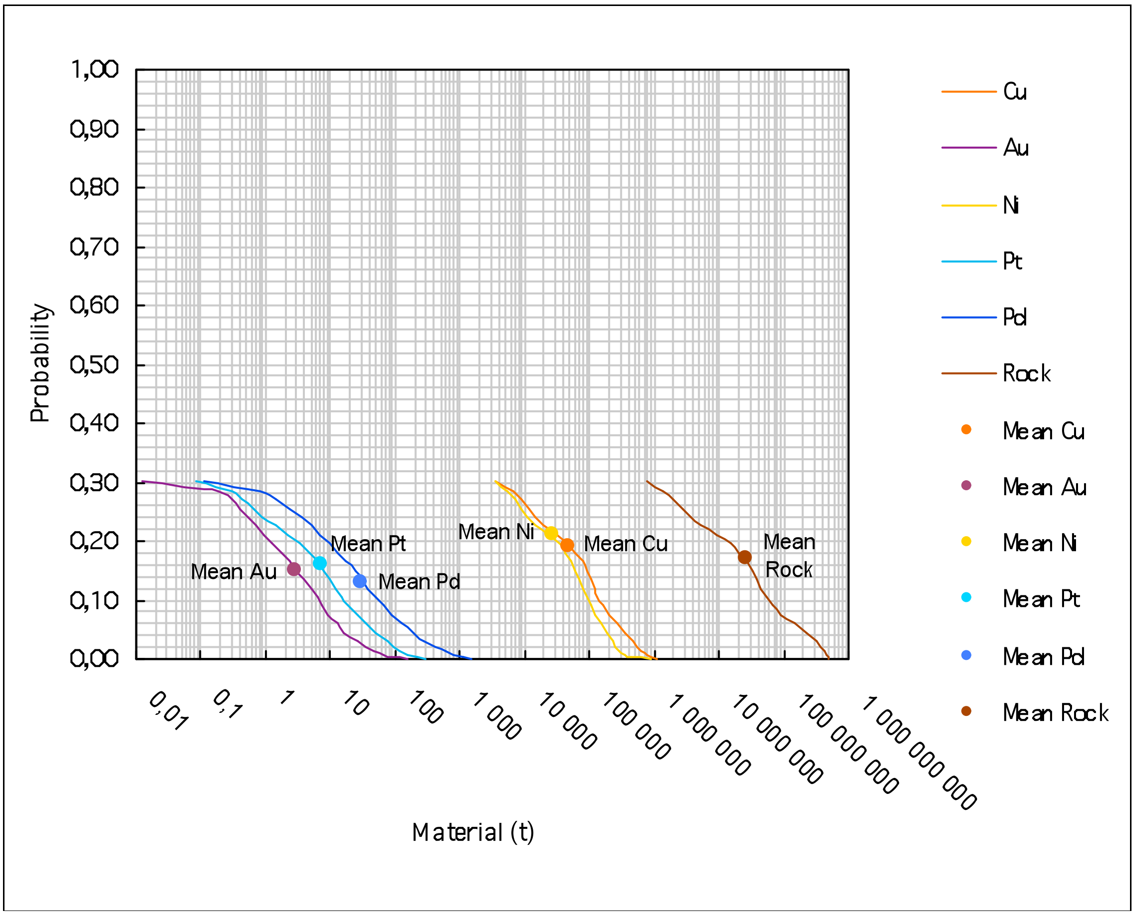

Figure 2. Cumulative frequency plot showing the results of Monte Carlo computer simulation of undiscovered resources in KoitelainenContactPGE.

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-TYPE PGE ASSESSMENT FOR TRACT KoitelainenReefPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Reef-type PGE-Ni-Cu
Descriptive model: Finnish reef-type PGE-Ni-Cu (Appendix 3)
Grade-tonnage model: Finnish reef-type PGE-Ni-Cu grade model, KoitelainenReefPGE tonnage model (Appendix 4)

LOCATION AND RESOURCE SUMMARY

The Koitelainen layered intrusion is located in northern Finland in the municipality of Sodankylä, 200 km NNE from Rovaniemi. The 1:100 000 KKJ map sheets are 3714, 3723, 3732 and 3741. The UTM map sheets containing the intrusion are U4443, U4444, U5221, U5222, and V5111. The PGE resource assessment carried out for this report is summarised in Table 1.

Table 1. Summary of selected resource assessment results for KoitelainenReefPGE. Only well-delineated deposits are included.

Date of assessment	Assessment depth (km)	Tract area (km²)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
27.08–01.10.2008	1	356	Pt	0	Pt	5,900	Pt	2,700
			Pd	0	Pd	11,000	Pd	5,300
			Au	0	Au	250	Au	140
			Ni	0	Ni	1,600,000	Ni	1,100,00
			Cu	0	Cu	2,000,000	Cu	1,100,00

t = metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The Koitelainen layered intrusion is subhorizontal. It dips at 0–10° to the NE in its northern and northeastern part, to the east in the eastern part and to the south in the southern and western parts of the intrusion. It has a stratigraphic thickness of about 3 km (Mutanen 1997). The upper part of the intrusion at and above the contact between an earlier Cr-rich and a later Cr-poor magma units is used to determine the permissive tract. Hence, the permissive tract matches the surface projection of this upper part of the intrusion down to 1 km depth. The sources of information used in the delineation of the tract are summarized in Table 4.

Known deposits

There are no well-explored reef-type PGE deposits within the Koitelainen permissive tract.

Prospects, mineral occurrences, and related deposit types

Two partially explored reef-type PGE occurrences are known within the Koitelainen permissive tract: Upper Chromitite (UC) and the Lower Chromitite (LC) (Table 2 and Figure 1). In addition, the lowermost 75 m of magnetite gabbro contains 0.5 ppm PGE+Au. There seem to be no other types of PGE mineralisation at Koitelainen, as the intrusion is reasonably well explored. The marginal series is boninitic, contains Cr-rich units, indicates peaceful intrusion conditions and is clearly unmineralised on PGE.

Table 2. Significant prospects and occurrences in KoitelainenReefPGE.

Name	X coordinate	Y coordinate	Age (Ma)	Comments (grade and tonnage data, if available)	Reference
Upper Chromitite	7526100	3512600	2.45	1.2 m true thickness, 21% Cr_2O_3, 0.4 % V, avg 1.1 ppm PGEtot. A rough estimate: 70 Mt @ 14.4% Cr, 1.1 ppm PGEtot	Mutanen (1997, 1998)
Lower chromitite	7524300	3505500	2.45	0.3 m to a few m thick layers within 37–59 m of stratigraphic thickness, dip 10° to SE, host pyroxenite, 10.6–32.2% Cr_2O_3, avg 1.4 ppm PGEtot. One part of LC: 2 Mt @ 15.7% Cr, 0.9 ppm Pd, 0.48 ppm Pt	Mutanen (1997, 1998), J. Parkkinen, pers. comm. (2002)

Exploration history

Exploration by GTK commenced in the Koitelainen area in late 1960s, and the chromitite reefs of the intrusion were soon detected (Mutanen 1974, 1997). Attention was drawn to the area of the intrusion by the presence of the mafic-ultramafic Keivitsa intrusion, which was already detected in the 1920s. Extensive metal exploration was performed in the area in the 1970s and 1980s. Reef-type PGE mineralisation was discovered in the 1970s (Mutanen 1997). Types of exploration work carried out in the Koitelainen intrusion, and known to us, are listed in Table 3.

Table 3. Exploration history for the Koitelainen intrusion.

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Detailed bedrock mapping, outcrop sampling	Yes	GTK	1970s, 1990s
Geochemical surveys	Till geochemical surveys for the entire area of the intrusion	Yes	GTK	1970s
	Till geochemical survey for SW part of the intrusion	No	Outokumpu	2000
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	1973
Ground geophysical surveys	Electromagnetic (slingram, VLF), magnetic and gravity surveys covering parts of the intrusion down-hole survey on drill holes		GTK	1970s, 1990s
Drilling	Tens of diamond-drill holes	Yes	GTK	1973–1995
Other	Ore mineralogical investigations on 700 polished thin sections.	Yes	GTK	1990–1998

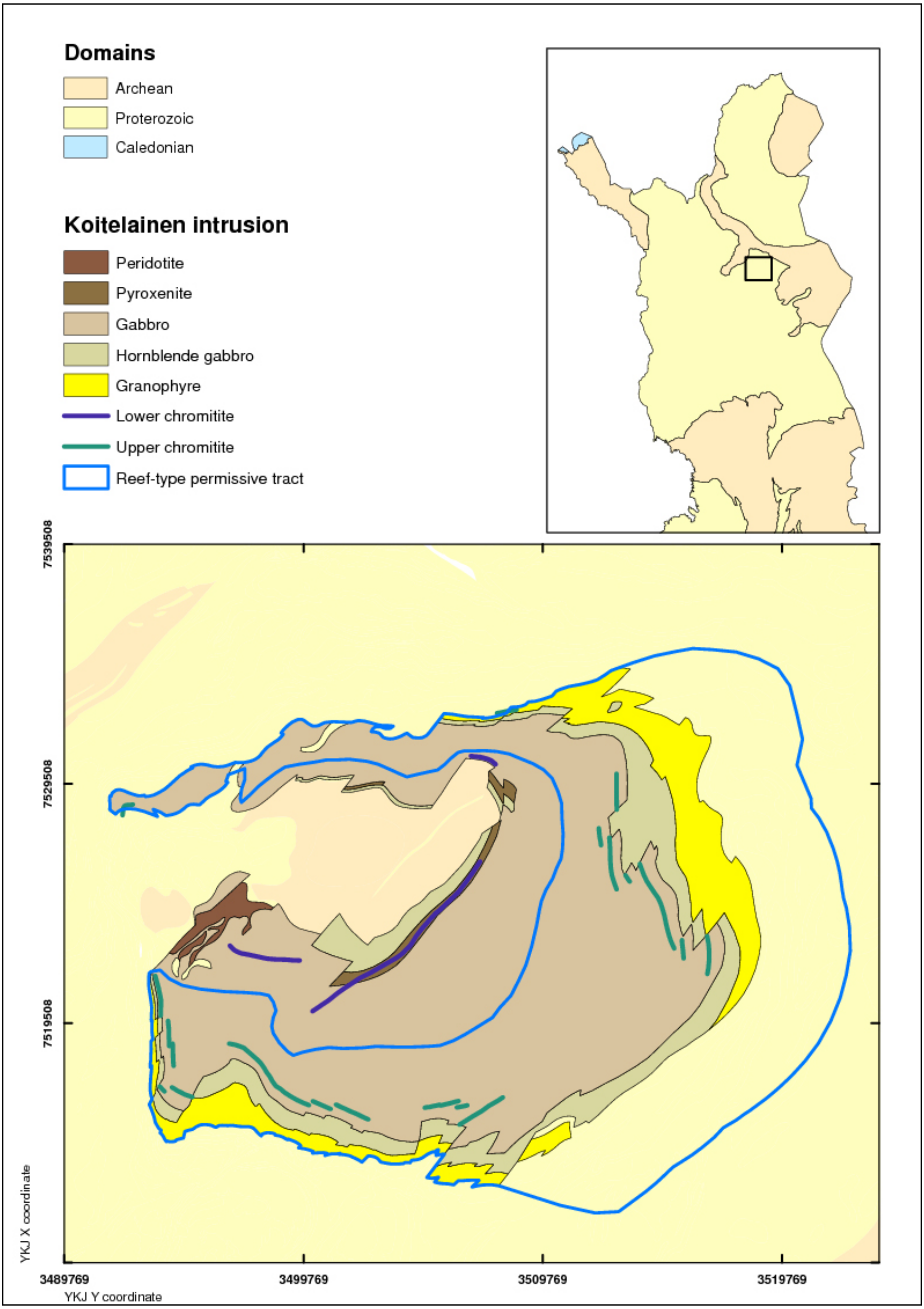

Figure 1. Location of the permissive tract KoitelainenReefPGE.

Sources of information

Principal sources of information used by the assessment team for the delineation of KoitelainenReefPGE are listed in Table 4.

Table 4. Principal sources of information used by the assessment team for KoitelainenReefPGE.

Theme	Type of source	Scale	Citation
Geology	PhD thesis on Akanvaara and Koitelainen intrusions		Mutanen (1997)
	Geological map of the Koitelainen intrusion		Mutanen (1997)
	Radiometric age for the intrusion		Mutanen & Huhma (2001)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
Mineral occurrences	PhD thesis and exploration report on Akanvaara and Koitelainen intrusions geology and mineral occurrences		Mutanen (1997)
Geochemistry	Reports on till geochemical surveys		Kontas & Niskavaara (1989)
Geophysics	Interpretations of ground-geophysical surveys		Mutanen (1974, 1997, 2002)
Exploration	General and detailed descriptions of exploration activities and results in the area of the intrusion		Puustinen (1977), Mutanen (1974, 1997, 2002), Vihreäpuu (2001)

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

Two reef-type prospects (LC and UC) are known within the tract. Since no good-quality resource estimates are available (Table 3), they were not included in the grade and tonnage model. This means that the number of undiscovered reef-type deposits within the tract would be at least two. However, none of the estimators considered it probable that both of these prospects would become mineable deposits (Table 5). As the estimators did not agree on the number of undiscovered deposits estimates, the mean values of the estimates (Table 5) were used as input to the Eminers software.

Table 5. Undiscovered deposit estimates, deposit numbers, and tract area, for KoitelainenReefPGE.

Mean undiscovered deposit estimate					Summary statistics					Area (km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}	
1	2	3			1.9	0.84	43	0	1.9	356

Estimator	Estimated number of undiscovered deposits N90	N50	N10	N05	N01
Estimator 1	1	3	3		
Estimator 2	1	3	4		
Estimator 3	0	1	2		
Mean	1	2	3		

Nxx = Estimated number of deposits associated with the xxth percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were calculated by combining the undiscovered deposit estimates with the Finnish reef-type PGE grade model and the KoitelainenReefPGE tonnage model (Appendix 4) using the EMINERS software (Root et al. 1992, Duval 2004). Selected simulation results are reported in Table 6. Results of the Monte Carlo simulation are presented as a cumulative frequency plots (Figure 2). The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralized rock.

Table 6. Results of Monte Carlo simulations of undiscovered resources in KoitelainenReefPGE.

Material	At least the indicated amount at the probability of					Mean	Probability of mean or greater	Probability of zero
	0.95	0.9	0.5	0.1	0.05			
Pt (t)	0	200	2,700	14,000	22,000	5,900	0.27	0.07
Pd (t)	0	420	5,300	25,000	38,000	11,000	0.27	0.07
Au (t)	0	10	140	610	870	250	0.32	0.07
Ni (t)	0	130,000	1,100,000	3,700,000	5,000,000	1,600,000	0.36	0.07
Cu (t)	0	53,000	1,100,000	5,000,000	7,300,000	2,000,000	0.32	0.07
Rock (Mt)	0	180	1,500	4,700	5,800	2,000	0.38	0.07

t – metric tonnes; Mt – millions of tonnes.

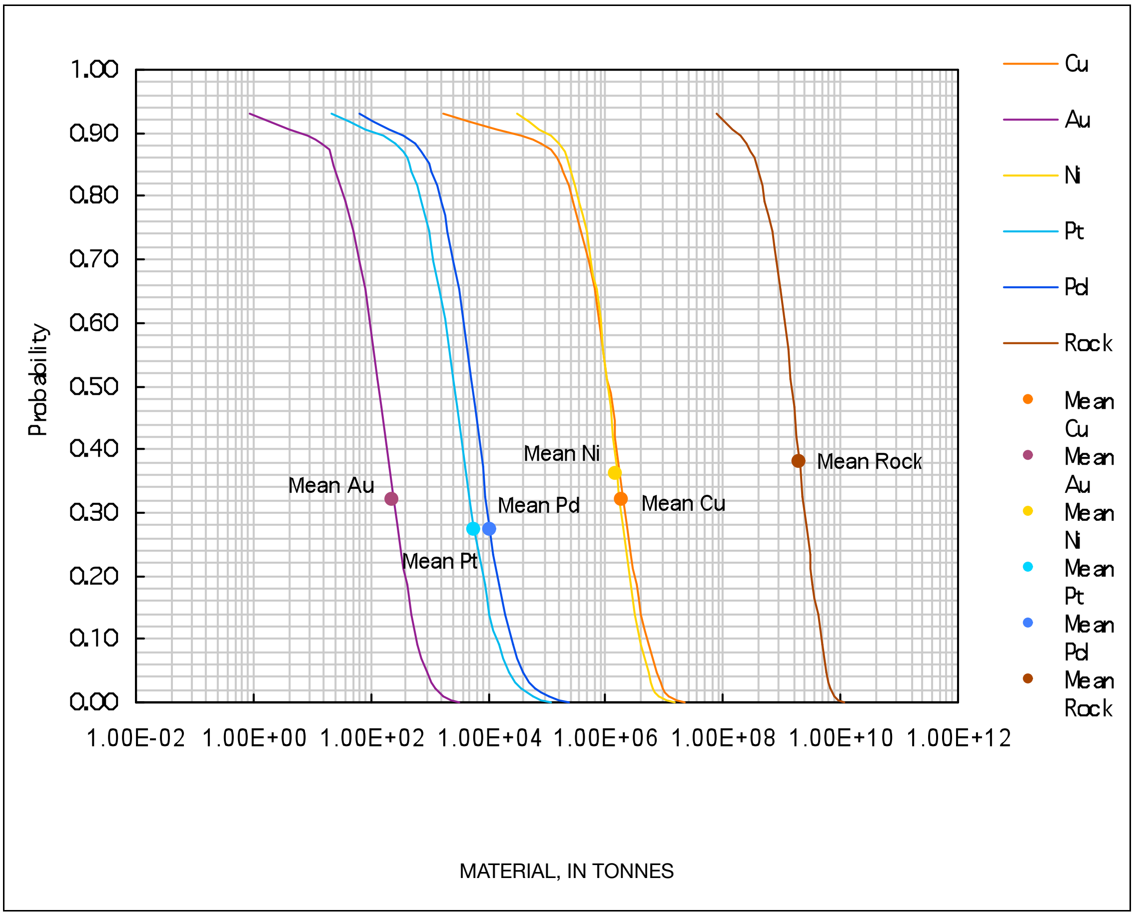

Figure 2. Cumulative frequency plot showing the results of Monte Carlo computer simulation of undiscovered resources in KoitelainenReefPGE.

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CONTACT-TYPE PGE ASSESSMENT FOR TRACT KonttijärviContactPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Contact-type Cu-Ni-PGE
Descriptive model: Fennoscandian contact-type Cu-Ni-PGE (Appendix 1)
Grade and tonnage model: Fennoscandian contact-type Cu-Ni-PGE (Appendix 2)

LOCATION AND RESOURCE SUMMARY

The Konttijärvi layered intrusion is located in northern Finland in the municipality of Ranua, 42 km south from Rovaniemi. The 1:100 000 KKJ map sheets are 3522. The UTM map sheet containing the intrusion is S4442. The PGE resource assessment carried out for this report is summarised in Table 1.

Table 1. Summary of selected resource assessment results for KonttijärviContactPGE.

Date of assessment	Assessment depth (km)	Tract area (km²)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
10–30.9.2008	1	0.7	Pt	17	Pt	0	Pt	0
			Pd	61	Pd	0	Pd	0
			Au	4.6	Au	0	Au	0
			Ni	25,000	Ni	0	Ni	0
			Cu	55,000	Cu	0	Cu	0

t = metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The permissive tract delineated in Figure 1 is a surface projection of the basal contact zone of the Konttijärvi intrusion. On the surface, the delineation is based on unpublished geological maps by Iljina. At depth, the tract is delineated based on drilling data. The sources of information used in the delineation of the tract are summarized in Table 4.

Known deposits

One contact-type PGE deposit, Konttijärvi, is known within the tract (Table 2 and Figure 1). This deposit nearly completely covers the basal contact zone of the intrusion (Iljina 1994, 2008 and Puritch et al. 2007). The Konttijärvi deposit is disseminated in character with no massive sulphide accumulations.

Table 2. Known contact-type PGE deposits in KonttijärviContactPGE.

Name	X coordinate	Y coordinate	Age (Ga)	Tonnage (Mt)	Grade					Contained PGE (t)		Reference
					Cu (%)	Ni (%)	Pt (g/t)	Pd (g/t)	Au (g/t)			
Kontti-järvi	7336800	3454150	2.44	42.1	0.13	0.06	0.41	1.44	011	Pt Pd	17 61	Puritch et al. (2007) Puritch et al. (2007)

Ma = millions of years; Mt = millions of metric tonnes; t = metric tonnes; g/t = grams per metric tonne.
Contained PGE is given in metric tonnes and computed as tonnage * grade.
Deposit ages are derived from an unpublished whole-rock Sm-Nd study by Iljina.
Cut-off grade for tonnage 0.8 g/t 2PGE+Au.

Prospects, mineral occurrences, and related deposit types

Drilling covers the entire Konttijärvi intrusion, and indicates that there is just one contact-type deposit, the one listed in Table 2. No other contact-type or reef-type prospects are known from the area.

Exploration history

Base metal sulphides were found in the area as early as in 1964, whereas high values of PGE were first documented in 1981 (Outokumpu Oy internal reports). The PGE discovery came through mineralogical studies and bedrock geochemical sampling. The first holes were drilled in 1981. This drilling phase culminated in the removal of overburden (180x100 m^2) and test pit mining by the end of the 1980s. All this work was performed by Outokumpu Oy (e.g., Ketola 1982, Lahtinen 1986). In 2000, exploration restarted through a joint venture between Outokumpu Oy and Gold Fields Ltd. Outokumpu dropped out of the JV in 2003. In 2006, North American Palladium Ltd (NAP) joined into JV with Gold Fields (GF). In 2008, NAP abandoned the project, and the property returned to GF, which still (May 2009) holds the rights to the property (the Suhanko mining concession). Outokumpu Oy – Gold Fields Ltd JV enlarged the cleaned bedrock surface to c. 350x150 m^2; this JV and the subsequent JV of GF and NAP also conducted test mining and pilot factory scale concentration tests. Table 3 summarises the exploration history of the Konttijärvi intrusion.

Table 3. Exploration history for KonttijärviContactPGE

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Detailed bedrock mapping, outcrop sampling	Yes	Outokumpu Oy	1960–1970
Geochemical surveys	Survey of some kind done; report of the work not available		Outokumpu Oy	
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	
Ground geophysical surveys	A number detailed geophysical surveys using various methods		Outokumpu Oy	1981–2000
Drilling	161 diamond-drill holes, total ca. 20,000 m	Yes	Outokumpu Oy	1981–2000
	470 diamond-drill holes, total 48,838 m	Yes	GFAP	2000–2005
Test mining	Pilot scale concentration tests		Outokumpu Oy	1987
	Pilot scale concentration tests		GFAP	2003
	Pilot scale concentration tests		Gold Fields Ltd – North American Palladium Ltd JV	2006

GFAP = Gold Fields Arctic Platinum Oy and its precursor Arctic Platinum Partnership Ay.

Sources of information

Principal sources of information used by the assessment team for delineation of KonttijärviContactPGE are listed in Table 4.

Table 4. Principal sources of information used by the assessment team for KonttijärviContactPGE.

Theme	Type of source	Scale	Citation
Geology	PhD thesis on Portimo intrusion geology and mineral occurrences		Iljina (1994, 2005, 2008)
	Section across Konttijärvi marginal series	1:1000	Iljina (1994)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
Mineral occurrences	PhD thesis on Portimo intrusion geology and mineral occurrences; general and detailed descriptions on the intrusion and an excursion guide		Iljina (1994, 2005, 2008)
	Preliminary assessment of Suhanko occurrences		Reino et al. (1978)
	Ahmavaara, etc. preliminary assessment		Lahtinen (1986)
	Suhanko NI-43-101 Scoping Study		Puritch et al. (2007)
Exploration	General and detailed descriptions of exploration activities in the area		Reino et al. (1978), Lahtinen (1986), Puritch et al. (2007)

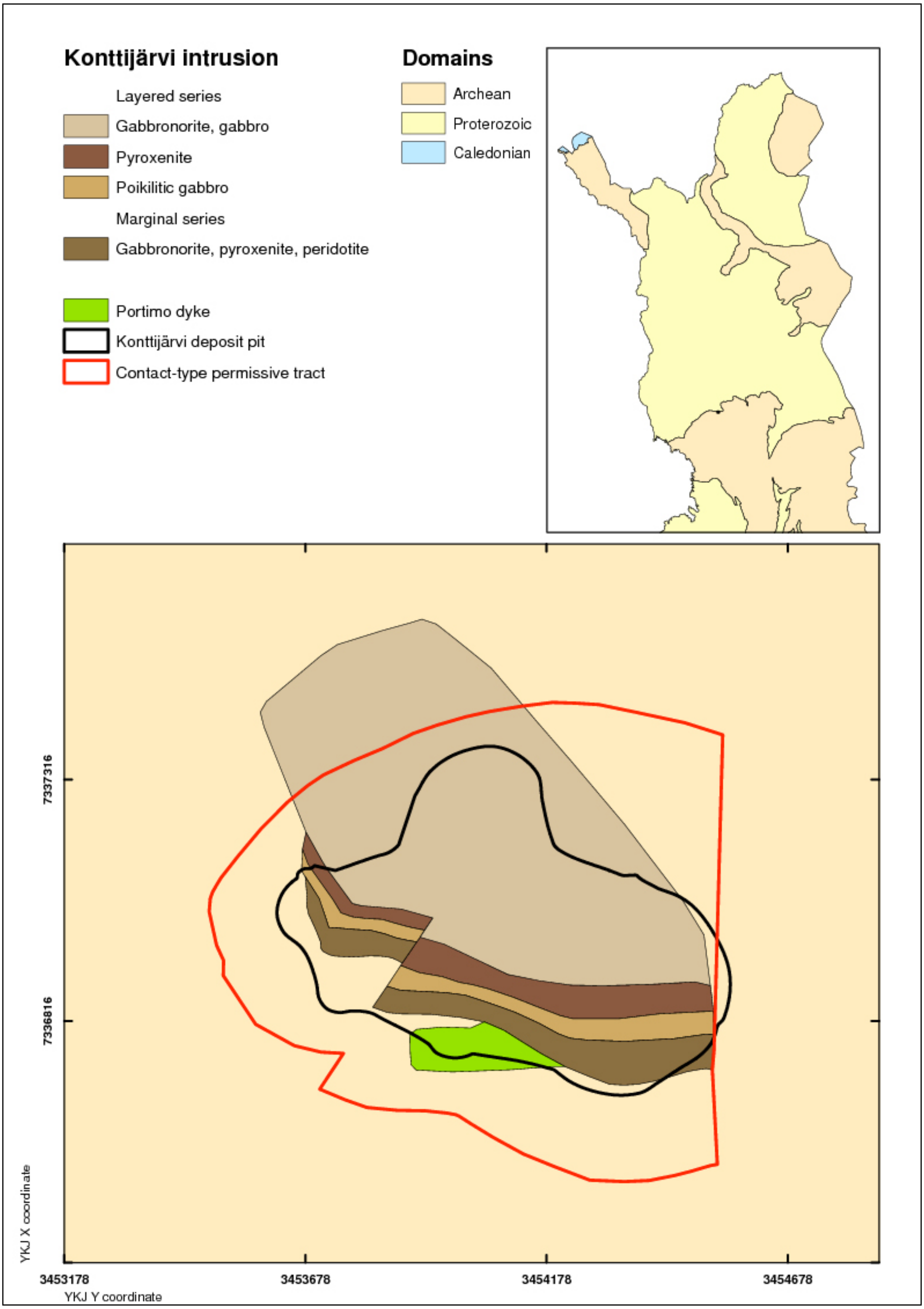

Figure 1. Location of the permissive tract KonttijärviContactPGE.

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

As indicated by drilling, there can be just one PGE deposit within the intrusion, and this has already been discovered. As exploration has a good coverage of the Konttijärvi intrusion and indicates that a possibility for an undiscovered contact-type deposit is zero, no further estimates on the matter were performed.

Table 5. Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for KonttijärviContactPGE.

Consensus of undiscovered deposit estimate					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
0	0	0			0	0		1	1	0.7	1.4

Estimator	Estimated number of undiscovered deposits N90	N50	N10	N05	N01
Estimator 1	0	0	0		
Estimator 2	0	0	0		
Estimator 3	0	0	0		
Consensus	0	0	0		

Nxx = Estimated number of deposits associated with the xx^{th} percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; Deposit density = deposit density reported as the total number of deposits per km^2. N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

The Konttijärvi permissive tract contains no undiscovered PGE deposits, hence no simulations were performed.

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REEF-TYPE PGE ASSESSMENT FOR TRACT KonttijärviReefPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Reef-type PGE-Ni-Cu
Descriptive model: Finnish reef-type PGE-Ni-Cu (Appendix 3)
Grade-tonnage model: Finnish reef-type PGE-Ni-Cu grade model, KonttijärviReefPGE tonnage model (Appendix 4)

LOCATION AND RESOURCE SUMMARY

The Konttijärvi layered intrusion is located in northern Finland in the municipality of Ranua, 42 km south from Rovaniemi. The 1:100 000 KKJ map sheets are 3522. The UTM map sheets containing the intrusion is S4442. The PGE resource assessment carried out for this report is summarised in Table 1.

Table 1. Summary of selected resource assessment results for KonttijärviReefPGE.

Date of assessment	Assessment depth (km)	Tract area (km²)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
10–30.9.2008	1	0.5	Pt	0	Pt	0	Pt	0
			Pd	0	Pd	0	Pd	0
			Au	0	Au	0	Au	0
			Ni	0	Ni	0	Ni	0
			Cu	0	Cu	0	Cu	0

t – metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The Konttijärvi layered intrusion dips to the north with an angle of about 40–70° (Iljina 1994). The middle and upper parts of the intrusion at and above the contact between earlier boninitic-like (Cr-rich) and later tholeiitic magma units are used to determine the permissive tract. Hence, the permissive tract matches the surface projection of this upper part of the intrusion (Figure 1). Drilling indicates that the entire intrusion extends no deeper than to 300 m vertically. The sources of information used in the delineation of the tract are summarised in Table 3.

Known deposits

No reef-type PGE deposits are known from Konttijärvi.

Prospects, mineral occurrences, and related deposit types

No reef-type prospects are known within the KonttijärviReefPGE tract. The Konttijärvi contact-type deposit is located within the tract.

Exploration history

Base metal sulphides were found in the area as early as in 1964, whereas high values of PGE were first documented in 1981 (Outokumpu Oy internal reports). The PGE discovery came through mineralogical studies and bedrock geochemical sampling. The first holes were drilled in 1981. This drilling phase culminated in the removal of overburden (350x150 m^2) and test pit mining by the end of the 1980s. All this work was performed by Outokumpu Oy (e.g., Ketola 1982, Lahtinen 1986). In 2000, exploration restarted through a joint venture between Outokumpu Oy and Gold Fields Ltd. Outokumpu dropped out of the JV in 2003. In 2006, North American Palladium Ltd (NAP) joined the JV with Gold Fields (GF). In 2008, NAP abandoned the project, and the property returned to GF, which still (December 2009) holds the rights to the property (the Suhanko mining concession). Table 2 summarises the exploration history of the Konttijärvi intrusion.

Table 2. Exploration history for KonttijärviReefPGE

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Detailed bedrock mapping, outcrop sampling	Yes	Outokumpu Oy	1960–1970
Geochemical surveys	Survey of some kind done; report of the work not available		Outokumpu Oy	
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	
Ground geophysical surveys	A number detailed geophysical surveys using various methods		Outokumpu Oy	1981–2000
Drilling	161 diamond-drill holes, total ca. 20,000 m	Yes	Outokumpu Oy	1981–2000
	470 diamond-drill holes, total 48,838 m	Yes	GFAP	2000–2005

GFAP = Gold Fields Arctic Platinum Oy and its precursor Arctic Platinum Partnership Ay.

Sources of information

Principal sources of information used by the assessment team for the delineation of KonttijärviReefPGE are listed in Table 3.

Table 3. Principal sources of information used by the assessment team for KonttijärviReefPGE.

Theme	Type of source	Scale	Citation
Geology	PhD thesis on Portimo intrusion geology and mineral occurrences		Iljina (1994, 2005, 2008)
	Section across Konttijärvi marginal series	1:1000	Iljina (1994)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
Mineral occurrences	PhD thesis on Portimo intrusion geology and mineral occurrences; general and detailed descriptions on the intrusion and the mineralisation excursion guide		Iljina (1994, 2005, 2008)
	Preliminary assessment of Suhanko occurrences		Reino et al. (1978)
	Ahmavaara, etc. preliminary assessment		Lahtinen (1986)
	Suhanko NI-43-101 Scoping Study		Puritch et al. (2007)
Exploration	General and detailed descriptions of exploration activities in the area		Reino et al. (1978), Lahtinen (1986), Puritch et al. (2007)

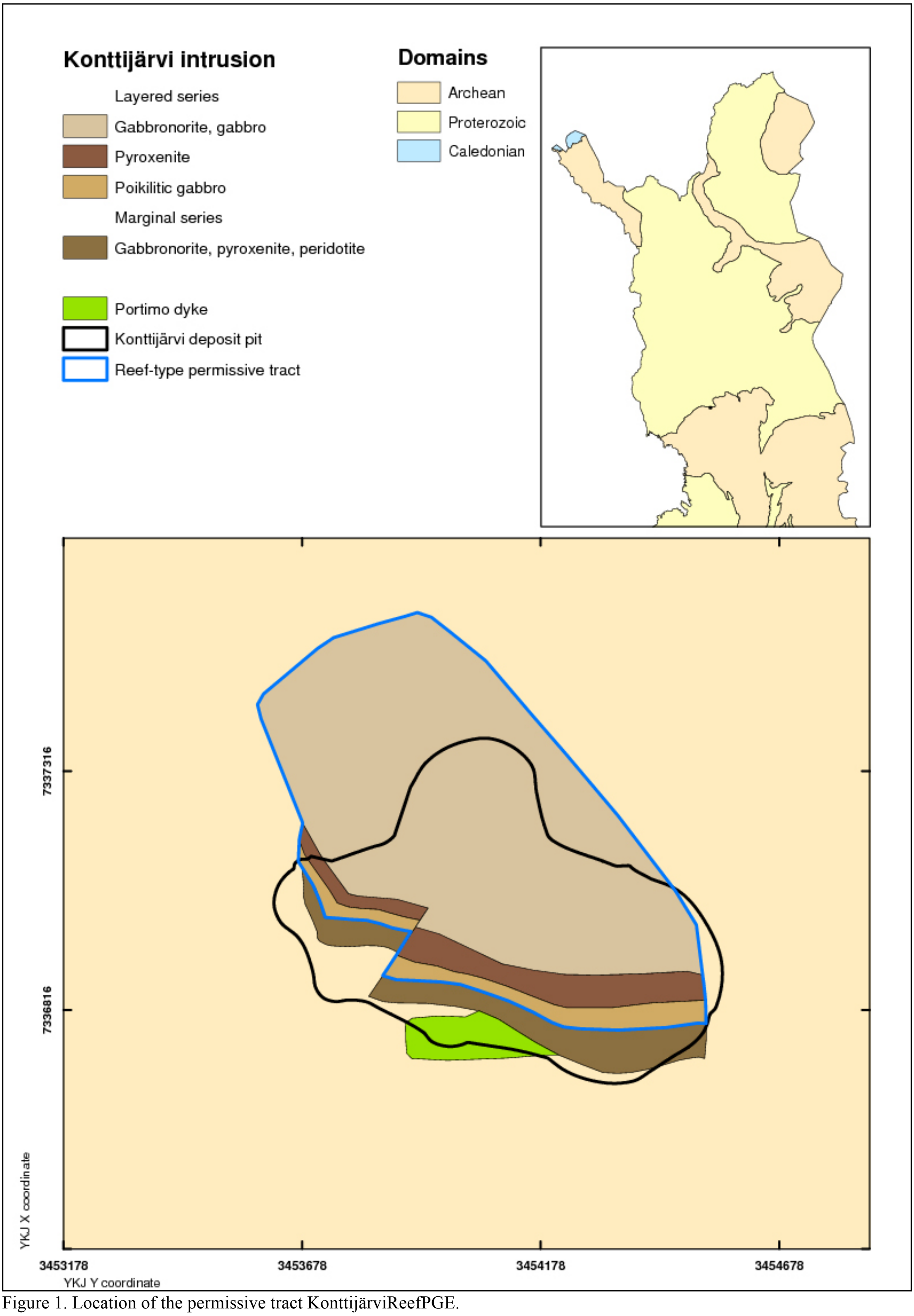

Figure 1. Location of the permissive tract KonttijärviReefPGE.

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

Exploration work, including drilling, has a good coverage of the Konttijärvi intrusion and indicates that the possibility for an undiscovered reef-type deposit is zero (Table 4).

Table 4. Undiscovered deposit estimates, deposit numbers, and tract area for KonttijärviReefPGE.

Consensus of undiscovered deposit estimate					Summary statistics					Area (km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}	
0	0	0			0	0		1	1	0.5

	Estimated number of undiscovered deposits				
Estimator	N90	N50	N10	N05	N01
Estimator 1	0	0	0		
Estimator 2	0	0	0		
Estimator 3	0	0	0		
Consensus	0	0	0		

Nxx = Estimated number of deposits associated with the xx^{th} percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

The Konttijärvi permissive tract contains no undiscovered PGE deposits, hence no simulations were performed.

REFERENCES

Geological Survey of Finland 2008. Bedrock Map Database DigiKP Finland, version 1.0. Accessed 21.11.2008.

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Ketola, M. 1982. On the application of geophysics and geology to exploration for nickel-copper ore deposits in Finland. Geological Survey of Finland, Report of Investigation 53. 103 p.

Lahtinen, J. 1986. Ni–Cu–PGE-mineralisaation tutkimukset; arvio malmimahdollisuuksista. Ranua, Ahmavaara. Outokumpu Oy, Report 001/3522/JJL/87/1.

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CONTACT-TYPE PGE ASSESSMENT FOR TRACT KoulumaoivaContactPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Contact-type Cu-Ni-PGE
Descriptive model: Fennoscandian contact-type Cu-Ni-PGE (Appendix 1)
Grade and tonnage model: Fennoscandian contact-type Cu-Ni-PGE (Appendix 2)

LOCATION AND RESOURCE SUMMARY

The 2466±26 Ma Koulumaoiva intrusion (unpubl. Sm-Nd age data by Juopperi & Huhma 1997) is located in northern Finland, in the municipality of Salla, 195 km NE from Rovaniemi. The map sheet containing the intrusion in the 1:100 000 KKJ system is sheet 4713; in the UTM system the map sheet is U5411. The PGE resource assessment carried out for this report is summarised in Table 1.

Table 1. Summary of selected resource assessment results for KoulumaoivaContactPGE.

Date of assessment	Assessment depth (km)	Tract area (km²)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
02.10.2008	1	4.2	Pt	0	Pt	8	Pt	0
			Pd	0	Pd	34	Pd	0
			Au	0	Au	3	Au	0
			Ni	0	Ni	28,000	Ni	0
			Cu	0	Cu	50,000	Cu	0

t = metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The Koulumaoiva intrusion is poorly known. It has a similar age to nearly all PGE-enriched layered intrusions in Finland, being 2466 ± 26 Ma (unpubl. Sm-Nd age data by H. Juopperi & H. Huhma 1997). It contains weak indications of PGE enrichment that perhaps best match with contact-type mineralisation, although one of the principal requirements, the reversed sequence of cumulates that would be expected in cumulate layers produced by fractional crystallization, has not been detected at Koulumaoiva. The permissive tract (Figure 1) covers the entire intrusion, representing its surface projection from 1 km depth combined with a buffer zone extending 200 m away from the contact into the country rocks. The sources of information used in the delineation of the tract are summarised in Table 3.

Known deposits

No contact-type PGE deposits are known within the tract.

Prospects, mineral occurrences, and related deposit types

No obvious contact-type PGE prospects are known from the tract.

Exploration history

Not much exploration has been performed in the area (Table 2). The Koulumaoiva intrusion was drilled first during a regional-scale lithological mapping project of GTK. At that time, the age of the intrusion was determined using the Sm-Nd method (Juopperi 2002). This age indicated that the intrusion belongs to the same age group as those intrusions that host significant PGE deposits in Finland, such as Penikat and the intrusions of the Portimo Complex (Iljina & Hanski 2005). This encouraged GTK to drill a bit more at Koulumaoiva (Iljina 2003). However, the drilling so far carried out has not intercepted any significant PGE grades, but only provided indications of contact-type PGE mineralisation by weakly elevated concentrations of chalcophile elements (Iljina 2003, M. Iljina, pers. comm., 2009).

Table 2. Exploration history for KoulumaoivaContactPGE.

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Bedrock mapping, outcrop sampling	Yes	GTK	1990s
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	2000–2001, 2005
Ground geophysical surveys	VLF-R and magnetic survey		GTK	1995, 2000
Drilling	Diamond-drill holes, total 577 m	Yes	GTK	1995, 2000

Sources of information

Principal sources of information used by the assessment team for the delineation of KoulumaoivaContact-PGE are listed in Tables 2 and 3.

Table 3. Principal sources of information used by the assessment team for KoulumaoivaContactPGE.

Theme	Type of source	Scale	Citation
Geology	General description of the geology and age determinations		Juopperi (2002)
	General description of the geology and drilling		Iljina (2003)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
Exploration	General description of exploration activities in the area		Iljina (2003)

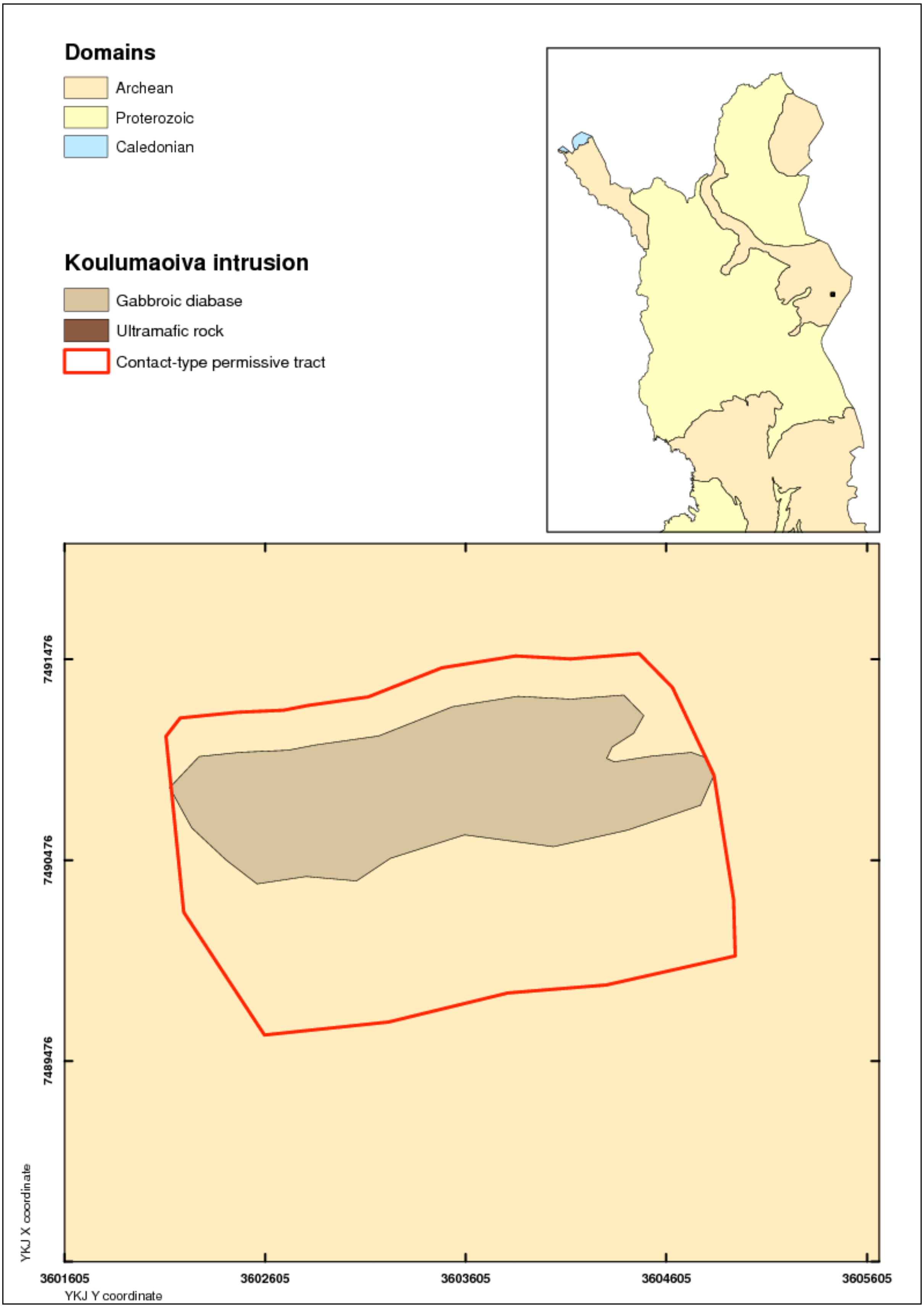

Figure 1. Location of the permissive tract KoulumaoivaContactPGE.

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

No contact-type deposits or prospects are known within the tract. This means that the number of undiscovered contact-type deposits within the tract can be zero or larger. There are only weak direct indications of PGE mineralisation within the intrusion. Hence, the ore potential was seen to be low by all estimators. Two estimators assumed that there is a small possibility for one deposit, whereas one estimator was more pessimistic, seeing no potential even at 10% probability (Table 4). Hence, the mean values were used in the statistical simulations for Koulumaoiva.

Table 4. Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for KoulumaoivaContactPGE.

Mean undiscovered deposit estimate					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
0	0	1			0.30	0.50	170		0.30	4.2	0.071

Estimator	N90	N50	N10	N05	N01
	Estimated number of undiscovered deposits				
Estimator 1	0	0	1		
Estimator 2	0	0	1		
Estimator 3	0	0	0		
Mean	0	0	1		

Nxx = Estimated number of deposits associated with the xxth percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; Deposit density = deposit density reported as the total number of deposits per km^2. N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were estimated by combining the means of estimated numbers of undiscovered contact-type PGE deposits with the Fennoscandian contact-type PGE grade and tonnage model (Appendix 2) using the EMINERS software (Root et al. 1992, Duval 2004). Selected simulation results are reported in Table 5. Results of the Monte Carlo simulation are presented as cumulative frequency plots (Figure 2). The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralized rock.

Table 5. Results of Monte Carlo simulations of undiscovered resources in KoulumaoivaContactPGE.

Material	At least the indicated amount at the probability of					Mean	Probability of mean or greater	Probability of zero
	0.95	0.90	0.50	0.10	0.05			
Pt (t)	0	0	0	18	49	8	0.16	0.69
Pd (t)	0	0	0	69	170	34	0.14	0.69
Au (t)	0	0	0	7	15	3	0.16	0.69
Ni (t)	0	0	0	97,000	180,000	28,000	0.21	0.69
Cu (t)	0	0	0	160,000	350,000	50,000	0.20	0.69
Rock (Mt)	0	0	0	62	220	29	0.17	0.69

t = metric tonnes; Mt = millions of tonnes.

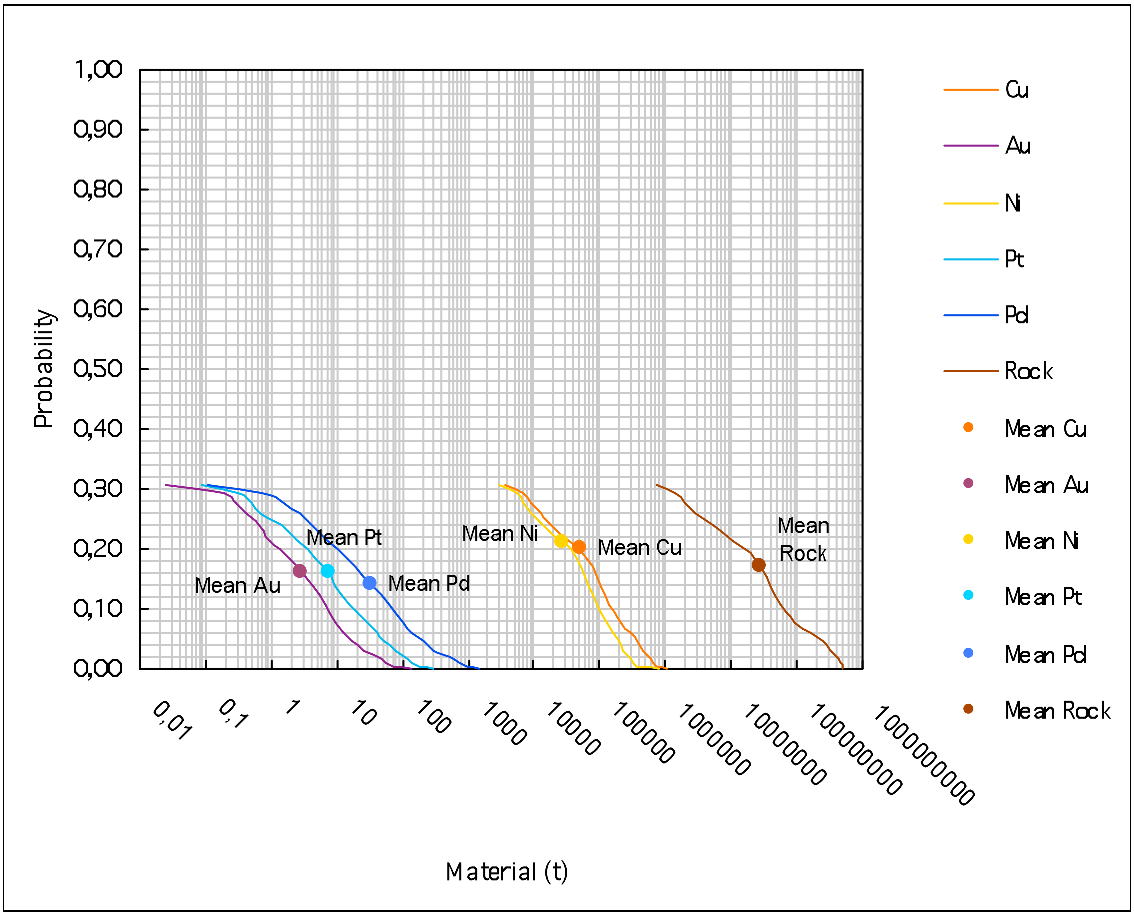

Figure 2. Cumulative frequency plot showing the results of Monte Carlo computer simulation of undiscovered resources in KoulumaoivaContactPGE.

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REEF-TYPE PGE ASSESSMENT FOR TRACT KoulumaoivaReefPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Reef-type PGE-Ni-Cu
Descriptive model: Finnish reef-type PGE-Ni-Cu (Appendix 3)
Grade-tonnage model: Finnish reef-type PGE-Ni-Cu grade model, KoulumaoivaReefPGE tonnage model (Appendix 4)

LOCATION AND RESOURCE SUMMARY

The 2466±26 Ma Koulumaoiva intrusion (unpubl. Sm-Nd age data by Juopperi & Huhma 1997) is located in northern Finland, in the municipality of Salla, 195 km NE from Rovaniemi. The map sheet containing the intrusion in the 1:100 000 KKJ system is sheet 4713; in the UTM system the map sheet is U5411. The PGE resource assessment carried out for this report is summarised in Table 1.

Table 1. Summary of selected resource assessment results for KoulumaoivaReefPGE. Only well-delineated deposits are included.

Date of assessment	Assessment depth (km)	Tract area (km²)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
28.08.–02.10.2008	1	4.6	Pt	0	Pt	16	Pt	0
			Pd	0	Pd	30	Pd	0
			Au	0	Au	1	Au	0
			Ni	0	Ni	4,800	Ni	0
			Cu	0	Cu	5,800	Cu	0

t = metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The Koulumaoiva intrusion is poorly known. However, it contains indications of PGE enrichment that perhaps best match with contact-type mineralisation, but may also indicate reef-type occurrences. The only criterion for including the Koulumaoiva intrusion in the PGE assessment is the 2.45 Ga age. It is likely that the division into Cr-poor and Cr rich magma types in the 2.45 Ga intrusions is a general rule rather than a strict constraint for the assessment and exploration – it is not a necessary rule for a reef-type mineralisation to occur in all intrusions of this age group. The permissive tract matches the surface projection of the intrusion down to 1 km depth. The sources of information used in the delineation of the tract are summarised in Table 5.

Known deposits

There are no well-explored reef-type PGE deposits within the Koulumaoiva permissive tract.

Prospects, mineral occurrences, and related deposit types

No reef-type PGE prospects are known from the tract. The tract does not contain deposits or prospects of any other type, either.

Exploration history

Lilttle exploration has been performed in the area. The Koulumaoiva intrusion was drilled first during a regional-scale lithological mapping project of GTK. At that time, the age of the intrusion was determined using the Sm-Nd method (Juopperi 2002). This unpublished dating indicated that the intrusion belongs to the same age group as those intrusions that host significant PGE deposits in Finland, such as Penikat and the intrusions of the Portimo Complex (Iljina & Hanski 2005). This encouraged GTK to carry out a bit more drilling at Koulumaoiva (Iljina 2003). However, the drilling so far performed has not intercepted any significant PGE grades, but provided indications of contact type PGE mineralization by weakly elevated concentrations of chalcophile elements (Iljina 2003, M. Iljina, pers. comm., 2009). Types of exploration work carried out in the area, and known to us, are listed in Table 2.

Table 2. Exploration history for Koulumaoiva intrusion.

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Bedrock mapping, outcrop sampling	Yes	GTK	1990s
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	2000–2001, 2005
Ground geophysical surveys	VLF-R and magnetic survey		GTK	1995, 2000
Drilling	Diamond-drill holes, total 577 m	Yes	GTK	1995, 2000
Mapping	Bedrock mapping, outcrop sampling	Yes	GTK	1990s

Sources of information

Principal sources of information used by the assessment team for the delineation of KoulumaoivaReefPGE are listed in Table 3.

Table 3. Principal sources of information used by the assessment team for KoulumaoivaReefPGE.

Theme	Type of source	Scale	Citation
Geology	General description of the geology and age determinations		Juopperi 2002
	General description of the geology and drilling		Iljina 2003
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
Exploration	General description of exploration activities in the area		Iljina 2003

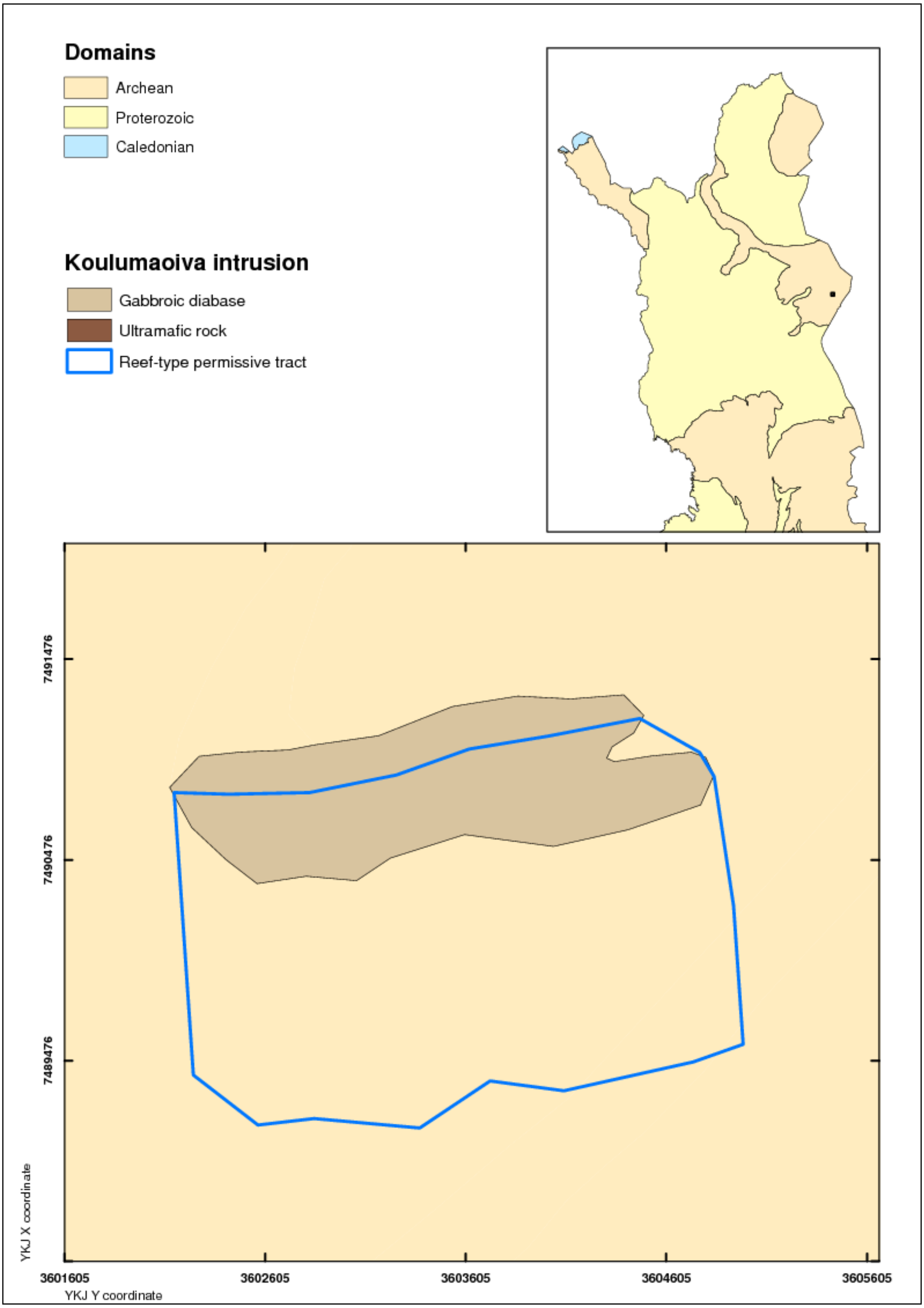

Figure 1. Location of the permissive tract KoulumaoivaReefPGE.

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

Not a single reef-type prospect is known within the tract. This means that the minimum number of undiscovered reef-type deposits within the tract is zero. There are only weak direct indications of PGE mineralisation within the intrusion. Hence, the ore potential was seen to be low by all estimators. Two estimators assumed that there is a small possibility for one deposit, whereas one estimator was more pessimistic, seeing no potential even at 10% probability (Table 4). Hence, the mean values of the individual estimates listed in the lower part of Table 4 were used in the statistical simulations for Koulumaoiva.

Table 4. Undiscovered deposit estimates, deposit numbers, and tract area for KoulumaoivaReefPGE.

Mean undiscovered deposit estimate					Summary statistics					Area (km²)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}	
0	0	1			0.30	0.50	167	0	0.30	4.6

	Estimated number of undiscovered deposits				
Estimator	N90	N50	N10	N05	N01
Estimator 1	0	0	1		
Estimator 2	0	0	1		
Estimator 3	0	0	0		
Mean	0	0	1		

Nxx = Estimated number of deposits associated with the xxth percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were calculated by combining the undiscovered deposit estimates with the Finnish reef-type PGE grade model and the KoulumaoivaReefPGE tonnage model (Appendix 4) using the EMINERS software (Root et al. 1992, Duval 2004). Results of the Monte Carlo simulation are presented as cumulative frequency plots (Figure 2) and selected simulation results are reported in Table 5. The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralized rock.

Table 5. Results of Monte Carlo simulations of undiscovered resources in KoulumaoivaReefPGE.

Material	At least the indicated amount at the probability of					Mean	Probability of mean or greater	Probability of zero
	0.95	0.9	0.5	0.1	0.05			
Pt (t)	0	0	0	34	78	16	0.17	0.70
Pd (t)	0	0	0	72	140	30	0.19	0.70
Au (t)	0	0	0	2	4	1	0.19	0.70
Ni (t)	0	0	0	16,000	26,000	4,800	0.23	0.70
Cu (t)	0	0	0	17,000	35,000	5,800	0.18	0.70
Rock (Mt)	0	0	0	21	33	6	0.25	0.70

t = metric tonnes; Mt = millions of tonnes.

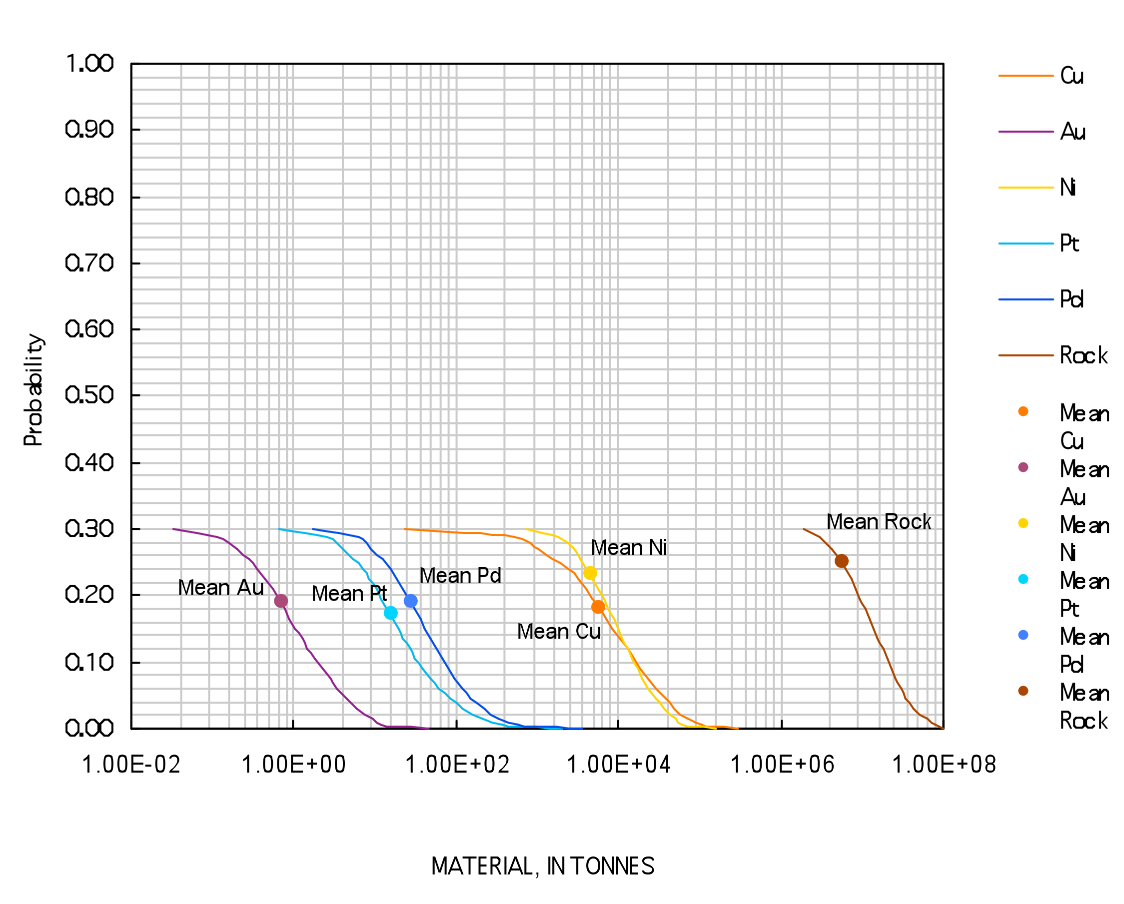

Figure 2. Cumulative frequency plot showing the results of Monte Carlo computer simulation of undiscovered resources in KoulumaoivaReefPGE.

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CONTACT-TYPE PGE ASSESSMENT FOR TRACT KuusijärviContactPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Contact-type Cu-Ni-PGE
Descriptive model: Fennoscandian contact-type Cu-Ni-PGE (Appendix 1)
Grade and tonnage model: Fennoscandian contact-type Cu-Ni-PGE (Appendix 2)

LOCATION AND RESOURCE SUMMARY

The Kuusijärvi block of the Western Intrusion of the Koillismaa Complex is located in northern Finland in the municipality of Posio, 130 km southeast from the town of Rovaniemi. The 1:100 000 KKJ map sheets are 3543 and 3544. The UTM map sheets containing the block are S5214, S5231 and S5232. The PGE resource assessment carried out for this report is summarised in Table 1.

Table 1. Summary of selected resource assessment results for KuusijärviContactPGE.

Date of assessment	Assessment depth (km)	Tract area (km^2)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
27.08–02.10.2008	1	23	Pt	5.7	Pt	43	Pt	17
			Pd	15	Pd	180	Pd	61
			Au	5.9	Au	16	Au	7
			Ni	65,000	Ni	150,000	Ni	110,000
			Cu	97,000	Cu	280,000	Cu	170,000

t = metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The permissive tract shown in Figure 2 is a surface projection of the basal contact zone of the Kuusijärvi block, which extends to the depth of more than 1 km. The estimated dip of layering in the marginal series in the western part of the block is about 60–80º to the north, and 30–50 º to the west in the easternmost part of the block. The drawn extent of the tract is based on projecting the estimated down-dip basal contact zone from the surface to 1 km depth. On the surface, the delineation is based on a geological map by Räsänen et al. (2004), drilling (Outokumpu, GTK, North Atlantic Natural Resources), geophysical information (local electromagnetic and magnetic surveys), and a structural model by Karinen & Salmirinne (2001). The sources of information used in the delineation of the tract are summarized in Table 4.

Known deposits

The 3 km long Haukiaho deposit is the only known contact-type PGE deposit within the Kuusijärvi permissive tract, and having a resource estimate it is regarded as a known deposit, although it is open at the depth of 150 m (Table 2, Figure 1). The principal sulphides at Haukiaho are chalcopyrite, pyrrhotite and pentlandite. The PGE minerals are mostly tellurides (kotulskite, merenskyite) and a Pt-As phase (sperrylite). Gold and silver are present in electrum. Haukiaho is characterised by metal ratios Cu/Ni > 1, and Pd/Pt > 1 (Kojonen & Iljina 2001, Iljina et al. 2005).

Table 2. Known contact-type PGE deposits in KuusijärviContactPGE.

Name	X coord (YKJ)	Y coord (YKJ)	Age (Ga)	Tonnage (Mt)	Grade					Contained PGE (t)		Reference
					Cu (%)	Ni (%)	Pt (g/t)	Pd (g/t)	Au (g/t)			
Haukiaho	7307 000	3547 900	2.45	27	0.36	0.24	0.21	0.55	0.22	Pt	5.7	Iljina et al. (2005)
										Pd	15	Iljina et al. (2005)

Ga – billions of years; Mt – millions of metric tonnes; t – metric tonne; g/t – grams per metric tonn. Cut-off value for tonnage is 0.7 g/t Pt+Pd+Au. The contained PGE is given in metric tonnes and computed as tonnage * grade. The deposit age is derived from the assumed age of the Kaukua block based on age data from the Koillismaa Complex (Alapieti 1982).

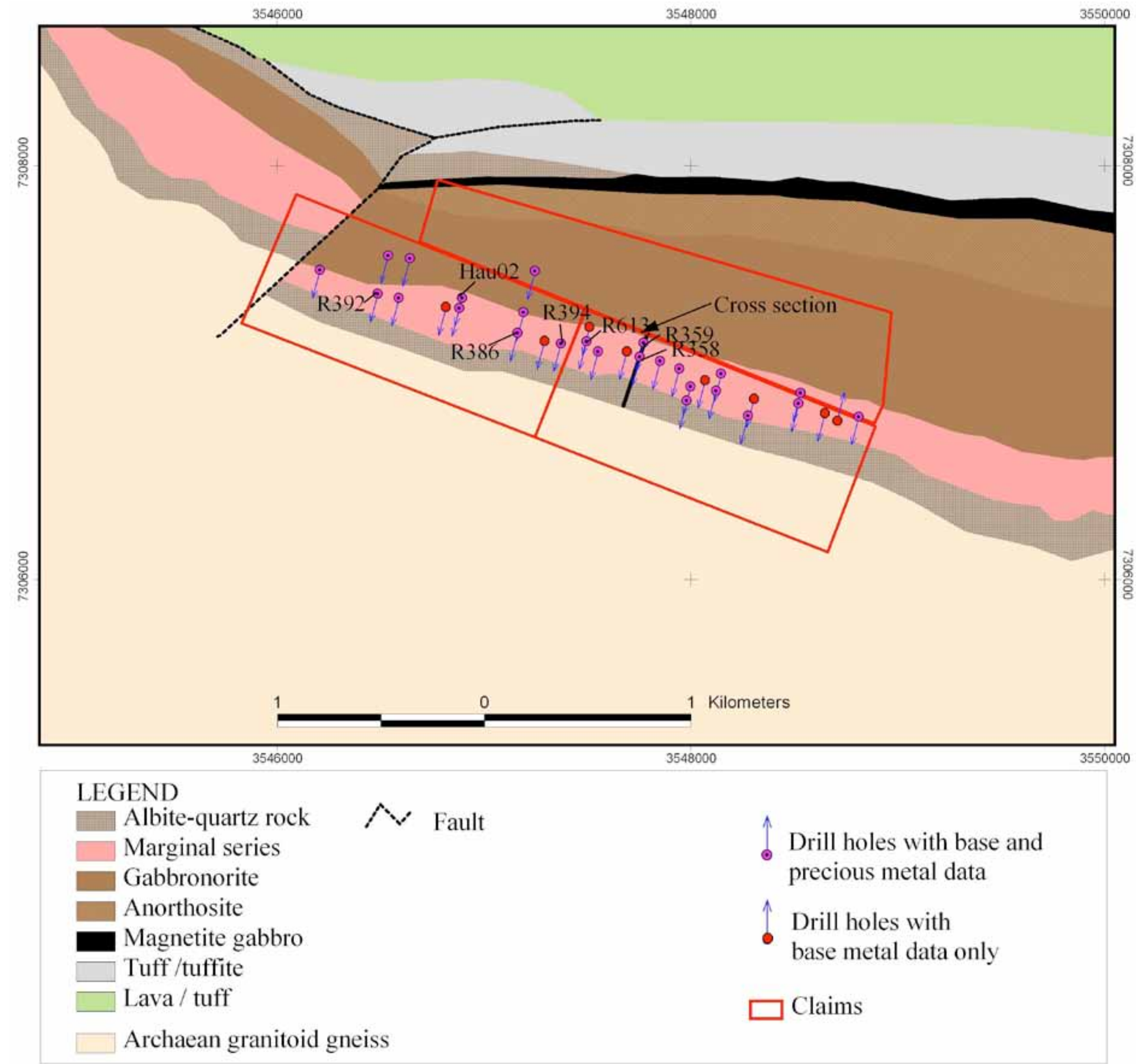

Figure 1. Surface geology and GTK drilling sites at Haukiaho (Iljina et al. 2005). North up.

Prospects, mineral occurrences, and related deposit types

Excluding Haukiaho (Table 2), the main indication of possible PGE ores at Kuusijärvi is the fact that wherever the marginal series has been intersected by drilling, the rocks are mineralised to a variable degree (Iljina et al. 2005).

Exploration history

Exploration commenced in the Kuusijärvi area in the 1960s when Outokumpu started to map and drill Ni-Cu targets in the Koillismaa Complex area. Attention was drawn by Ni- and Cu-rich sulphide-bearing glacial erratic boulders found in the 1960s. The first indications on contact-type deposits in outcrop and drill core were also discovered by Outokumpu in the 1960s (Iljina 2004). Exploration for PGE started seriously in the 1980s when >10 g/t PGE grades were discovered in glacial erratic boulders at Haukiaho. GTK explored the area in 1996–2000 and North Atlantic Natural Resources (NAN) in 2000–2002. Types of exploration work carried out in the area, and known to us, are listed in Table 3.

Table 3. Exploration history for KuusijärviContactPGE.

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Detailed bedrock mapping, outcrop sampling	A few cases	Outokumpu	1960s 1990s
Geochemical surveys	Apparently none has been performed			
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	1998
	Low-altitude airborne magnetic and electromagnetic survey		NAN	2000
Ground geophysical surveys	Magnetic survey		Outokumpu	1963–1965, 1981
	Gravity survey line		Univ. Oulu	1971
	Magnetic, VLF-R and IP survey		GTK	1997–1999, 2005
	Regional gravity survey		GTK	1999–2001, 2003, 2004
	Magnetic, IP survey		NAN	2000–2001
Drilling	16 diamond-drill holes	Some holes	Outokumpu	1963–1964
	29 diamond-drill holes	Yes	GTK	1998, 2004
	Four diamond-drill holes	Yes	NAN	2001
Other	Regional research and mapping programme in the KLIC region.	No	Univ. Oulu	1971–1976
	Regional research and exploration programme in the KLIC region.	Yes	GTK	1996–2000

PGE reanalysed in the early 1980s from part of the 1960s drill core.
NAN = North Atlantic Natural Resources.
KLIC = Koillismaa Layered Igneous Complex.

Sources of information

Principal sources of information used by the assessment team for the delineation of KuusijärviContactPGE are listed in Table 4.

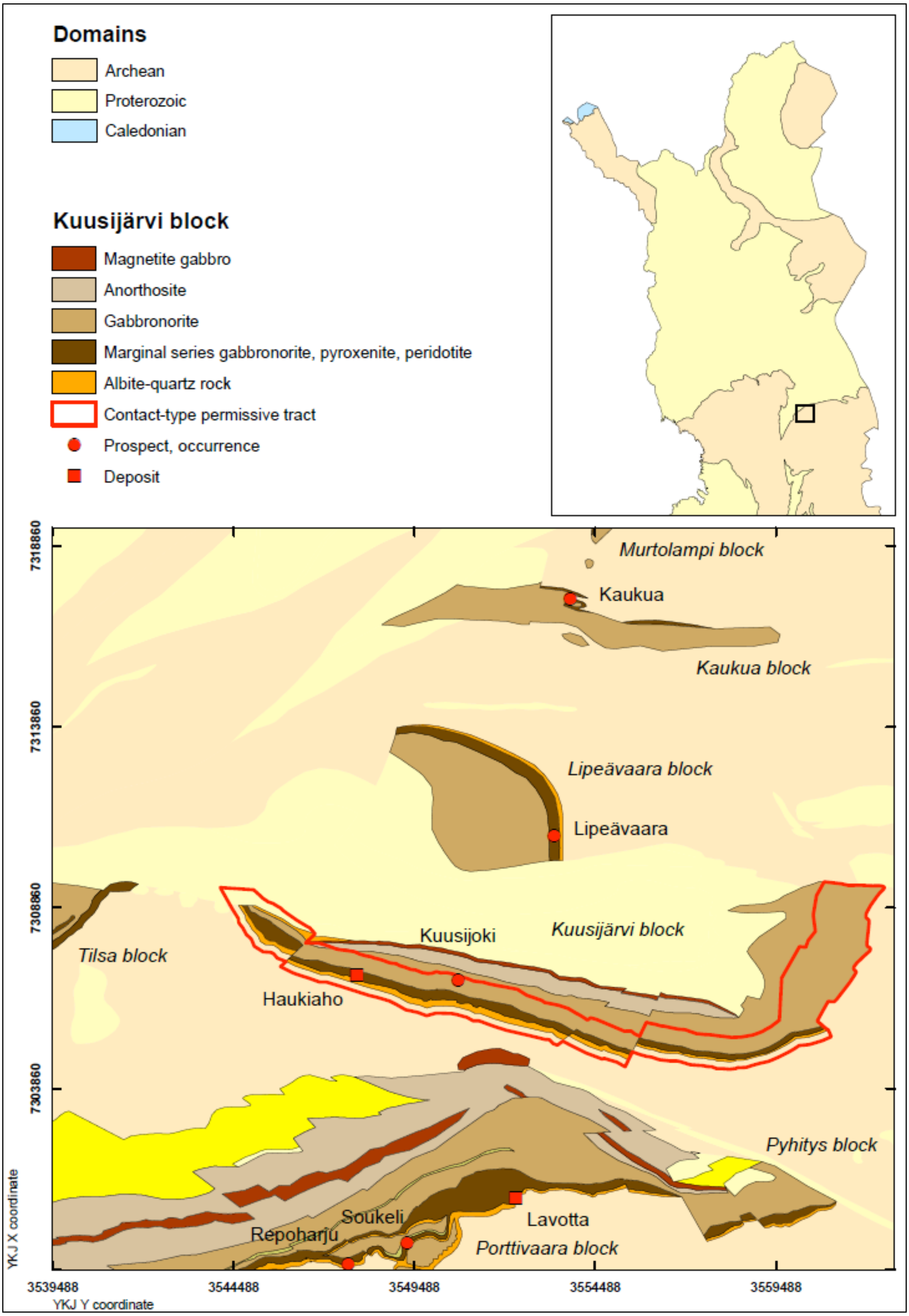

Figure 2. Location of the permissive tract KuusijärviContactPGE.

Table 4. Principal sources of information used by the assessment team for KuusijärviContactPGE.

Theme	Type of source	Scale	Citation
Geology	Geological description of the KLIC geology and the known mineral occurrences	1:150 000	Piirainen et al. (1974, 1978), Juopperi (1977), Alapieti (1982)
	Geological description of the KLIC geology and the known mineral occurrences		Lahtinen (1983), Iljina (2004)
	Geological map of the KLIC region	1:200 000	Räsänen et al. (2004)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
	PhD on geology and reef-type mineralisation in the Western Koillismaa Intrusion		Karinen (2010)
Mineral occurrences	Description of the Haukiaho PGE occurrence and its geological setting		Iljina et al. (2005)
Geochemistry	NA		
Geophysics	Magnetic, VLF-R and IP survey		Iljina (2004), Iljina et al. (2005)
Exploration	Summary report on exploration activities by Outokumpu		Lahtinen (1983)
	Detailed description of exploration activities in the area by GTK and NAN, and a brief summary of the activities by Outokumpu		Iljina (2004), Iljina et al. (2005)

KLIC = Kollismaa Layered Igneous Complex.
NA = not available.
NAN = North Atlantic Natural Resources.

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

One contact-type deposit, Haukiaho, is known within the tract. Haukiaho was included in the grade and tonnage model. This means that the number of undiscovered contact-type deposits within the tract can be zero or more. It is noteworthy that, in the Koillismaa Complex Western Intrusion area, the contact-type deposits with the highest PGE concentrations (Kaukua and Haukiaho) are furthest from the positive gravity anomaly, which has been interpreted as an indication of a feeder channel for the entire intrusion (Alapieti 1982). This may indicate magma dynamics powerful enough to produce contact type deposits in the distal rather than proximal parts of the magma chamber of the intrusion. Hence, the largest potential for contact-type deposits at Koillismaa would be in those intrusive blocks that are tens of kilometres away from the supposed feeder channel.

Between the estimators, no consensus was reached for the number of undiscovered contact-type PGE deposit at Kuusijärvi (Table 5). One estimator argued that a high gravity anomaly in the eastern part of the Kuusijärvi block may indicate lower possibilities for PGE deposits, as the known occurrences in the block and in an adjacent block (i.e., Haukiaho and Kaukua, respectively) are away from gravity highs. Another estimator commented that as Haukiaho is only a medium-sized deposit, there is room for quite many occurrences of the same size within the Kuusijärvi block. The mean values of the individual estimates were used in the simulations.

Table 5. Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for KuusijärviContactPGE.

Mean undiscovered deposit estimate					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
0	2	3			1.7	1.1	63	1	2.7	23	0.12

	Estimated number of undiscovered deposits				
Estimator	N90	N50	N10	N05	N01
Estimator 1	0	1	2		
Estimator 2	0	2	3		
Estimator 3	1	2	3		
Mean	0	2	3		

Nxx = Estimated number of deposits associated with the xxth percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; Deposit density = deposit density reported as the total number of deposits per km^2. N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were estimated by combining the means of estimated numbers of undiscovered contact-type PGE deposits with the Fennoscandian contact-type PGE grade and tonnage model (Appendix 2) using the EMINERS software (Root et al. 1992, Duval 2004). Selected simulation results are reported in Table 6. Results of the Monte Carlo simulation are presented as a cumulative frequency plots (Figure 3). The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralised rock.

Table 6. Results of Monte Carlo simulations of undiscovered resources in KuusijärviContactPGE.

Material	At least the indicated amount at the probability of					Mean	Probability of mean or greater	Probability of zero
	0.95	0.90	0.50	0.10	0.05			
Pt (t)	0	0	17	130	180	43	0.31	0.20
Pd (t)	0	0	61	560	850	180	0.28	0.20
Au (t)	0	0	7	47	71	16	0.29	0.20
Ni (t)	0	0	110,000	370,000	460,000	150,000	0.40	0.20
Cu (t)	0	0	170,000	730,000	920,000	280,000	0.37	0.20
Rock (Mt)	0	0	64	470	540	150	0.32	0.20

t = metric tonnes; Mt = millions of tonnes.

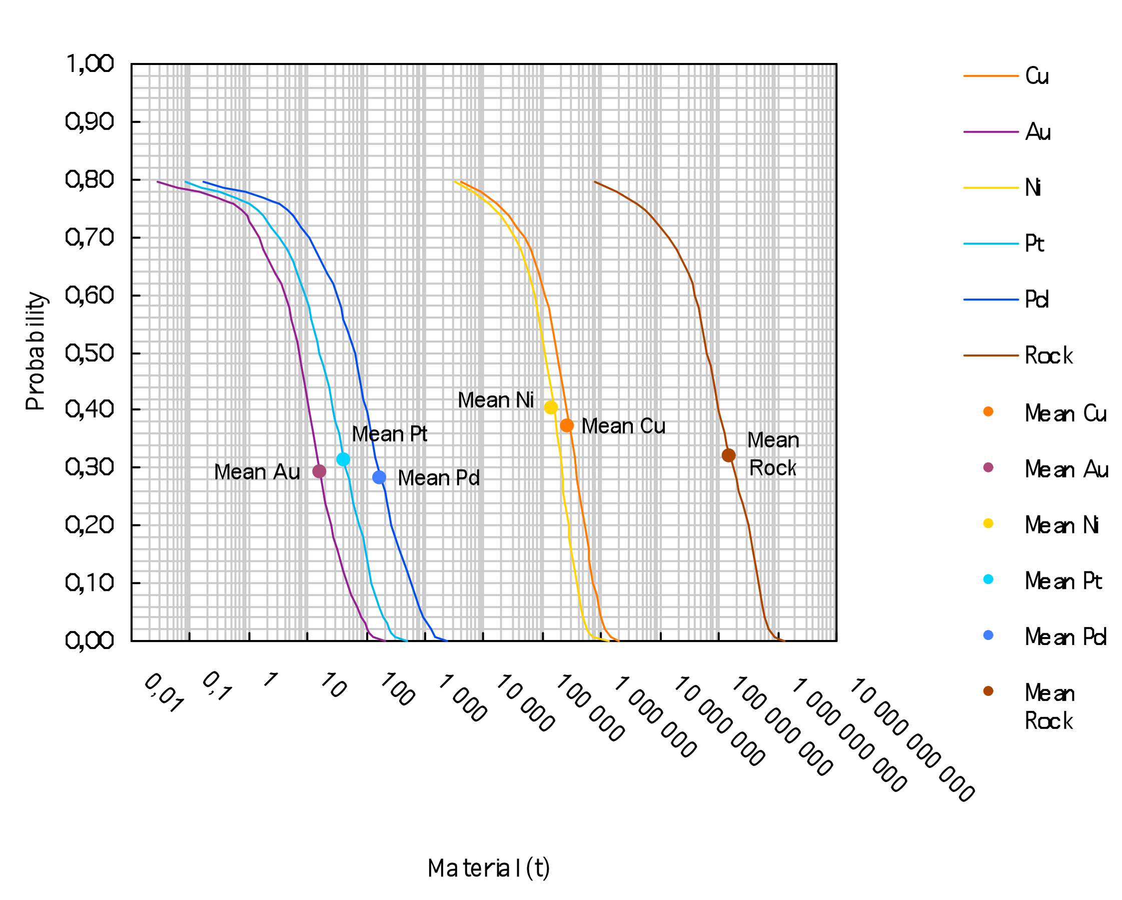

Figure 3. Cumulative frequency plot showing the results of Monte Carlo computer simulation of undiscovered resources in KuusijärviContactPGE.

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REEF-TYPE PGE ASSESSMENT FOR TRACT KuusijärviReefPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Reef-type PGE-Ni-Cu
Descriptive model: Finnish reef-type PGE-Ni-Cu (Appendix 3)
Grade-tonnage model: Finnish reef-type PGE-Ni-Cu grade model, KuusijärviReefPGE tonnage model (Appendix 4)

LOCATION AND RESOURCE SUMMARY

The Kuusijärvi block of the Western Intrusion of the Koillismaa Layered Igneous Complex is located in northern Finland in the municipality of Posio, 130 km southeast from the town of Rovaniemi. The 1:100 000 KKJ map sheets are 3543 and 3544. The UTM map sheets containing the block are S5214, S5231 and S5232.

Table 1. Summary of selected resource assessment results for KuusijärviReefPGE.

Date of assessment	Assessment depth (km)	Tract area (km²)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
22.09–1.10.2008	1	76	Pt	0	Pt	420	Pt	150
			Pd	0	Pd	760	Pd	310
			Au	0	Au	18	Au	8
			Ni	0	Ni	120,000	Ni	70,000
			Cu	0	Cu	140,000	Cu	65,000

t = metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The tract delineation is based on a geological map by Räsänen et al. (2004), drilling (Outokumpu, Rautaruukki, GTK, Akkerman-Nortec), geophysical information (local gravity survey) and a structural model by Karinen & Salmirinne (2001). The ESE-trending Kuusijärvi block dips from subvertical in the western part to 60-45° to the N in the central part, whereas in the eastern end the dip is 30–50 ° to the west. The block continues down to over 1 km depth, as indicated by a regional gravity survey by GTK. The northern border of the blocks is in a deep vertical fault against the Lipeävaara block and rocks that mostly belong to the Archaean basement. Hence, the permissive tract roughly matches the surface projection of the block (Figure 1). The sources of information used in the delineation of the tract are summarized in Table 4.

Known deposits

There are no well-explored reef-type PGE deposits within the Kuusijärvi permissive tract.

Prospects, mineral occurrences, and related deposit types

The continuum of the same uneconomic reef-type mineralization found in the layered series of the Syöte block (Rometölväs prospect) and the Porttivaara block (Baabelinälkky prospect) has been penetrated by one drill hole (PSO-21) in the Kuusijoki area of the Kuusijärvi block (Table 2). The Baabelinälkky and Rometölväs prospects have been described by Isohanni (1976) and Piispanen & Tarkian (1982).

Table 2. Significant prospects and occurrences in KuusijärviReefPGE.

Name	X coordinate	Y coordinate	Age (Ma)	Comments (grade and tonnage data, if available)	Reference
Kuusijoki	7306839	3550694	2.45	0.7% Cu, 0.35% Ni, 190 ppb Pd (Au and Pt not detected)	GTK database

Deposit ages are derived from the assumed age of the Kuusijärvi block based on age data from the Complex (Alapieti 1982).

Exploration history

Exploration commenced in the Kuusijärvi area in the 1960s when Outokumpu started to map and drill Ni-Cu targets in the Koillismaa Complex area. Attention was drawn to the area by Ni- and Cu-rich sulphide-bearing glacial erratic boulders found in the 1960s. The first indications of contact-type deposits in outcrop and drill core were discovered by Outokumpu in the 1960s (Iljina 2004). Exploration for PGE started seriously in the 1980s when >10 g/t PGE grades were discovered in glacial erratic boulders at Haukiaho. GTK explored the area in 1996–2000 and NAN in 2000–2002.

However, the aforementioned exploration has been involved with contact type deposits and the only exploration directly related to the reef-type is a 730.20 m long drill core from hole PSO-21. The core (3543/65/R623 in GTK database) was drilled in 1965 by Outokumpu Oy as part of exploration of the contact type deposits. The drill hole penetrated the reef at the depth of around 350 m. Types of exploration work carried out in the area, and known to us, are listed in Table 3.

Table 3. Exploration history for Kuusijärvi intrusion.

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Detailed bedrock mapping, outcrop sampling, glacial erratic boulder survey	Yes*	Outokumpu	1980s, 1990
Geochemical surveys	Apparently none has been performed			
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	1998
	Low-altitude airborne magnetic and electromagnetic survey		NAN	2001
Ground geophysical surveys	Magnetic survey		Outokumpu	1963–1965, 1981
	Gravity survey line		Univ. Oulu	1971
	Magnetic, VLF-R and IP survey		GTK	1997–2000, 2005
	Regional gravity survey		GTK	1999–2001, 2003, 2004
	Magnetic, IP survey		NAN	2000–2001
Drilling	16 diamond-drill holes	Some	Outokumpu	1963–1964
	29 diamond-drill holes	Yes	GTK	1998, 2004
	4 diamond-drill holes	Yes	NAN	2001
Other	Regional research and mapping programme in the KLIC region.	No	Univ. Oulu	1971–1976
	Regional research and exploration programme in the KLIC region.	Yes	GTK	1996-2000

* PGE reanalysed in the early 1980s from part of the 1960s drill core.
NAN = North Atlantic Natural Resources.
KLIC = Koillismaa Layered igneous Complex.

Sources of information

Principal sources of information used by the assessment team for the delineation of KuusijärviReefPGE are listed in Table 4.

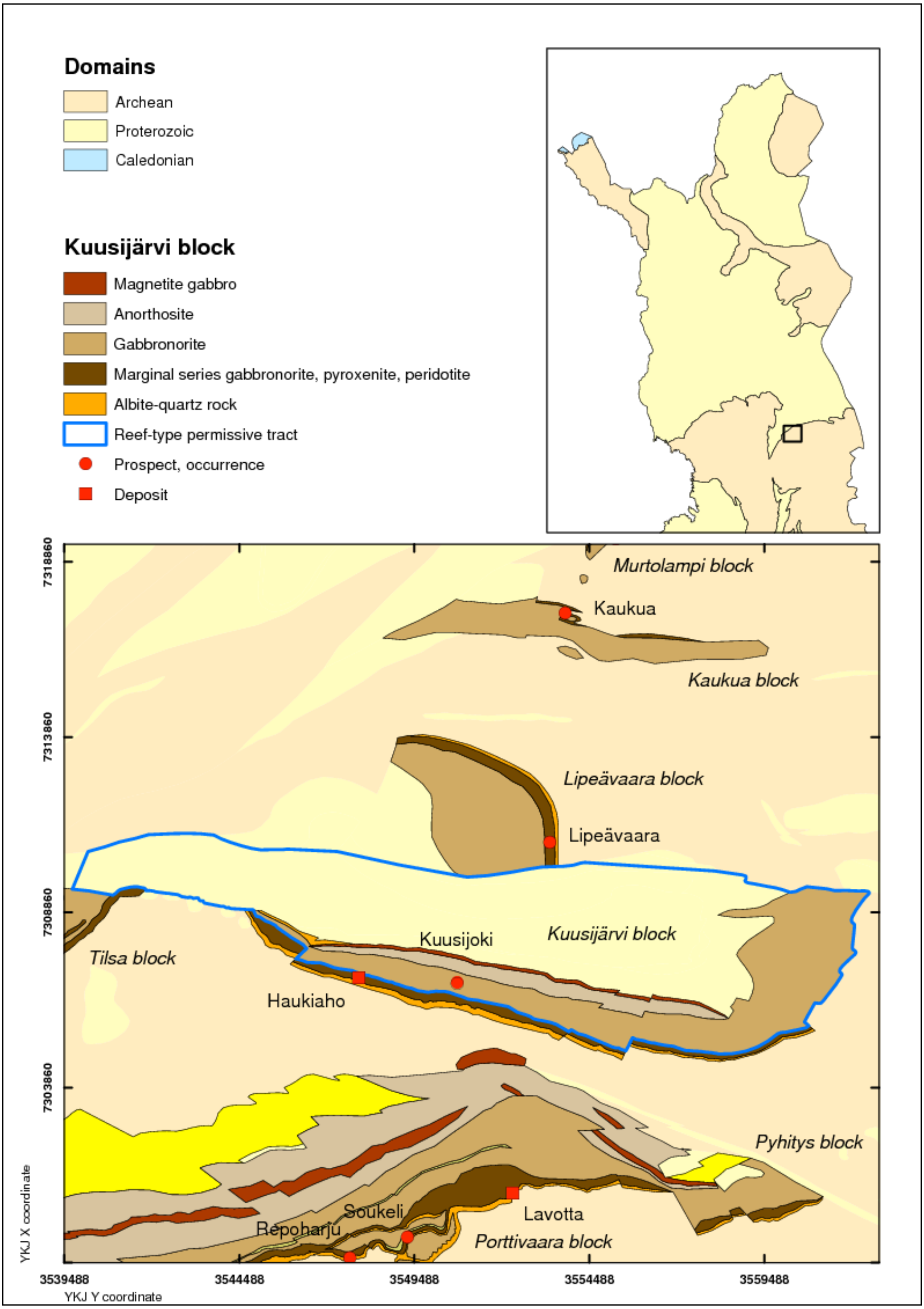

Figure 1. Location of the permissive tract KuusijärviReefPGE.

Table 4. Principal sources of information used by the assessment team for KuusijärviReefPGE.

Theme	Type of source	Scale	Citation
Geology	Geological description of the KLIC geology and known mineral occurrences	1:150 000	Piirainen et al. (1974, 1978), Juopperi (1977), Alapieti (1982)
	Geological description of the KLIC geology and known mineral occurrences		Lahtinen (1985), Iljina (2004)
	Geological map of the KLIC region	1:200 000	Räsänen et al. (2004)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
	PhD on geology and reef-type mineralisation in the Western Koillismaa Intrusion		Karinen (2010)
Mineral occurrences	NA		
Geochemistry	NA		
Geophysics	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK aerogeophysical data bases
	Ground magnetic and VLF survey, IP survey		Iljina et al. (2005)
Exploration	Summary report on exploration activities by Outokumpu		Lahtinen (1983)
	Detailed description of exploration activities in the area by GTK and NAN, and a brief summary of the activities by Outokumpu		Iljina et al. (2005)
	Description on exploration activities by Akkerman – Nortec JV		Nortec Ventures (2008)

KLIC = Kollismaa Layered Igneous Complex.
NA = not available.

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

Not a single reef-type prospect is known within the tract. This means that the minimum number of undiscovered reef-type deposits within the tract is zero. A deep diamond drill hole intersects reef-type mineralization at the Kuusijoki area (Table 2). This indicates that the reef-type mineralisation detected in the layered series in the adjoining Porttivaara and Syöte blocks does continue into the Kuusijärvi block (Table 2). One of the estimators was of the opinion that there is no room for more than one reef in the Kuusijärvi block. Since no consensus was reached, the mean values of the individual estimates were used as input to the Eminers software.

Table 5. Undiscovered deposit estimates, deposit numbers, and tract area for KuusijärviReefPGE.

Mean undiscovered deposit estimate					Summary statistics					Area (km2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}	
1	1	2			1.2	0.55	45	0	1.2	76

Estimator	N90	N50	N10	N05	N01
	Estimated number of undiscovered deposits				
Estimator 1	1	2	2		
Estimator 2	1	1	2		
Estimator 3	1	1	1		
Mean	1	1	2		

Nxx = Estimated number of deposits associated with the xx^{th} percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were calculated by combining the undiscovered deposit estimates with the Finnish reef-type PGE grade model and the KuusijärviReefPGE tonnage model (Appendix 4) using the EMINERS software (Root et al. 1992, Duval 2004). Results of the Monte Carlo simulation are presented as cumulative frequency plots (Figure 2) and selected simulation results are reported in Table 6. The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralized rock.

Table 6. Results of Monte Carlo simulations of undiscovered resources in KuusijärviReefPGE.

Material	At least the indicated amount at the probability of					Mean	Probability of mean or greater	Probability of zero
	0.95	0.9	0.5	0.1	0.05			
Pt (t)	0	15	150	1,000	1,800	420	0.25	0.06
Pd (t)	0	35	310	1,800	2,900	760	0.26	0.06
Au (t)	0	1	8	44	66	18	0.29	0.06
Ni (t)	0	9,900	70,000	280,000	390,000	120,000	0.33	0.06
Cu (t)	0	3,300	65,000	380,000	580,000	140,000	0.31	0.06
Rock (Mt)	0	15	99	360	490	150	0.36	0.06

t – metric tonnes; Mt – millions of tonnes.

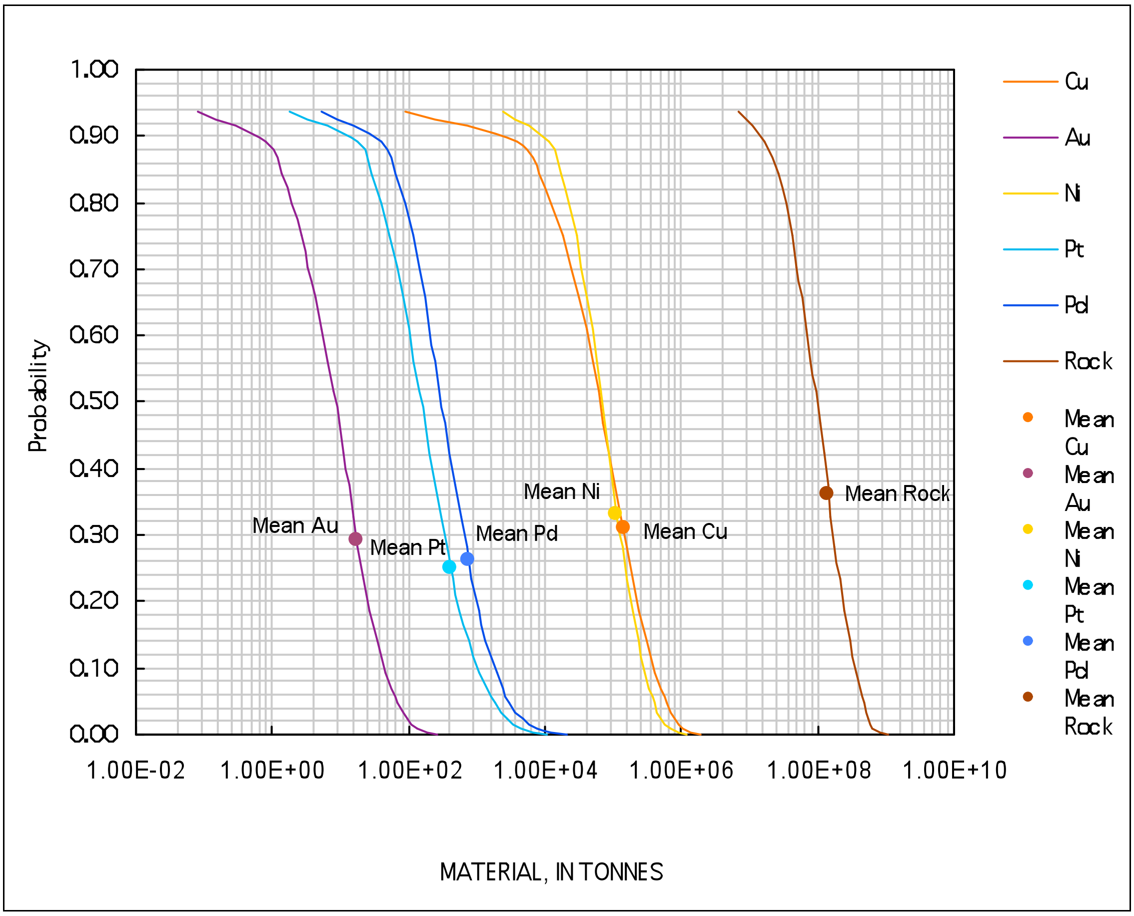

Figure 2. Cumulative frequency plot showing the results of Monte Carlo computer simulation of undiscovered resources in KuusijärviReefPGE.

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CONTACT-TYPE PGE ASSESSMENT FOR TRACT LipeävaaraContactPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Contact-type Cu-Ni-PGE
Descriptive model: Fennoscandian contact-type Cu-Ni-PGE (Appendix 1)
Grade and tonnage model: Fennoscandian contact-type Cu-Ni-PGE (Appendix 2)

LOCATION AND RESOURCE SUMMARY

The Lipeävaara block of the Western Intrusion of the Koillismaa Complex is located in northern Finland in the municipality of Posio, 130 km southeast from the town of Rovaniemi. The 1:100 000 KKJ map sheet is 3544. The UTM map sheets containing the block is S5232. The PGE resource assessment carried out for this report is summarised in Table 1.

Table 1. Summary of selected resource assessment results for LipeävaaraContactPGE.

Date of assessment	Assessment depth (km)	Tract area (km^2)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
28.08.–30.09.2008	1	9.6	Pt	0	Pt	26	Pt	5
			Pd	0	Pd	110	Pd	14
			Au	0	Au	9	Au	2
			Ni	0	Ni	90,000	Ni	45,000
			Cu	0	Cu	160,000	Cu	64,000

t = metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The permissive tract delineated in Figure 1 is a surface projection of the basal contact zone of the approximately 2.45 Ga Lipeävaara intrusive block of the Koillismaa intrusion. The estimated dip of layering in the marginal series of the block is generally 45° to the southwest. The southern contact of the Lipeävaara block towards the Kuusijärvi block seems to be tectonic (vertical fault), but elsewhere in the block the original magmatic contacts are preserved. Based on a gravity anomaly, the Lipeävaara block is estimated to continue at least to the depth of 1 km. On the surface, the delineation is based on a geological map by Räsänen et al. (2004), drilling of a 9-hole profile (by Oulu University in 1973 and GTK in 1999), geophysical information (airborne and local surveys) and a structural model by Karinen & Salmirinne (2001). The sources of information used in the delineation of the tract are summarised in Table 4.

Known deposits

No contact-type PGE deposits are known within the tract.

Prospects, mineral occurrences, and related deposit types

One contact-type PGE prospect is known within the tract (Table 2 and Figure 1), the Lipeävaara PGE occurrence (also known as 'Ohenojan Monttu' and 'Hautaperä') at the SE corner of the Lipeävaara block. It is incompletely delineated and no representative grade or tonnage information is available.

Table 2. Significant prospects and occurrences in LipeävaaraContactP

Name	X coordinate	Y coordinate	Age (Ma)	Comments (grade and tonnage data, if available)	Reference
Lipeävaara	7310930	3553340	2.45	0.38–0.79 g/t Pd, 0.22–0.26 g/t Au; outcrop samples	Lahtinen (1983)

The deposit age is derived from the assumed age of the Lipeävaara block based on age data from the Koillismaa Complex (Alapieti 1982).

Exploration history

Exploration commenced in the Lipeävaara area in the 1960s when Outokumpu started to map and drill Ni-Cu targets in the Koillismaa Complex area (Lahtinen 1985). Attention was drawn to the area by Ni- and Cu-rich sulphide-bearing glacial erratic boulders found in the 1960s. The 'Ohenojan Monttu' was drilled by the University of Oulu by two short drill cores (Piirainen et al. 1974, 1978). GTK explored the Koillismaa Complex area in between 1996 and 2000, during which a profile of 7 drill holes was drilled in the Lipeävaara block. These drillings are inside the tract of the contact type deposit assessment of the block. Types of exploration work carried out in the area, and known to us, are listed in Table 3.

Table 3. Exploration history for LipeävaaraContactPGE.

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Detailed bedrock mapping, outcrop sampling, glacial erratic boulder survey		Univ. Oulu GTK	1971 1996–2002
Geochemical surveys	Apparently none has been performed			
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	1989, 1998
Ground geophysical surveys	Gravity survey line		Univ. Oulu	1971
	Magnetic and VLF-R		GTK	1998–1999
	Regional gravity survey		GTK	1999–2001, 2003, 2004
Drilling	Two diamond-drill holes, total 83.10 m	Yes	Univ. Oulu	1973
	Seven diamond-drill holes, total 999.29 m		GTK	1999
Other	Regional research and mapping programme in the KLIC region.		Univ. Oulu	1971–1973
	Regional research and exploration programme in the KLIC region	Yes	GTK	1996–2002

KLIC = Koillismaa Layered Igneous Complex.

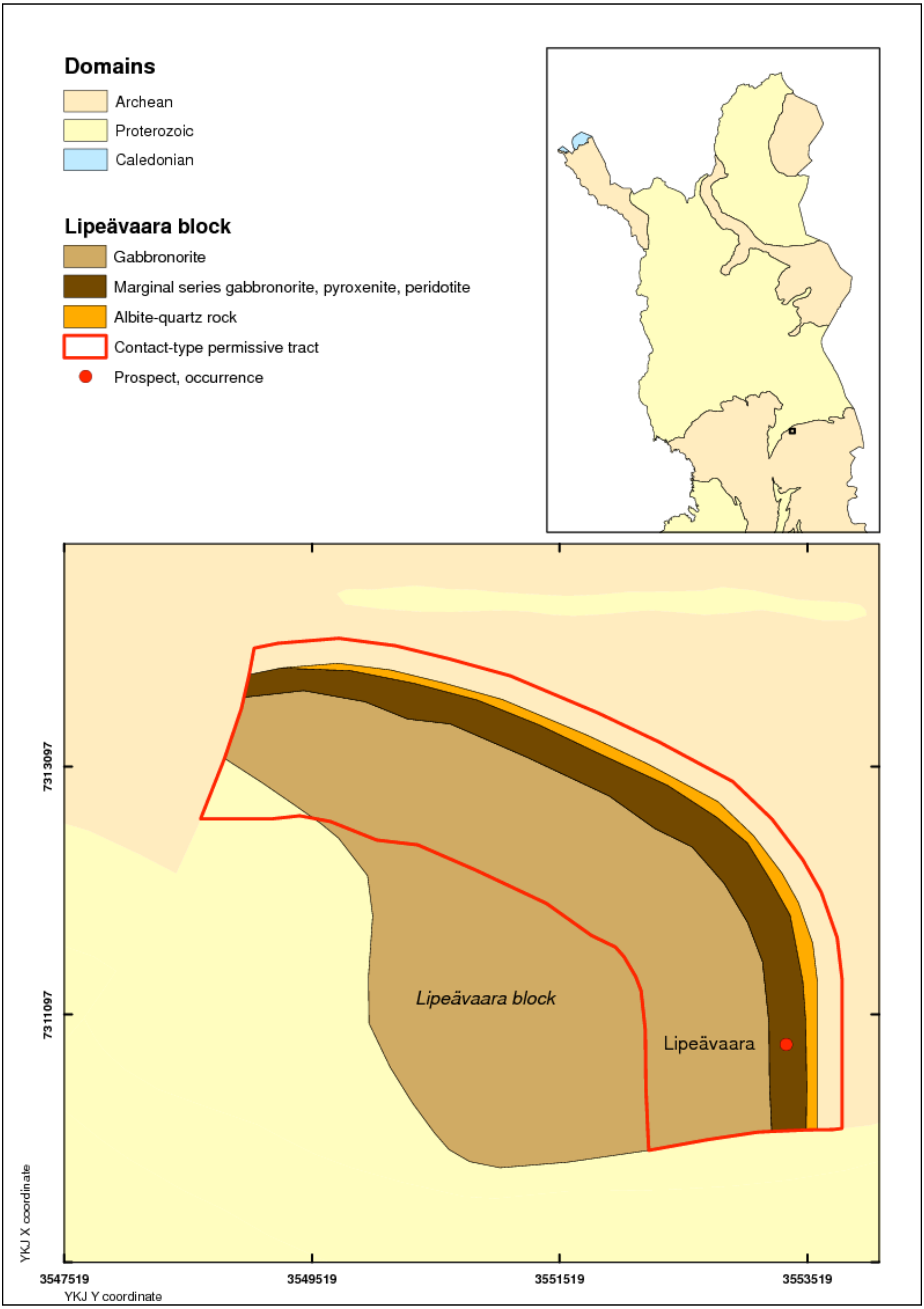

Figure 1. Location of the permissive tract LipeävaaraContactPGE.

Sources of information

Principal sources of information used by the assessment team for the delineation of LipeävaaraContact-PGE are listed in Tables 3 and 4.

Table 4. Principal sources of information used by the assessment team for LipeävaaraContactPGE.

Theme	Type of source	Scale	Citation
Geology	Geological description of the KLIC geology and known mineral occurrences		Piirainen et al. (1974, 1978), Juopperi (1977), Alapieti (1982), Iljina & Hanski (2005)
	Geological description of the KLIC geology and then known mineral occurrences		Lahtinen (1985)
	Geological map of the KLIC region	1:200 000	Räsänen et al. (2004)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
	PhD on geology and reef-type mineralisation in the Western Koillismaa Intrusion		Karinen (2010)
Mineral occurrences	Description of the Lipeävaara PGE prospect		Lahtinen (1983)
Geochemistry	NA		
Geophysics	Aeromagnetic surveys		Ruotsalainen (1977)
	Regional gravity survey		Karinen & Salmirinne (2001)
Exploration	Summary report on exploration activities by Outokumpu		Lahtinen (1983)
	Description of exploration activities in the area by GTK		Iljina (2003)

KLIC = Kollismaa Layered Igneous Complex.
NA = not available.

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

One contact-type prospect (Lipeävaara) is known within the tract. Since no good quality resource estimate is available (Table 2), it was not included in the grade-tonnage model. This means that the number of undiscovered contact-type deposits within the tract is at least one, but only if that prospect indeed has enough grade and tonnage to possibly be suitable for mining. The known prospect appears to be small and perhaps uneconomic. Consequently, the minimum number of undiscovered deposits that could exist within the tract is zero.

Surface size of the permissive tract is similar to that for Kaukua, but the intrusive block contains more mass as it has a deeper extent than Kaukua. The intrusive block is richer in Na than any other block at Koillismaa. This indicates advanced fractionation, more leucocratic units present, and that the block might be at a rather high level in the intrusive sequence, which may make the possibilities for marginal series deposits lower than for the other blocks of the KLIC. As a consensus on the number of undiscovered deposits was not achieved, the mean values were used in the statistical simulations for Lipeävaara (Table 5).

Table 5. Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for LipeävaaraContactPGE.

Mean of undiscovered deposit estimate					Summary statistics					Area (km2)	Deposit density (N/km2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
0	1	2			1.0	0.79	79	0	1.0	9.6	0.10

	Estimated number of undiscovered deposits				
Estimator	N90	N50	N10	N05	N01
Estimator 1	0	1	2		
Estimator 2	0	1	2		
Estimator 3	0	0	1		
Mean	0	1	2		

Nxx = Estimated number of deposits associated with the xx^th percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; Deposit density = deposit density reported as the total number of deposits per km^2. N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were estimated by combining the means of estimated numbers of undiscovered contact-type PGE deposits with the Fennoscandian contact-type PGE grade and tonnage model (Appendix 2) using the EMINERS software (Root et al.1992, Duval 2004). Selected simulation results are reported in Table 6. Results of the Monte Carlo simulation are presented as cumulative frequency plots (Figure 2). The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralized rock.

Table 6. Results of Monte Carlo simulations of undiscovered resources in LipeävaaraContactPGE.

Material	At least the indicated amount at the probability of					Mean	Probability of mean or greater	Probability of zero
	0.95	0.90	0.50	0.10	0.05			
Pt (t)	0	0	5	89	130	26	0.25	0.29
Pd (t)	0	0	14	310	590	110	0.23	0.29
Au (t)	0	0	2	28	46	9	0.25	0.29
Ni (t)	0	0	45,000	250,000	330,000	90,000	0.36	0.29
Cu (t)	0	0	64,000	510,000	690,000	160,000	0.30	0.29
Rock (Mt)	0	0	21	360	470	92	0.25	0.29

t = metric tonnes; Mt = millions of tonnes.

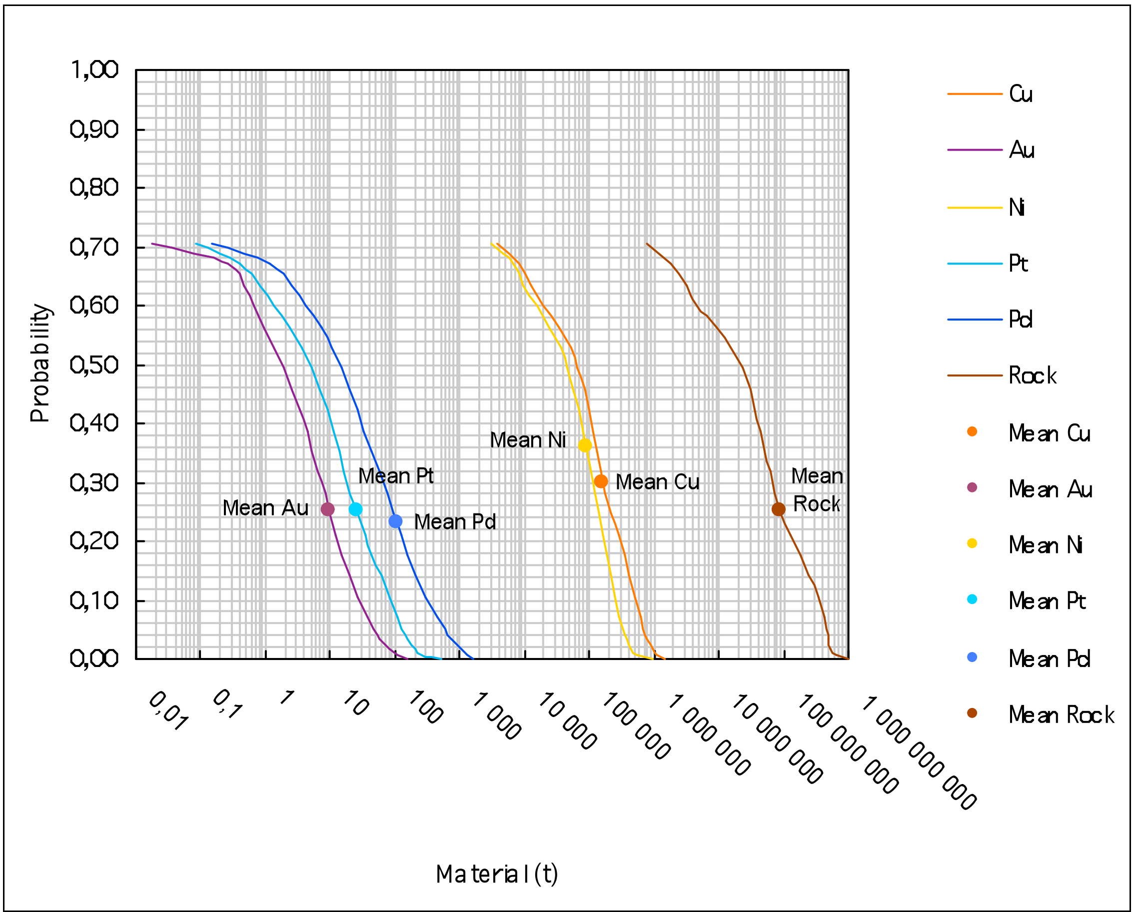

Figure 2. Cumulative frequency plot showing the results of Monte Carlo computer simulation of undiscovered resources in LipeävaaraContactPGE.

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REEF-TYPE PGE ASSESSMENT FOR TRACT LipeävaaraReefPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Reef-type PGE-Ni-Cu
Descriptive model: Finnish reef-type PGE-Ni-Cu (Appendix 3)
Grade-tonnage model: Finnish reef-type PGE-Ni-Cu grade model, LipeävaaraReefPGE tonnage model (Appendix 4)

LOCATION AND RESOURCE SUMMARY

The Lipeävaara block of the Western Intrusion of the Koillismaa Complex is located in northern Finland in the municipality of Posio, 130 km southeast from the town of Rovaniemi. The 1:100 000 KKJ map sheet is 3544. The UTM map sheet containing the block is S5232. The PGE resource assessment carried out for this report is summarised in Table 1.

Table 1. Summary of selected resource assessment results for LipeävaaraReefPGE.

Date of assessment	Assessment depth (km)	Tract area (km²)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
			Pt	0	Pt	62	Pt	16
			Pd	0	Pd	110	Pd	34
1.9.2008	1	15	Au	0	Au	3	Au	1
			Ni	0	Ni	16,000	Ni	7,700
			Cu	0	Cu	20,000	Cu	6,000

t = metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The Lipeävaara intrusive block dips at about 45° to the SW. Based on gravity anomaly, the block is estimated to continue at least to the depth of 1 km. The southern contact of the Lipeävaara block with the Kuusijärvi block seems to be tectonic (vertical fault), but elsewhere in the block the original magmatic contacts are preserved. Therefore, the permissive tract matches the surface projection of the layered series of the block. The delineation is based on a geological map by Räsänen et al. (2004), drilling of one 9-hole profile (by Oulu University in 1973 and GTK in 1999), geophysical information and a structural model by Karinen & Salmirinne (2001). The sources of information used in the delineation of the tract are summarized in Table 3.

Known deposits

No reef-type PGE deposits are known within the Lipeävaara permissive tract.

Prospects, mineral occurrences, and related deposit types

No obvious reef-type PGE prospects are known from the tract. One contact-type PGE prospect, described in report LipeävaaraContactPGE, is known within the intrusive block.

Exploration history

Exploration commenced in the Lipeävaara area in the 1960s when Outokumpu started to map and drill Ni-Cu targets in the Koillismaa Complex area (Lahtinen 1985). Attention was drawn to the area by Ni- and Cu-rich sulphide-bearing glacial erratic boulders found in the 1960s. GTK explored the area in 1996–2000, during which time a profile of seven holes was drilled and analysed. Of these, six drill cores are within the permissive tract. Types of exploration work carried out in the area, and known to us, are listed in Table 2.

Table 2. Exploration history for LipeävaaraReefPGE.

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Detailed bedrock mapping, outcrop sampling, glacial erratic boulder survey	Yes	Outokumpu Oy	1960s, 1980s
	Detailed bedrock mapping, outcrop sampling	Yes	University of Oulu	1970s
Geochemical surveys	Apparently none has been performed			
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	1989, 1998
Ground geophysical surveys	Gravity survey line		Univ. Oulu	1971
	Magnetic and VLF-R		GTK	1998–1999
	Regional gravity survey		GTK	1999–2001, 2003, 2004
Drilling	6 diamond-drill holes, total 894.29 m.	Yes	GTK	1999
Other	Regional research and mapping programme in the KLIC region.	?	Univ. Oulu	1971–1973
	Regional research and exploration programme in the KLIC region.	Yes	GTK	1996–2002

KLIC = Koillismaa Layered Igneous Complex.

Sources of information

Principal sources of information used by the assessment team for the delineation of LipeävaaraContactPGE are listed in Tables 2 and 3.

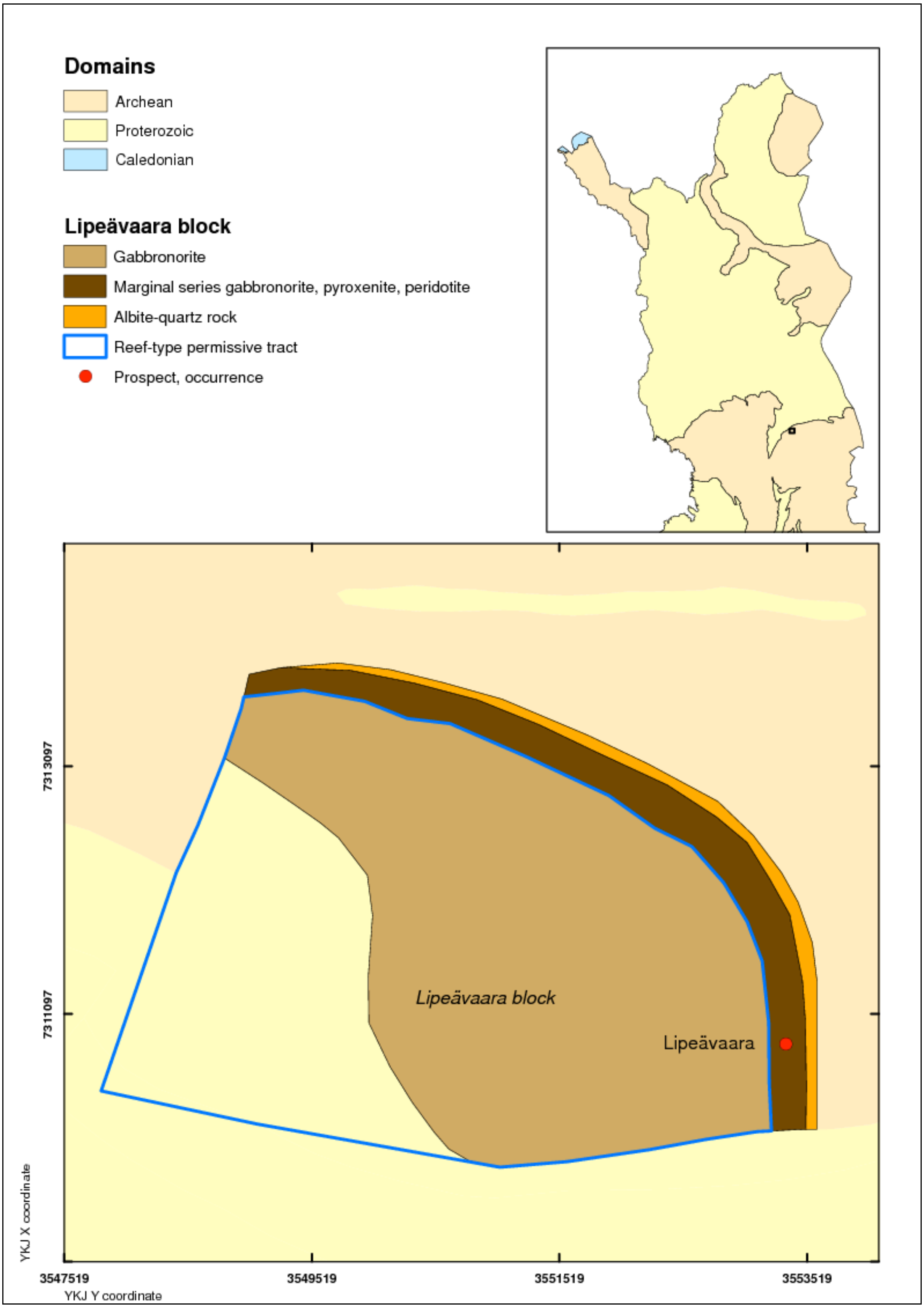

Figure 1. Location of the permissive tract LipeävaaraReefPGE.

Table 3. Principal sources of information used by the assessment team for LipeävaaraReefPGE.

Theme	Type of source	Scale	Citation
Geology	Geological description of the KLIC geology and then known mineral occurrences		Piirainen et al. (1974), Kerkkonen (1975), Juopperi (1977), Alapieti (1982)
	Geological description of the KLIC geology and then known mineral occurrences		Lahtinen (1985)
	Geological map of the KLIC region	1:200 000	Räsänen et al. (2004)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
	PhD on geology and reef-type mineralisation in the Western Koillismaa Intrusion		Karinen (2010)
Mineral occurrences	NA		
Geochemistry	NA		
Geophysics	Aeromagnetic surveys		Ruotsalainen (1977)
Geophysics	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK aerogeophysical data bases
Exploration	Summary report on exploration activities by Outokumpu		Lahtinen (1983)
	Description of exploration activities in the area by GTK		Iljina (2003)

NA = not available.
KLIC = Kollismaa Layered Igneous Complex

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

Not a single reef-type prospect is known within the tract. This means that the minimum number of undiscovered reef-type deposits within the tract is zero. All estimators agreed that, so far, only weak indications of reef-type PGE mineralisation have been detected from the Liepävaara intrusive block. However, the estimators suggested that the Kaukua Reef may continue within the Lipeävaara Block, and that the block may have the same potential for reef-style mineralisation as the Kuusijärvi Block. No consensus on the number of undiscovered deposits was achieved, however, and the mean values were used in the statistical simulations for Lipeävaara (Table 4).

Table 4. Undiscovered deposit estimates, deposit numbers, and tract area for LipeävaaraReefPGE.

Mean undiscovered deposit estimate					Summary statistics					Area (km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}	
1	1	1			0.93	0.17	18	0	0.93	15

	Estimated number of undiscovered deposits				
Estimator	N90	N50	N10	N05	N01
Estimator 1	0	1	1		
Estimator 2	1	1	2		
Estimator 3	1	1	1		
Mean	1	1	1		

Nxx = Estimated number of deposits associated with the xx^{th} percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were calculated by combining the undiscovered deposit estimates with the Finnish reef-type PGE grade model and the LipeävaaraReefPGE tonnage model (Appendix 4) using the EMINERS software (Root et al. 1992, Duval 2004). Results of the Monte Carlo simulation are presented as cumulative frequency plots (Figure 2) and selected simulation results are reported in Table 5. The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralized rock.

Table 5. Results of Monte Carlo simulations of undiscovered resources in LipeävaaraReefPGE.

Material	At least the indicated amount at the probability of					Mean	Probability of mean or greater	Probability of zero
	0.95	0.9	0.5	0.1	0.05			
Pt (t)	0	0	16	140	250	62	0.22	0.08
Pd (t)	0	0	34	240	420	110	0.23	0.08
Au (t)	0	0	1	7	11	3	0.26	0.08
Ni (t)	0	87	7,700	44,000	63,000	16,000	0.31	0.08
Cu (t)	0	54	6,000	55,000	91,000	20,000	0.26	0.08
Rock (Mt)	0	0	11	55	83	21	0.34	0.08

t – metric tonnes; Mt – millions of tonnes.

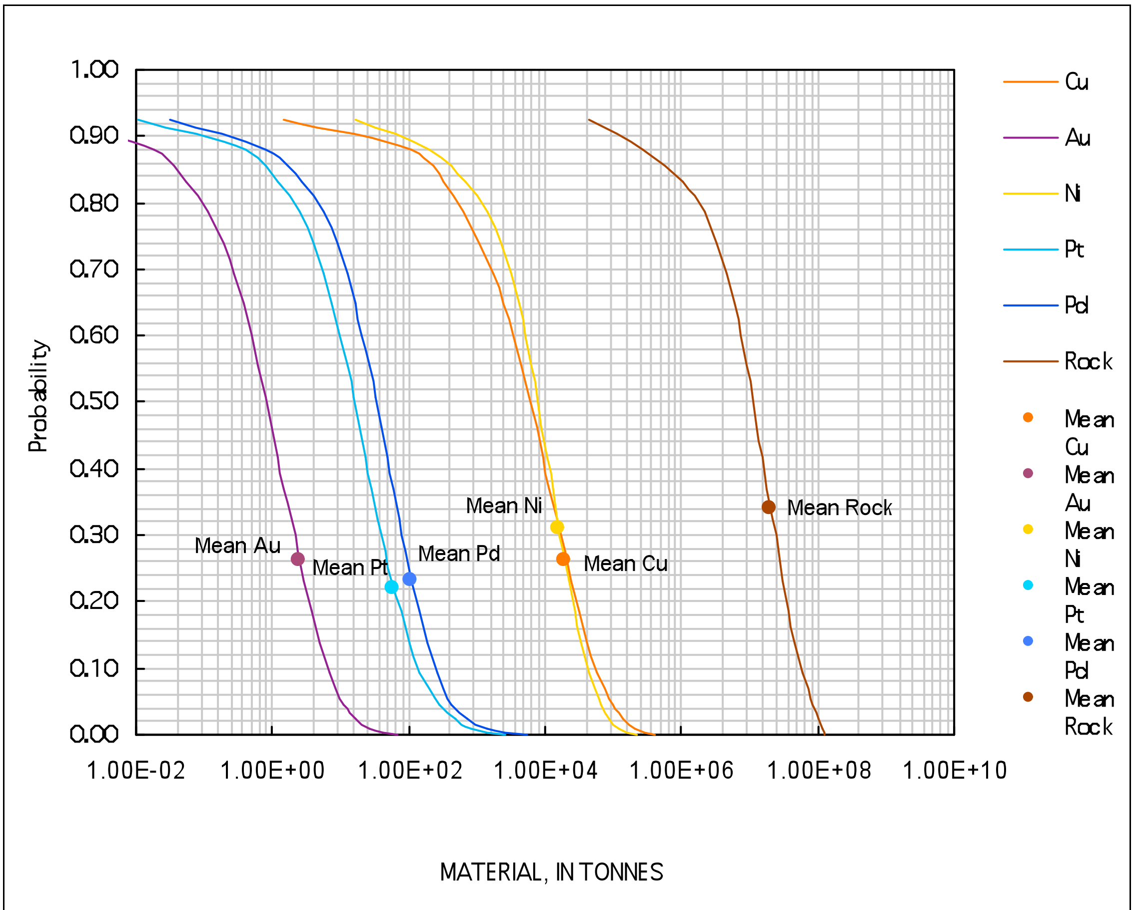

Figure 2. Cumulative frequency plot showing the results of Monte Carlo computer simulation of undiscovered resources in LipeävaaraReefPGE.

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CONTACT-TYPE PGE ASSESSMENT FOR TRACT MurtolampiContactPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Contact-type Cu-Ni-PGE
Descriptive model: Fennoscandian contact-type Cu-Ni-PGE (Appendix 1)
Grade and tonnage model: Fennoscandian contact-type Cu-Ni-PGE (Appendix 2)

LOCATION AND RESOURCE SUMMARY

The Murtolampi block is located in northern Finland in the municipality of Posio, 125 km southeast from the town of Rovaniemi. The 1:100 000 KKJ map sheet is 3544. The UTM map sheet containing the block is S5241. The PGE resource assessment carried out for this report is summarized in Table 1.

Table 1. Summary of selected resource assessment results for MurtolampiContactPGE.

Date of assessment	Assessment depth (km)	Tract area (km^2)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
28.08.–01.10.2008	1	0.7	Pt	0	Pt	8	Pt	0
			Pd	0	Pd	35	Pd	0
			Au	0	Au	3	Au	0
			Ni	0	Ni	27,000	Ni	0
			Cu	0	Cu	51,000	Cu	0

t = metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The permissive tract delineated in Figure 1 is a surface projection of the basal contact zone of the Murtolampi intrusive block of the ca. 2.45 Ga of the Koillismaa intrusion (Iljina & Hanski 2005). The estimated dip of layering of the marginal series in the Murtolampi block is about 25° south-southwest. On the surface, the delineation is based on a geological map by Räsänen et al. (2004), drilling (by GTK in 1999), geophysical information (ground surveys) and a structural model by Karinen & Salmirinne (2001). The block is bounded in its eastern contact by a vertical shear zone, and is estimated to have a maximum thickness of 200–300 m, thus limiting the extent of the permissive tract which follows the margins of the intrusion at the surface. The sources of information used in the delineation of the tract are summarized in Table 3.

Known deposits

No well-delineated contact-type PGE deposits are known from Murtolampi.

Prospects, mineral occurrences, and related deposit types

One contact-type PGE prospect is known from the tract, the Murtolampi prospect (Table 2, Figure 1).

Table 2. Significant prospects and occurrences in MurtolampiContactPGE

Name	X coordinate	Y coordinate	Age (Ga)	Comments (grade and tonnage data, if available)	Reference
Murtolampi	7319 520	3555 230	2.45	Drill core intersection: 1 m @ 1.05 g/t Pd, 0.54 g/t Pt, 0.11 g/t Au, 0.23% Ni, 0.35% Cu	Iljina (2004)

Exploration history

Attention was drawn to the Koillismaa Complex Western Intrusion area by Ni- and Cu-rich sulphide-bearing glacial erratic boulders found in the 1960s. The first indications of contact-type deposits in the Murtolampi area were discovered from outcrops by Outokumpu in the late 1980s. GTK explored the complex area in 1996–2000, and NAN in 2000–2002. The exploration work carried out in the area is listed in Table 2.

Table 2. Exploration history for MurtolampiContactPGE.

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Detailed bedrock mapping, outcrop sampling	Yes	Outokumpu Oy	1980s
Geochemical surveys	Not available			
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	1998
Ground geophysical surveys	Gravity survey line		Univ. Oulu	1971
	Magnetic and VLF survey		GTK	1998, 2000
	Regional gravity survey		GTK	1999-2001, 2003, 2004
	Magnetic and IP survey		NAN	2001
Drilling	Six diamond-drill holes, total 301.90 m	Yes	GTK	1999
Other	Regional research and mapping programme in the KLIC region.	No	Univ. Oulu	1971-1976
	Regional research and exploration programme in the KLIC region.	Yes	GTK	1996-2000

NAN = North Atlantic Natural Resources.
KLIC = Koillismaa Layered Igneous Complex.

Sources of information

Principal sources of information used by the assessment team for the delineation of HoikanvaaraContact-PGE are listed in Tables 2 and 3.

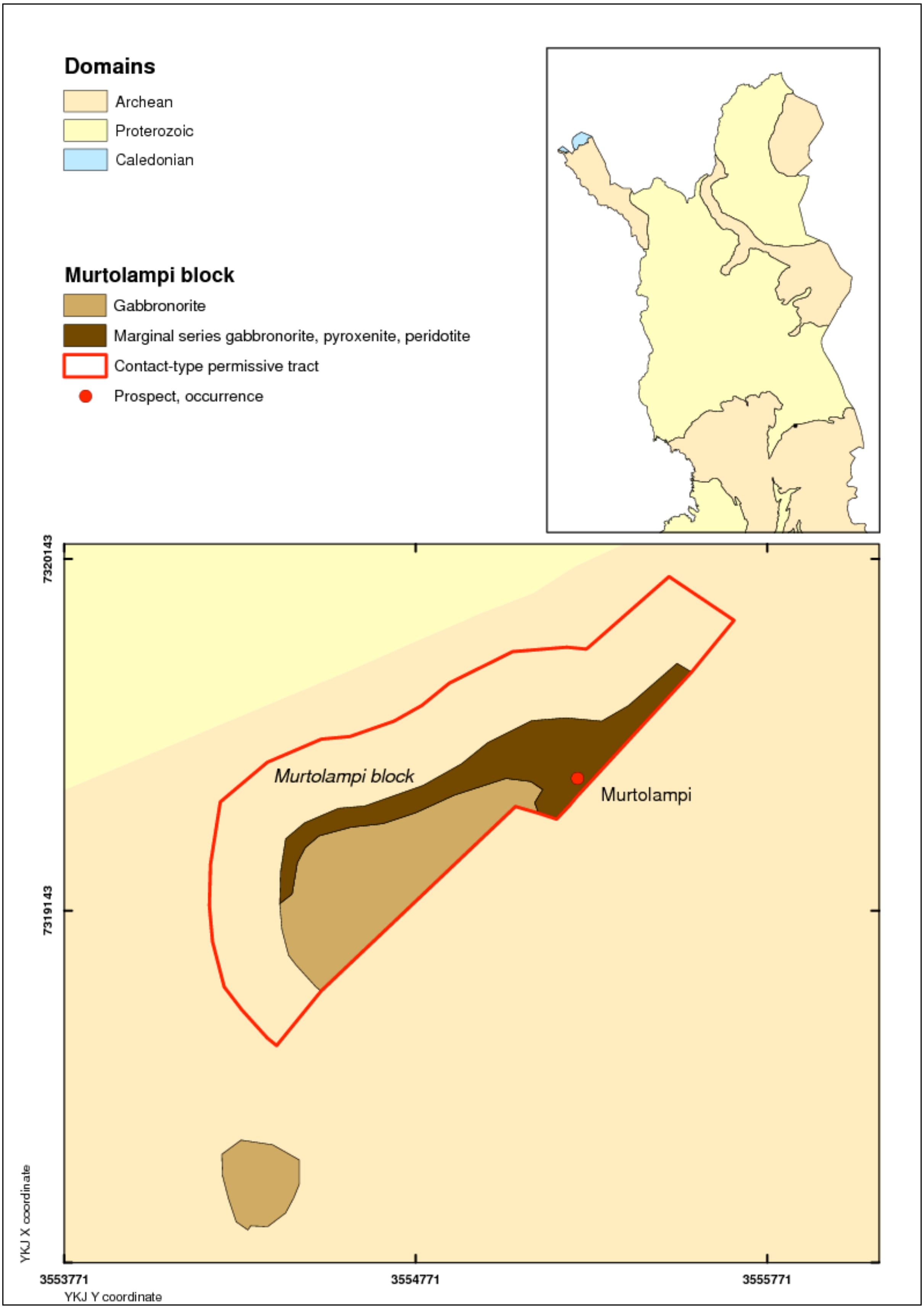

Figure 1. Location of the permissive tract MurtolampiContactPGE.

Table 3. Principal sources of information used by the assessment team for MurtolampiContactPGE.

Theme	Type of source	Scale	Citation
Geology	Geological description of the KLIC geology and then known mineral occurrences	1:150 000	Alapieti (1982)
	Geological map of the KLIC region	1:200 000	Räsänen et al. (2004)
	Geological description of the KLIC geology and the known mineral occurrences		Iljina (2004)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
	PhD on geology and reef-type mineralisation in the Western Koillismaa Intrusion		Karinen (2010)
Mineral occurrences	PGE deposits in the marginal series of layered intrusions		Iljina & Lee (2005)
Geochemistry	NA		
Geophysics	Magnetic and VLF-R survey		Iljina (2004)
Exploration	General description of exploration activities in the region by Outokumpu.		Lahtinen (1985)
	Detailed description of exploration activities in the area by GTK		Iljina (2004)

NA = not available.
KLIC = Koillismaa Layered Igneous Complex.

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

One small contact-type prospect is known within the tract. The prospect is quite weak, and hence the minimum number of undiscovered contact-type deposits within the tract can be zero. The surface area of the Murtolampi block is small, and the maximum thickness of the block is only 200–300 m. However, the area of the block is not significantly smaller than the area of Konttijärvi intrusion. The block could contain a Konttijärvi-size deposit, but drilling and an outcropping marginal series have not shown any indications of such an occurrence. A full consensus that the likelihood of a contact-type deposit is low was reached between the estimators for the number of undiscovered contact-type PGE deposits at Murtolampi, as shown in Table 4.

Table 4. Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for MurtolampiContactPGE.

Consensus of undiscovered deposit estimate					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
0	0	1			0.30	0.50	170	0	0.30	0.7	0.41

Estimator	Estimated number of undiscovered deposits N90	N50	N10	N05	N01
Estimator 1	0	0	1		
Estimator 2	0	0	1		
Estimator 3	0	0	1		
Consensus	0	0	1		

Nxx = Estimated number of deposits associated with the xx^{th} percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; Deposit density = deposit density reported as the total number of deposits per km^2. N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were estimated by combining the means of estimated numbers of undiscovered contact-type PGE deposits with the Fennoscandian contact-type PGE grade and tonnage model (Appendix 2) using the EMINERS software (Root et al. 1992, Duval 2004). Selected simulation results are reported in Table 5. Results of the Monte Carlo simulation are presented as cumulative frequency plots (Figure 2). The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralised rock.

Table 5. Results of Monte Carlo simulations of undiscovered resources in MurtolampiContactPGE.

Material	At least the indicated amount at the probability of					Mean	Probability of mean or greater	Probability of zero
	0.95	0.90	0.50	0.10	0.05			
Pt (t)	0	0	0	18	52	8	0.15	0.70
Pd (t)	0	0	0	64	200	35	0.13	0.70
Au (t)	0	0	0	7	17	3	0.15	0.70
Ni (t)	0	0	0	98,000	170,000	27,000	0.20	0.70
Cu (t)	0	0	0	150,000	360,000	51,000	0.19	0.70
Rock (Mt)	0	0	0	63	210	28	0.16	0.70

t = metric tonnes; Mt = millions of tonnes.

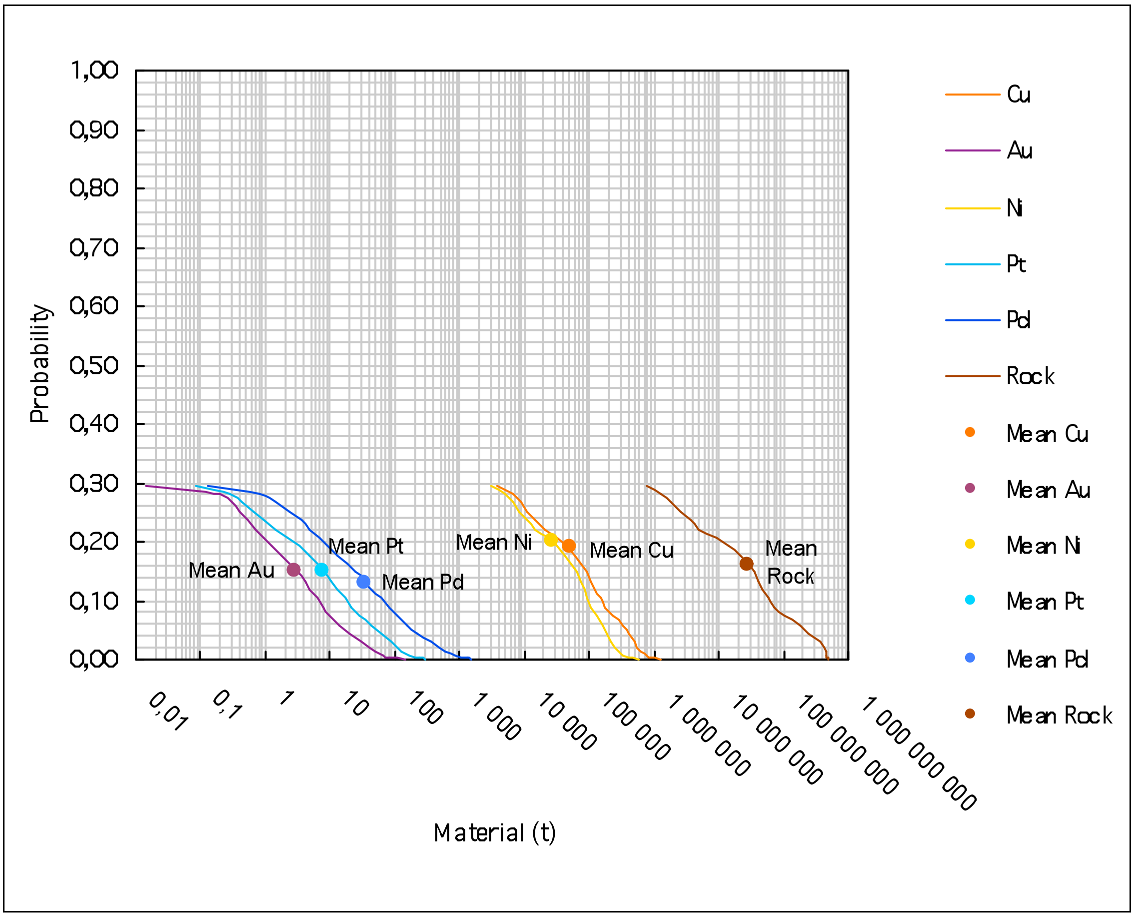

Figure 2. Cumulative frequency plot showing the results of Monte Carlo computer simulation of undiscovered resources in MurtolampiContactPGE.

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REEF-TYPE PGE ASSESSMENT FOR TRACT MurtolampiReefPGE001, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Reef-type PGE-Ni-Cu
Descriptive model: Finnish reef-type PGE-Ni-Cu (Appendix 3)
Grade-tonnage model: Finnish reef-type PGE-Ni-Cu grade model, MurtolampiReefPGE tonnage model (Appendix 4)

LOCATION AND RESOURCE SUMMARY

The Murtolampi Block of the Koillismaa intrusion is located in northern Finland in the municipality of Posio, 130 km southeast from the town of Rovaniemi. The 1:100 000 KKJ map sheet is 3544. The UTM map sheet containing the block is S5241. The PGE resource assessment carried out for this report is summarised in Table 1.

Table 1. Summary of selected resource assessment results for MurtolampiReefPGE001.

Date of assessment	Assessment depth (km)	Tract area (km²)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
1.10.2008	1	0.5	Pt	0	Pt	1	Pt	0
			Pd	0	Pd	2	Pd	0
			Au	0	Au	0	Au	0
			Ni	0	Ni	380	Ni	0
			Cu	0	Cu	460	Cu	0

t = metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The small WSW-trending Murtolampi intrusive block dips at about 25° to the SSE. Based on magnetic and gravity surveys, the block is estimated to continue to the depth of 200–300 m. The middle and upper parts of the block, at and above the contact between earlier Cr-rich and later Cr-poor magma units, are used to determine the permissive tract. The permissive tract matches the surface projection of this upper part of the intrusion. On the surface, the delineation is based on a geological map by Räsänen et al. (2004), drilling (by GTK in year 1999), geophysical information (ground surveys by GTK) and a structural model by Karinen & Salmirinne (2001). Contacts seem to be tectonic (subvertical faults) at the S and NW margins of the block. The sources of information used in the delineation of the tract are summarized in Table 5.

Known deposits

No reef-type PGE deposits are known from the Murtolampi permissive tract.

Prospects, mineral occurrences, and related deposit types

No obvious reef-type PGE prospects are known from the tract. One contact-type prospect occurs within the tract, the Murtolampi prospect.

Exploration history

Attention was drawn to the Koillismaa Complex Western Intrusion area by Ni- and Cu-rich sulphide-bearing glacial erratic boulders found in the 1960s. The first indications of contact-type deposits in the Murtolampi area were discovered from outcrops by Outokumpu in the late 1980s. GTK explored the complex area in 1996–2000, and NAN in 2000–2002. The exploration work carried out in the area is listed in Table 2.

Table 2. Exploration history for MurtolampiReefPGE.

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Detailed bedrock mapping, outcrop sampling	Yes	Outokumpu Oy	1980s
Geochemical surveys	Not available			
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	1998
Ground geophysical surveys	Gravity survey line		Univ. Oulu	1971
	Magnetic and VLF survey		GTK	1998, 2000
	Regional gravity survey		GTK	1999–2001, 2003, 2004
	Magnetic and IP survey		NAN	2001
Drilling	Six diamond-drill holes, total 301.90 m	Yes	GTK	1999
Other	Regional research and mapping programme in the KLIC region.	No	Univ. Oulu	1971–1976
	Regional research and exploration programme in the KLIC region.	Yes	GTK	1996–2000

NAN = North Atlantic Natural Resources.
KLIC = Koillismaa Layered Igneous Complex.

Sources of information

Principal sources of information used by the assessment team for the delineation of MurtolampiReef-PGE001 are listed in Table 3.

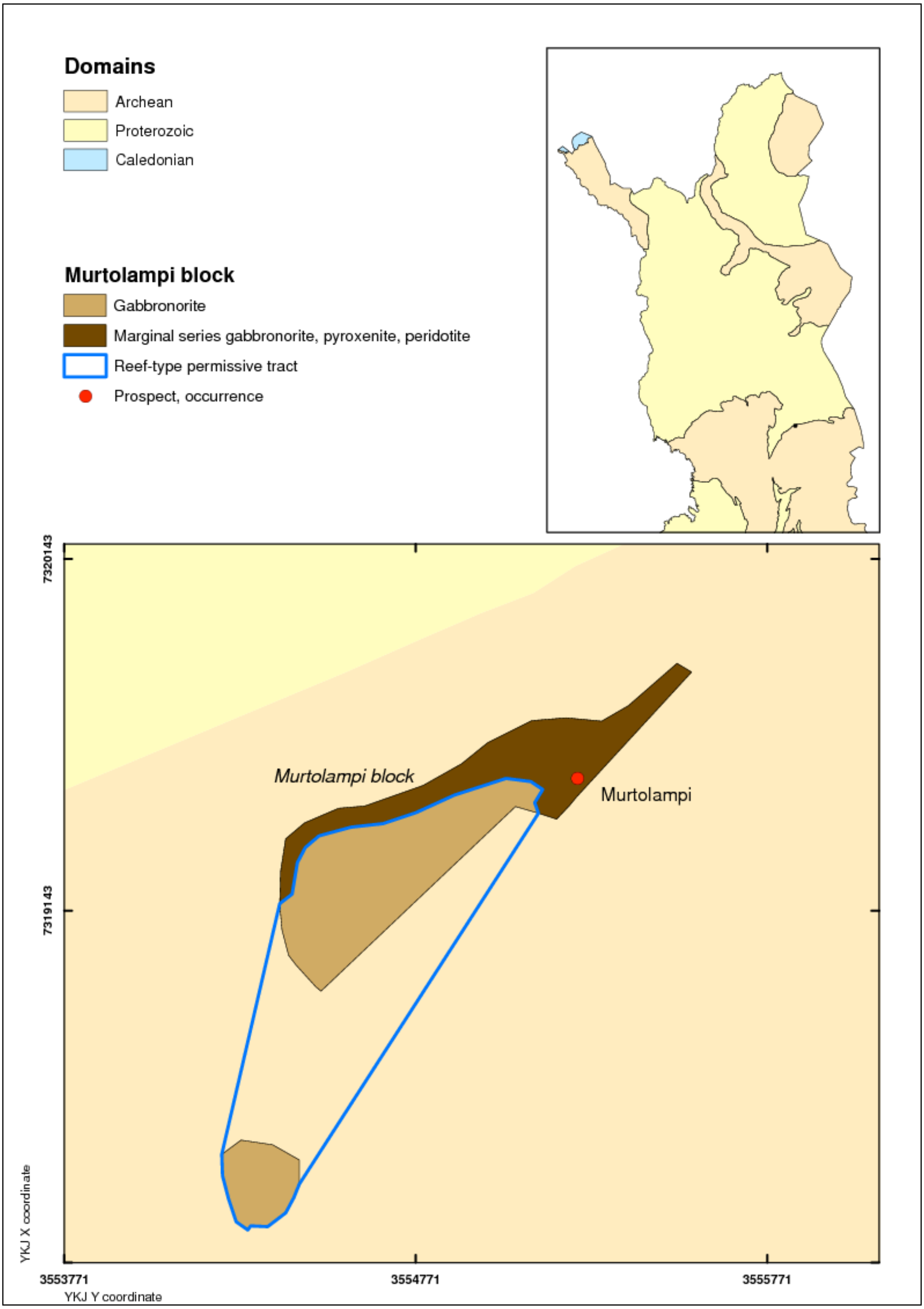

Figure 1. Location of the permissive tract MurtolampiReefPGE.

Table 3. Principal sources of information used by the assessment team for MurtolampiContactPGE.

Theme	Type of source	Scale	Citation
Geology	Geological description of the KLIC geology and then known mineral occurrences	1:150 000	Alapieti (1982)
	Geological map of the KLIC region	1:200 000	Räsänen et al. (2004)
	Geological description of the KLIC geology and the known mineral occurrences		Iljina (2004)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
	PhD on geology and reef-type mineralisation in the Western Koillismaa Intrusion		Karinen (2010)
Mineral occurrences	PGE deposits in the marginal series of layered intrusions		Iljina & Lee (2005)
Geochemistry	NA		
Geophysics	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK aerogeophysical data bases
	Magnetic and VLF-R survey		Iljina (2004)
Exploration	General description of exploration activities in the region by Outokumpu.		Lahtinen (1985)
	Detailed description of exploration activities in the area by GTK		Iljina (2004)

NA = not available.
KLIC = Koillismaa Layered Igneous Complex.

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

Not a single reef-type prospect is known within the tract. This means that the minimum number of undiscovered reef-type deposits within the tract is zero. The Murtolampi intrusive block is small and quite well known, so the possibility for an undiscovered reef-type deposit is rather low. Since no consensus on the probabilities of the number of undiscovered deposits was reached, mean values of the individual estimates were used in the simulation (Table 4).

Table 4. Undiscovered deposit estimates, deposit numbers and tract area for MurtolampiReefPGE001.

Mean undiscovered deposit estimate					Summary statistics					Area (km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}	
0	0	1			0.30	0.50	170	0	0.30	0.5

	Estimated number of undiscovered deposits				
Estimator	N90	N50	N10	N05	N01
Estimator 1	0	0	1		
Estimator 2	0	1	1		
Estimator 3	0	0	1		
Mean	0	0	1		

Nxx = Estimated number of deposits associated with the xxth percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were calculated by combining the undiscovered deposit estimates with the Finnish reef-type PGE grade model and the MurtolampiReefPGE tonnage model (Appendix 4) using the EMINERS software (Root et al. 1992, Duval 2004). Results of the Monte Carlo simulation are presented as cumulative frequency plots (Figure 2) and selected simulation results are reported in Table 5. The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralized rock.

Table 5. Results of Monte Carlo simulations of undiscovered resources in MurtolampiReefPGE.

Material	At least the indicated amount at the probability of					Mean	Probability of mean or greater	Probability of zero
	0.95	0.9	0.5	0.1	0.05			
Pt (t)	0	0	0	3	7	1	0.16	0.69
Pd (t)	0	0	0	6	12	2	0.17	0.69
Au (t)	0	0	0	0	0	0	0.18	0.69
Ni (t)	0	0	0	1,100	2,200	380	0.21	0.69
Cu (t)	0	0	0	1,200	2,700	460	0.17	0.69
Rock (Mt)	0	0	0	2	3	0	0.23	0.69

t = metric tonnes; Mt = millions of tonnes.

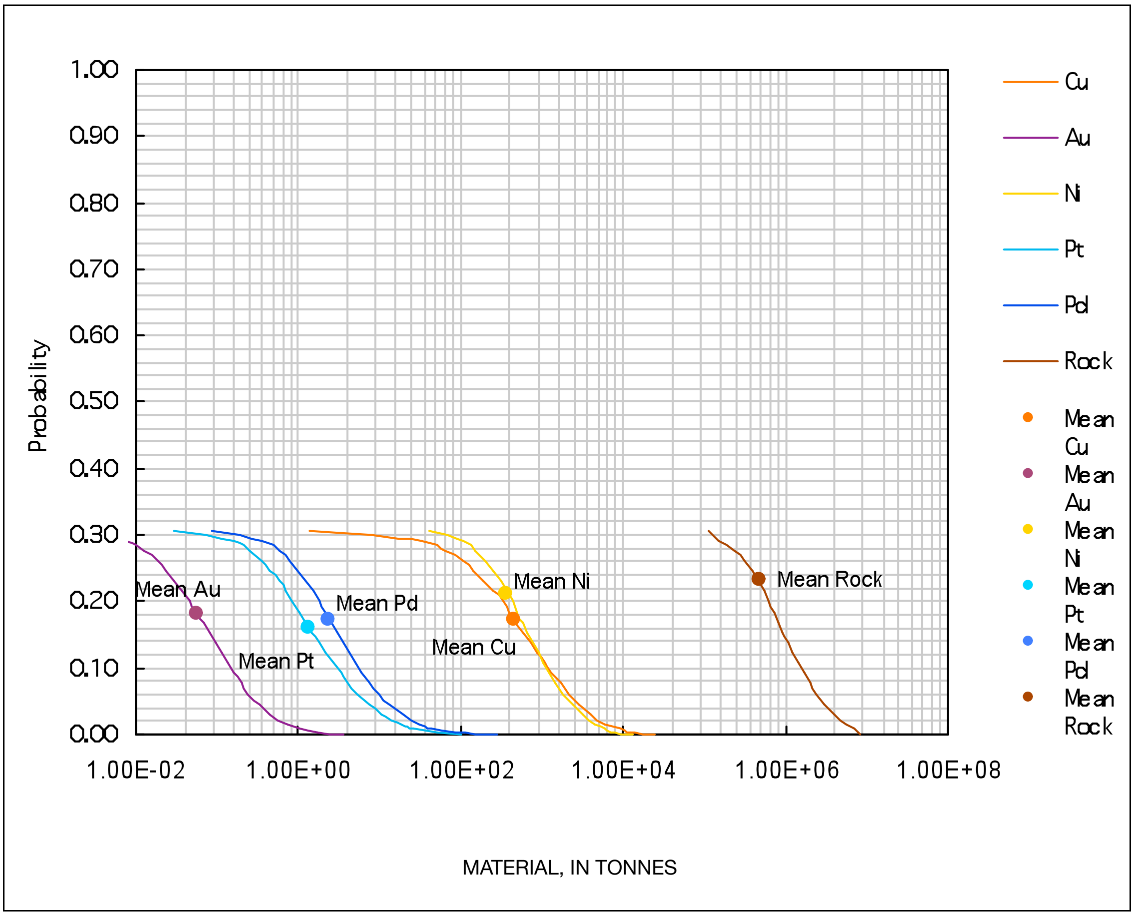

Figure 2. Cumulative frequency plot showing the results of Monte Carlo computer simulation of undiscovered resources in MurtolampiReefPGE.

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REEF-TYPE PGE ASSESSMENT FOR TRACT NäränkävaaraReefPGE001, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Reef-type PGE-Ni-Cu
Descriptive model: Finnish reef-type PGE-Ni-Cu (Appendix 3)
Grade-tonnage model: Finnish reef-type PGE-Ni-Cu grade model, NäränkävaaraReefPGE tonnage model (Appendix 4)

LOCATION AND RESOURCE SUMMARY

The Näränkävaara layered intrusion is located in northern Finland in the municipality of Kuusamo, about 190 km SE from Rovaniemi. The 1:100 000 KKJ map sheets are 4514 and 4523. The UTM map sheets containing the intrusion are S5322, S5323 and S5324. The PGE resource assessment carried out for this report is summarised in Table 1.

Table 1. Summary of selected resource assessment results for NäränkävaaraReefPGE.

Date of assessment	Assessment depth (km)	Tract area (km^2)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
1.9.2008	1	24	Pt	0	Pt	290	Pt	81
			Pd	0	Pd	510	Pd	170
			Au	0	Au	12	Au	4
			Ni	0	Ni	77,000	Ni	40,000
			Cu	0	Cu	96,000	Cu	32,000

t – metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The NW part of the Näränkävaara intrusion dips about 20° to the NE. The permissive tract is the surface projection of the middle and upper parts of the Näränkävaara layered intrusion at and above the contact between earlier Cr-rich and later Cr-poor magma units. The extent of the intrusion down-dip is unknown, but it is assumed to continue at least to the ultramafic NW-trending intrusions about 700 m to the NE. The NE margin of the permissive tract is placed at the contact of these intrusions. On the surface, the delineation is based on a geological map by Räsänen et al. (2004), drilling (by Outokumpu and GTK), and geophysical information (low-altitude airborne magnetic survey by GTK). The sources of information used in the delineation of the tract are summarized in Table 5.

Known deposits

There are no well-explored reef-type PGE deposits within the Näränkävaara permissive tract.

Prospects, mineral occurrences, and related deposit types

No reef-type prospects are known within the NäränkävaaraReefPGE tract. There seem to be no other types of PGE mineralisation at Näränkävaara, either; the intrusion is reasonably well explored, and no indications of contact-type mineralisation have been discovered. The marginal series is boninitic, contains Cr-rich units, indicates peaceful intrusion conditions and is clearly unmineralised on PGE.

Exploration history

Exploration for base metals commenced in the Näränkävaara area in 1962, when Outokumpu started to map, survey and drill Ni-Cu targets in the Koillismaa Complex area (Alapieti, 1982, Lahtinen 1985). Attention was drawn to the region by Ni- and Cu-rich sulphide-bearing glacial erratic boulders found in the 1960s from the areas of other intrusive blocks at Koillismaa. Exploration for PGE started in the 1980s. Rautaruukki explored the area in 1980 (outcrop profiles; Lahtinen 1985), GTK in 1996–1999, and North Atlantic Natural Resources Ab in 2000–2002. The latest work has been done by Nortec Ventures, which indicated from an airborne TDEM survey two targets (conductors) at a depth of 100–300 below the surface. In late 2007, two holes were planned to be drilled into these targets (Nortc Ventures 2007). Types of exploration work carried out in the Näränkävaara intrusionarea, and known to us, are listed in Table 2.

Table 2. Exploration history for Näränkävaara intrusion.

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Detailed bedrock mapping, outcrop sampling, glacial erratic boulder survey	Yes	Outokumpu	1960s, 1980s
	Detailed bedrock mapping, outcrop sampling	Yes	Univ. Oulu	1970s
	An outcrop profile across the intrusion sampled	Yes	Rautaruukki	1980
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	1988, 1996
	Low-altitude airborne magnetic and electromagnetic survey		Outokumpu	2002
	Low-altitude airborne electromagnetic survey (TDEM)		Akkerman – Nortec	2006
Ground geophysical surveys	VLF-R and magnetic surveys		GTK	1996, 1999
Drilling	5 diamond-drill holes, total 1068.6 m	Yes	Outokumpu	2001–
	7 diamond-drill holes, total 1374.78 m	Yes	GTK	1967, 1972, 1996
	2 diamond drill holes, total 801.25 m	Yes	Akkerman – Nortec	2007
Other	Regional research and mapping programme in the KLIC region	No	Univ. Oulu	1971–1976
	Regional research and exploration programme in the KLIC region	Yes	GTK	1996–2000

Akkerman–Nortec =Akeerman Exploration – Nortec Ventures Joint venture.
KLIC = Koillismaa Layered Igneous Complex.

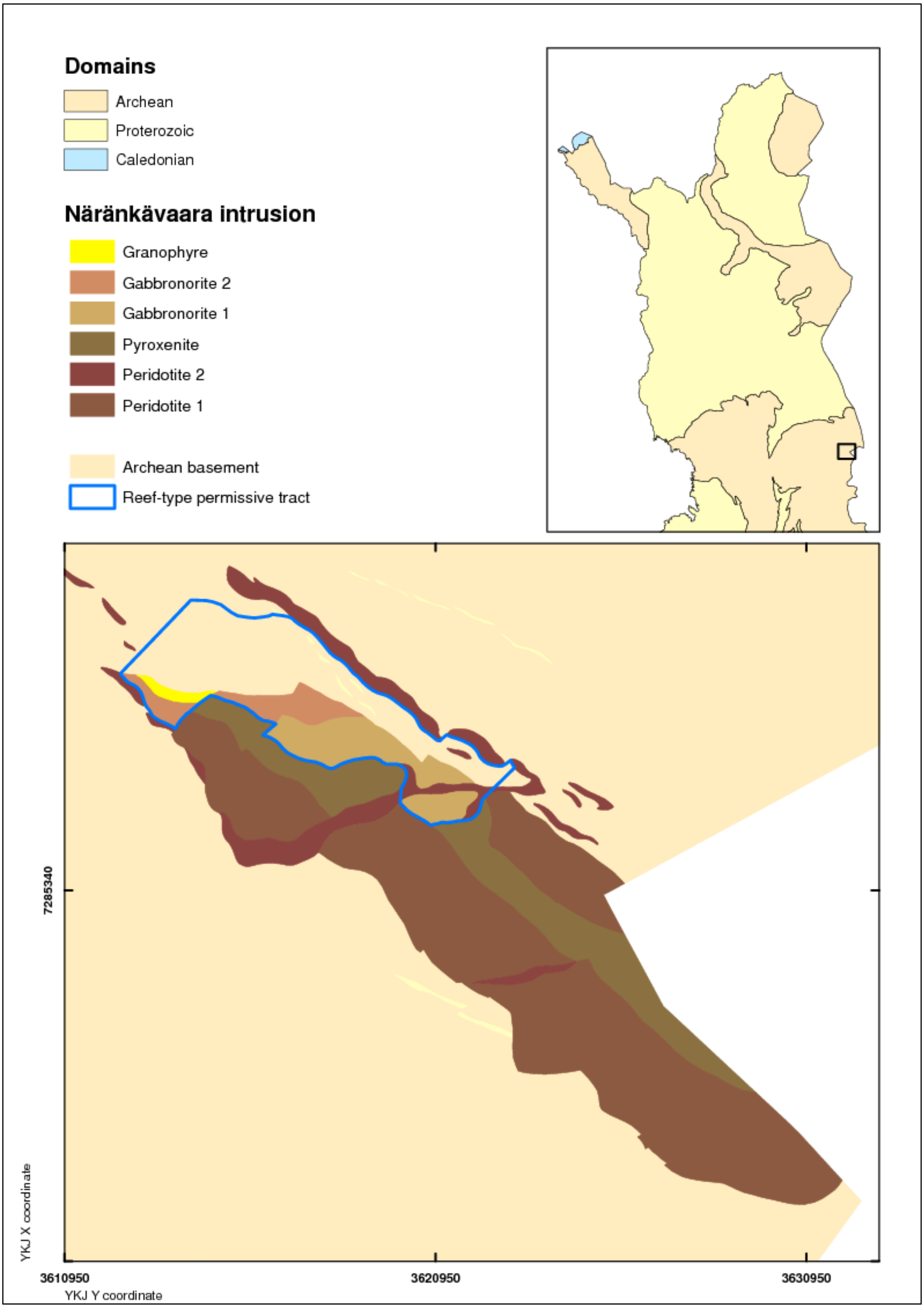

Figure 1. Location of the permissive tract NäränkävaaraReefPGE.

Sources of information

Principal sources of information used by the assessment team for delineation of NäränkävaaraReefPGE001 are listed in Table 3.

Table 3. Principal sources of information used by the assessment team for NäränkävaaraReefPGE001.

Theme	Type of source	Scale	Citation
Geology	Geological description of Näränkävaara and the KLIC geology and then known mineral occurrences	1:150 000	Alapieti et al. (1979), Alapieti (1982)
	Geological map of the KLIC region	1:200 000	Räsänen et al. (2004)
	Geological description of the KLIC geology and the known mineral occurrences		Iljina (2004)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
Mineral occurrences	NA		
Geochemistry	NA		
Geophysics	Low-altitude airborne magnetic, electromagnetic and radiometric survey, airborne TDEM survey		GTK aerogeophysical databases, Vesanto (2003), Akkerman (2008)
	Ground-geophysical surveys		Lahtinen (1985),
Exploration	General description of exploration activities in the region by Outokumpu.		Lahtinen (1985)
	Detailed description of exploration activities in the area by GTK		Iljina (2004)

NA = not available.
KLIC = Koillismaa Layered Igneous Complex.

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

No reef-type deposits or prospects are known within the tract. This means that the minimum number of undiscovered reef-type deposits within the tract is zero. The average undiscovered deposit estimates at various probability levels and the values given by individual estimators are shown in Table 4.

Table 4. Undiscovered deposit estimates, deposit numbers, and tract area for NäränkävaaraReefPGE.

Consensus undiscovered deposit estimate					Summary statistics					Area (km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}	
0	1	2			1.0	0.79	79	0	1.0	24

	Estimated number of undiscovered deposits				
Estimator	N90	N50	N10	N05	N01
Estimator 1	0	1	2		
Estimator 2	0	1	2		
Estimator 3	0	1	2		
Consensus	0	1	2		

Nxx = Estimated number of deposits associated with the xx^{th} percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie, 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were calculated by combining the undiscovered deposit estimates with the Finnish reef-type PGE grade model and the NäränkävaaraReefPGE tonnage model (Appendix 4) using the EMINERS software (Root & others, 1991; Duval, 2004). Results of the Monte Carlo simulation are presented as cumulative frequency plots (Figure 2) and selected simulation results are reported in Table 5. The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralized rock.

Table 6. Results of Monte Carlo simulations of undiscovered resources in NäränkävaaraReefPGE.

Material	At least the indicated amount at the probability of					Mean	Probability of mean or greater	Probability of zero
	0.95	0.9	0.5	0.1	0.05			
Pt (t)	0	0	81	720	1,200	290	0.25	0.31
Pd (t)	0	0	170	1,300	2,000	510	0.26	0.31
Au (t)	0	0	4	32	51	12	0.29	0.31
Ni (t)	0	0	40,000	210,000	290,000	77,000	0.34	0.31
Cu (t)	0	0	32,000	280,000	430,000	96,000	0.29	0.31
Rock (Mt)	0	0	57	270	360	97	0.37	0.31

t = metric tonnes; Mt = millions of tonnes.

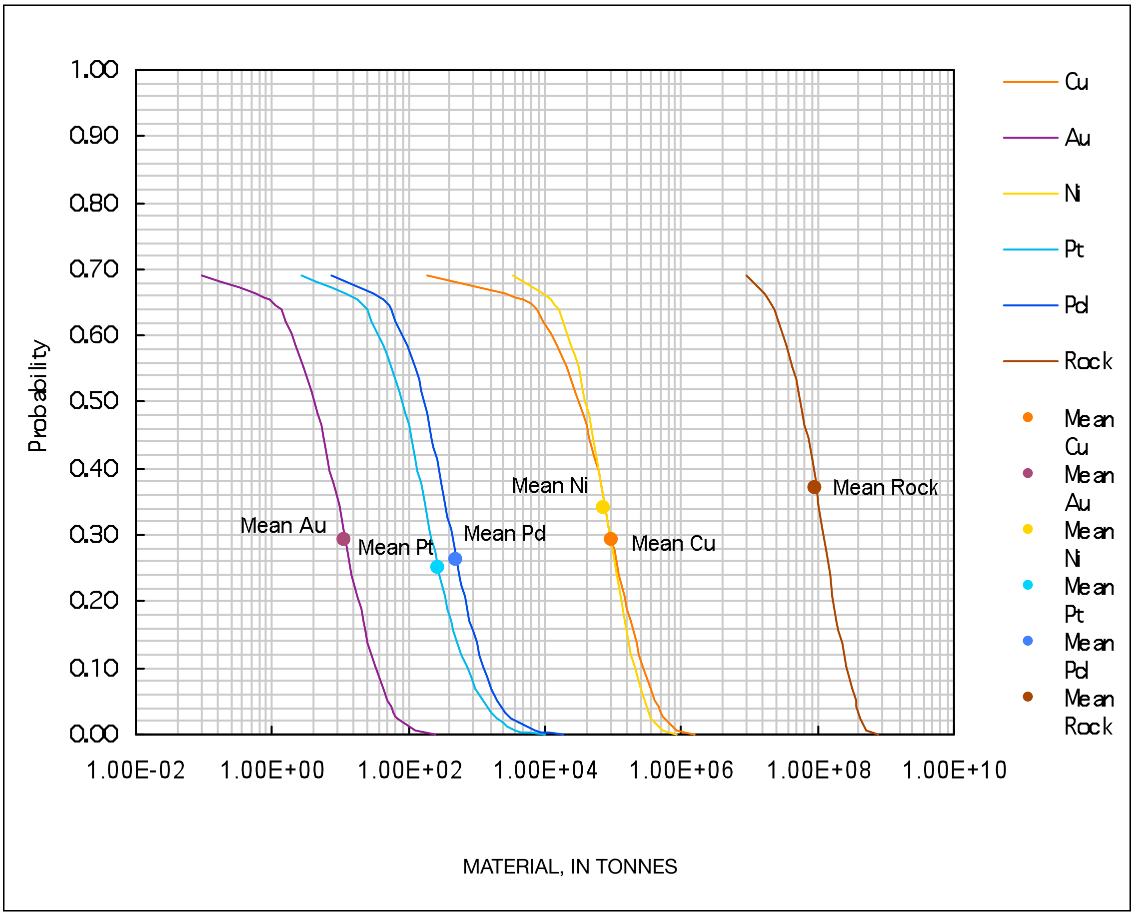

Figure 2. Cumulative frequency plot showing the results of Monte Carlo computer simulation of undiscovered resources in NäränkävaaraReefPGE.

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CONTACT-TYPE PGE ASSESSMENT FOR TRACT NarkausContactPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Contact-type Cu-Ni-PGE
Descriptive model: Fennoscandian contact-type Cu-Ni-PGE (Appendix 1)
Grade and tonnage model: Fennoscandian contact-type Cu-Ni-PGE (Appendix 2)

LOCATION AND RESOURCE SUMMARY

The Narkaus layered intrusion is located in northern Finland in the municipality of Rovaniemi, 40–60 km south from Rovaniemi. The 1:100 000 KKJ map sheets are 3611 and 3613. The UTM map sheets containing the intrusion are T4331, T4332, and T4333. The PGE resource assessment carried out for this report is summarised in Table 1.

Table 1. Summary of selected resource assessment results for NarkausContactPGE.

Date of assessment	Assessment depth (km)	Tract area (km²)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
			Pt	0	Pt	220	Pt	200
			Pd	0	Pd	930	Pd	770
1.10.2008	1	22	Au	0	Au	83	Au	70
			Ni	0	Ni	770,000	Ni	750,000
			Cu	0	Cu	1,400,000	Cu	1,400,000

t = metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The permissive tract delineated in Figure 1 is a surface projection of the basal contact zone of the Narkaus intrusion. On the surface, the delineation is based on a geological map by Iljina (1994). At depth, the tract is delineated based on geophysical information (Iljina 1994) and drilling data. The intrusion has an average dip of 50° to the NNW and NW, and has a maximum depth of about 650 m. At the westernmost part of the intrusion, the dip is to the west. The basal zone favourable for contact-type mineralisation projected to the surface, plus the above-mentioned 200 m buffer zone, forms the permissive tract for contact-type mineralisation at Narkaus. The sources of information used in the delineation of the tract are summarised in Table 4.

Known deposits

No contact-type PGE deposits are known within the tract.

Prospects, mineral occurrences, and related deposit types

Four partially delineated offset-type PGE prospects (Table 2 and Figure 1) and two offset occurrences without any resource estimates (Saunakivalo and Kuohunki) are known within the tract. In addition, Pd-Cu enriched sulphides are sporadically encountered practically throughout the entire 23 km strike length of the basal contact zone of the Narkaus intrusion, and reef-type mineralization has been encountered at Siika-Kämä, Kuohunki and Nutturalampi.

Table 2. Significant prospects and occurrences in NarkausContactPGE

Name	X coordinate	Y coordinate	Age (Ma)	Comments (grade and tonnage data, if available)	Reference
Kilvenjärvi	7350500	3462700	2.44	0.7 Mt @ 2.74% Cu, 7.27 ppm Pd, 1.12 ppm Pt, 0.8 ppm Au; no data for Ni	Outokumpu (1987)
Kilvenjoki	7352500	3462700	2.44	0.175 Mt @ 6.11% Cu, 0.28% Ni, 2.5 ppm Pd, 0.06 ppm Pt, 0.84 ppm Au	Outokumpu (1987)
Kilven-latvalampi	7351400	3467380	2.44	3.2 Mt @ 0.5% Cu, 1.4 ppm Pd, 0.5 ppm Pt; no data for Ni	Saltikoff et al. (2000)
Kuohunki	7353000	3472800	2.44	Best section: 9.6 m @ 0.18% Cu, 0.08% Ni, 5.01 ppm Pd, 1.28 ppm Pt, 0.17 ppm Au	Lahtinen (1987)
Nutturalampi	7351500	3469400	2.44	0.4 Mt @ 0.09% Cu, 5.5 ppm Pd, 1.5 ppm Pt, 0.15 ppm Au	Eerola et al. (1990)
Saunakivalo	7349100	3457700	2.44	Best section: 0.3 m @ 0.05% Cu, 1.93% Ni, 2.73 ppm Pd, <0.05 ppm Au	Lahtinen (1983)

Exploration history

Outokumpu Oy drilled offset sulphide deposits located below the Narkaus Intrusion in 1973–78. High Pd contents from one of the deposits were assayed in 1982. The subsequent drilling resulted in the finding of the Kilvenjärvi offset in 1984. Exploration commenced in the Narkaus area in 1973 when a local layman found a Cu-Pd enriched mica schist boulder. The subsequent exploration conducted by Outokumpu Oy led to the delineation of a number offset deposits by the mid-1980s. Later, at the beginning of 2000, exploration started again through a joint venture between Outokumpu Oy and Gold Fields Ltd. Outokumpu dropped out of the joint venture in 2003 and in 2006, North American Palladium Ltd (NAP) formed a new joint venture with Gold Fields Ltd. Moreover, NAP dropped out of the JV in August 2008 and the entire Narkaus intrusion and related deposits are held exclusively by the Gold Fields Ltd (May 2009). The types of exploration work carried out in the area, and known to us, are listed in Table 3.

Table 3. Exploration history for NarkausContactPGE.

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Detailed bedrock mapping, outcrop sampling		Outokumpu Oy	1973–1985
Geochemical surveys	Till geochemical survey	Yes	Outokumpu Oy	1973–1980
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	
Ground geophysical surveys	Slingram, magnetic, IP, etc. surveys		Outokumpu Oy	1973–1985
	Detailed gravimetric survey		GFAP	2000–2005
Drilling	About 100 diamond-drill holes, total 25,000 m	Yes	Outokumpu Oy	until 1988

GFAP = Gold Fields Arctic Platinum Oy and its precursor Arctic Platinum Partnership Ay.

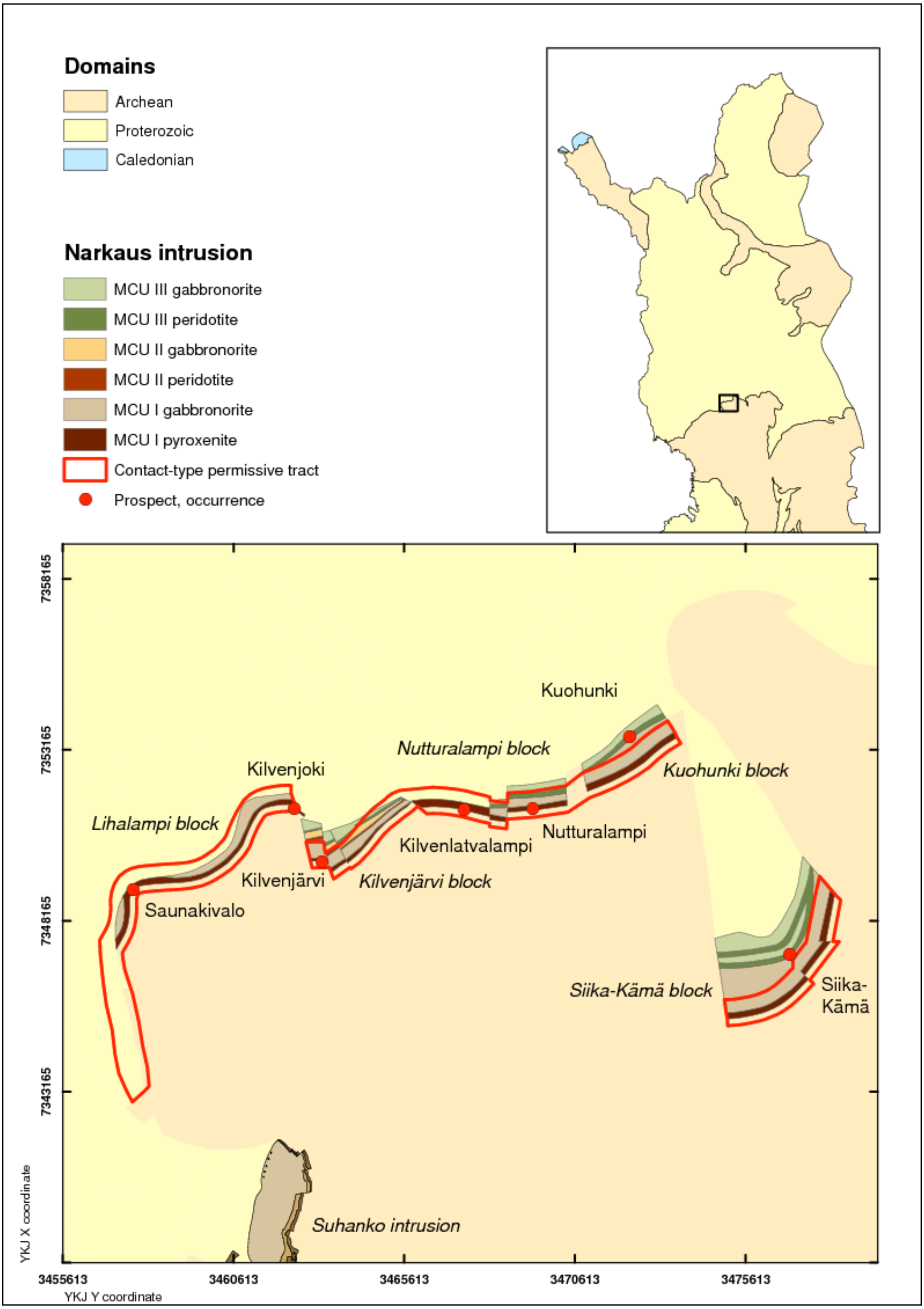

Figure 1. Location of the permissive tract NarkakusContactPGE.

Sources of information

Principal sources of information used by the assessment team for the delineation of NarkausContactPGE are listed in Table 4.

Table 4. Principal sources of information used by the assessment team for NarkausContactPGE.

Theme	Type of source	Scale	Citation
Geology	PhD thesis and publications on Portimo intrusion geology and mineral occurrences		Iljina (1994, 2005, 2007)
	Geological map of the Portimo complex		Iljina (1994)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
Mineral occurrences	PhD thesis and publications on Portimo intrusion geology and mineral occurrences		Iljina (1994, 2005, 2007)
Geochemistry	Extended conference abstract		Iljina & Lahtinen (1991)
Geophysics	GTK databases		GTK databases
Exploration	FINPGE database		Iljina et al. (2009)

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

In total, six offset-type occurences are known from the tract. Geological factors that were used to estimate the number of undiscovered deposits included the geology of the intrusion, the distribution of the known deposits, and the available geophysical and drilling data (Tables 3 and 4). For the nearby Suhanko permissive tract (contact type), where the most extensive data are available, we estimated that the highest possible deposit density is one deposit per 3 km^2 within the permissive tract. The same rule was applied to the Narkaus contact-type PGE tracts.

The mean values for the estimated number of undiscovered deposits at various probability levels and the values given by individual estimators are shown in Table 5. The expected number of deposits, its standard deviation, and the coefficient of variation, also given in Table 5, were calculated by the Eminers software from the undiscovered deposit estimates using a regression equation (Singer & Menzie 2005). Estimators 1 and 2 initially assessed the N10 quantile for undiscovered deposits at about 15. On the other hand, estimator 3 concluded on a significantly lower number of deposits within the permissive tract. After discussions, estimators 1 and 2 lowered their estimates slightly and estimator 3 raised his estimates slightly. Since consensus was not reached, the calculated mean values of undiscovered deposits at 90th, 50th and 10th percentiles (Table 5) were used in the Monte Carlo simulations.

Table 5. Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for NarkausContactPGE.

Mean undiscovered deposit estimate					Summary statistics					Area (km2)	Deposit density (N/km²)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
7	9	11			8.5	1.8	21	0	8.5	22	0.38

Estimator	N90	N50	N10	N05	N01
	Estimated number of undiscovered deposits				
Estimator 1	6	8	10		
Estimator 2	6	8	9		
Estimator 3	10	12	14		
Mean	7	9	11		

Nxx = Estimated number of deposits associated with the xxth percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; Deposit density = deposit density reported as the total number of deposits per km^2. N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were estimated by combining the means of estimated numbers of undiscovered contact-type PGE deposits with the Fennoscandian contact-type PGE grade and tonnage model (Appendix 2) using the EMINERS software (Root et al.1992, Duval 2004). Selected simulation results are reported in Table 6. Results of the Monte Carlo simulation are presented as a cumulative frequency plots (Figure 2). The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralized rock.

Table 6. Results of Monte Carlo simulations of undiscovered resources in NarkausContactPGE.

Material	At least the indicated amount at the probability of					Mean	Probability of mean or greater	Probability of zero
	0.95	0.9	0.5	0.1	0.05			
Pt (t)	31	58	200	430	500	220	0.43	0.01
Pd (t)	110	210	770	1,900	2,300	930	0.41	0.01
Au (t)	13	23	70	160	190	83	0.41	0.01
Ni (t)	220,000	350,000	750,000	1,200,000	1,400,000	770,000	0.48	0.01
Cu (t)	330,000	570,000	1,400,000	2,300,000	2,700,000	1,400,000	0.47	0.01
Rock (Mt)	130	230	740	1,400	1,600	790	0.46	0.01

t = metric tonnes; Mt = millions of tonnes.

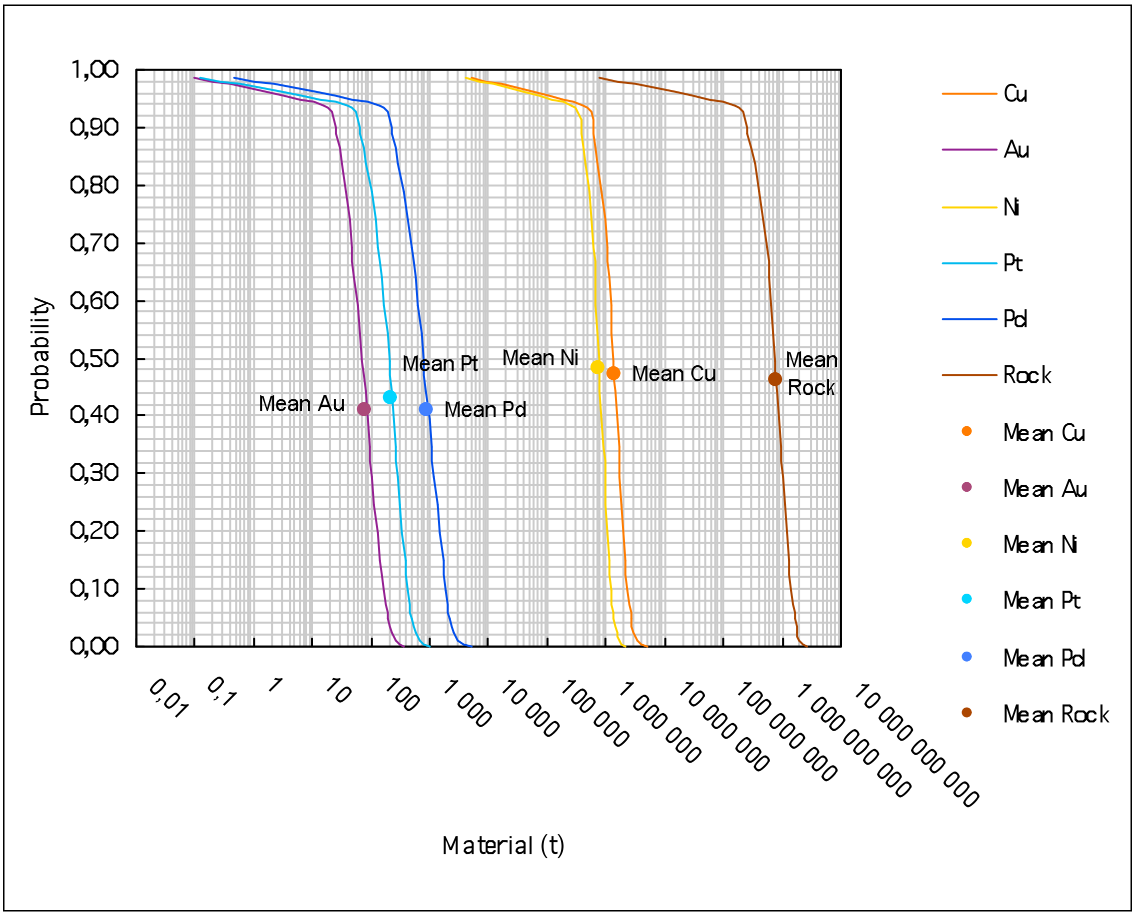

Figure 2. Cumulative frequency plot showing the results of Monte Carlo computer simulation of undiscovered resources in NarkausContactPGE.

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REEF-TYPE PGE ASSESSMENT FOR TRACT NarkausReefPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Reef-type PGE-Ni-Cu
Descriptive model: Finnish reef-type PGE-Ni-Cu (Appendix 3)
Grade-tonnage model: Finnish reef-type PGE-Ni-Cu grade model, NarkausReefPGE tonnage model (Appendix 4)

LOCATION AND RESOURCE SUMMARY

The Narkaus layered intrusion is located in northern Finland in the municipality of Rovaniemi, 40–60 km south from Rovaniemi. The 1:100 000 KKJ map sheets are 3611 and 3613. The UTM map sheets containing the intrusion are T4331, T4332, and T4333. The PGE resource assessment carried out for this report is summarised in Table 1.

Table 1. Summary of selected resource assessment results for NarkausContactPGE.

Date of assessment	Assessment depth (km)	Tract area (km²)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
30.09.2008	1	12	Pt	0	Pt	260	Pt	120
			Pd	0	Pd	460	Pd	240
			Au	0	Au	11	Au	6
			Ni	0	Ni	71,000	Ni	50,000
			Cu	0	Cu	89,000	Cu	51,000

t – metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The Narkaus layered intrusion dips to N to NNW with an angle of about 50 degrees to a depth of about 650 m. The middle and upper units of the intrusion, at and above the contact between earlier Cr-rich and later Cr-poor magma units, are used to define the permissive tract. Hence, the permissive tract follows the extent of this upper part of the intrusion projected from the depth to the surface. Note that the tract only comprises those blocks of the intrusion where these upper parts are shown to exist (Iljina 1994). On the surface, the delineation is based on a geological map by Iljina (1994). At depth, the tract is delineated based on geophysical information (Iljina 1994) and drilling data. The sources of information used in the delineation of the tract are summarized in Table 5.

Known deposits

There are no well-explored reef-type PGE deposits within the Narkaus permissive tract.

Prospects, mineral occurrences, and related deposit types

One explored reef-type PGE occurrence, SK Reef, is known within the Narkaus reef-type permissive tract (Table 2 and Fig 1). Six offset-type (Saunakivalo, Kilvenjoki, Kilvenjärvi, Kilvenlatvalampi, Nutturalampi, and Kuohunki) and one contact-type occurrence (Kilvenjärvi) are known from the Narkaus intrusion (Eerola et al. 1990, Lahtinen 1983, Lahtinen 1987, Outokumpu 1987, Saltikoff et al. 2000). Reef-type mineralisation has also been encountered at Kuohunki and Nutturalampi (Lahtinen 1987).

Table 2. Significant prospects and occurrences in NarkausReefPGE.

Name	X coordinate	Y coordinate	Age (Ma)	Comments (grade and tonnage data, if available)	Reference
SK Reef	7347260	3476100	2.44	43.1 Mt @ 0.11% Cu, 0.08% Ni, 2.7 ppm Pd, 0.72 ppm Pt, 0.08 ppm Au; cut-off grade 0.5 g/t Pd+Pt+Au, open at the depth of 200 m	Gold Fields (2003)

Exploration history

Outokumpu Oy drilled offset sulphide deposits located below the Narkaus Intrusion in 1973–78. High Pd contents from one of the deposits were assayed in 1982. The subsequent drilling resulted in the finding of the Kilvenjärvi offset in 1984. Exploration commenced in the Narkaus area in 1973 when a local layman found a Cu-Pd enriched mica schist boulder. The subsequent exploration conducted by Outokumpu Oy led to the delineation of a number offset deposits by the mid-1980s. Later, at the beginning of 2000, exploration started again through a joint venture between Outokumpu Oy and Gold Fields Ltd. Outokumpu dropped out of the joint venture in 2003 and in 2006, North American Palladium Ltd (NAP) formed a new joint venture with Gold Fields Ltd. Moreover, the NAP dropped out of the JV in August 2008 and the entire Narkaus intrusion and related deposits are held exclusively by Gold Fields Ltd (May 2009). The types of exploration work carried out in the area, and known to us, are listed in Table 3.

Table 3. Exploration history for NarkausContactPGE.

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Detailed bedrock mapping, outcrop sampling		Outokumpu Oy	1973–1985
Geochemical surveys	Till geochemical survey	Yes	Outokumpu Oy	1973–1980
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	
Ground geophysical surveys	Slingram, magnetic, IP, etc. surveys		Outokumpu Oy	1973–1985
	Detailed gravimetric survey		GFAP	2000–2005
Drilling	About 100 diamond-drill holes, total 25,000 m	Yes	Outokumpu Oy	until 1988

GFAP = Gold Fields Arctic Platinum Oy and its precursor Arctic Platinum Partnership Ay.

Sources of information

Principal sources of information used by the assessment team for the delineation of NarkausReefPGE are listed in Table 4.

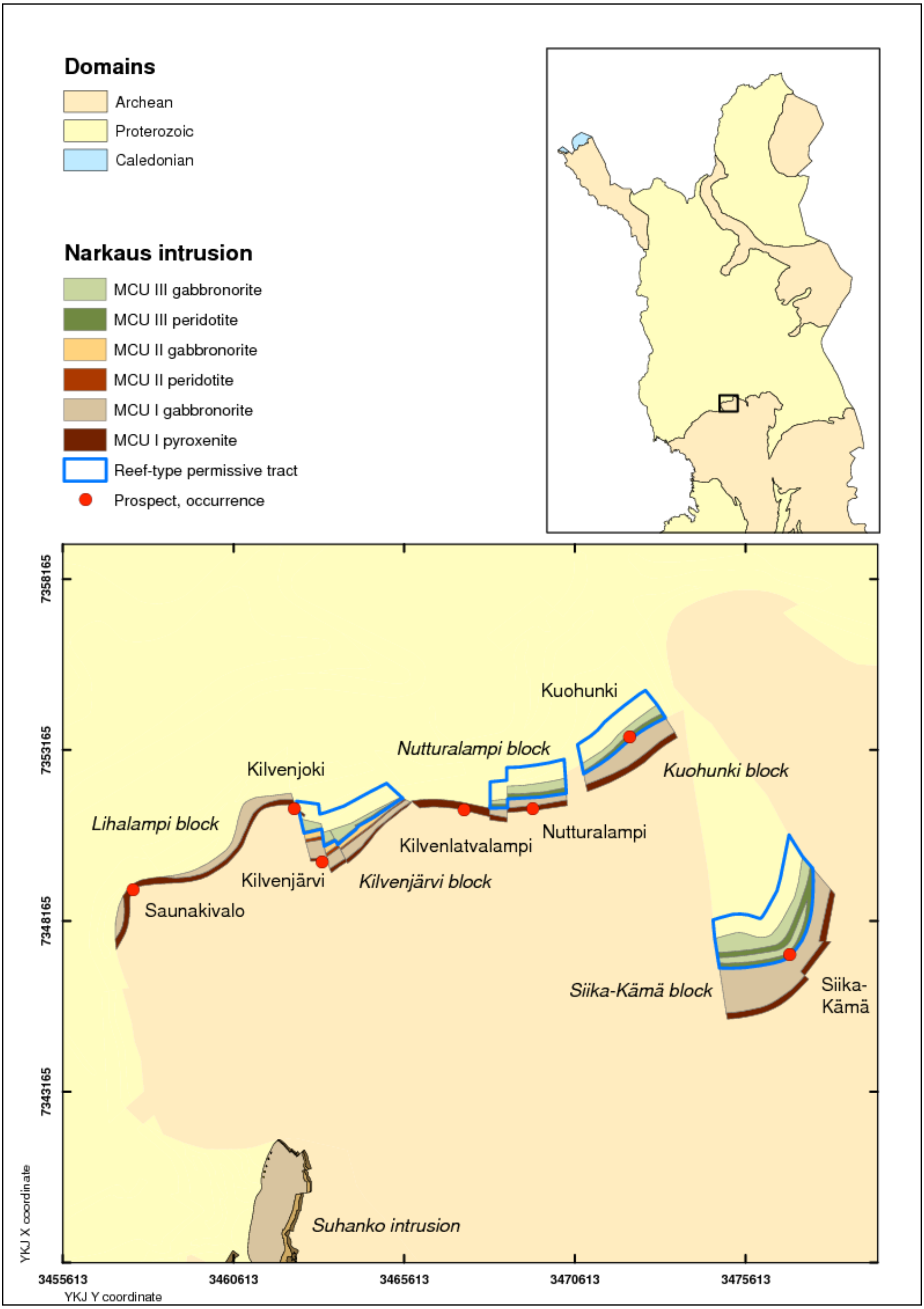

Figure 1. Location of the permissive tract NarkakusReefPGE.

Table 4. Principal sources of information used by the assessment team for NarkausContactPGE.

Theme	Type of source	Scale	Citation
Geology	PhD thesis and publications on Portimo intrusion geology and mineral occurrences		Iljina (1994, 2005, 2007)
	Geological map of the Portimo complex		Iljina (1994)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
Mineral occurrences	PhD thesis and publications on Portimo intrusion geology and mineral occurrences		Iljina (1994, 2005, 2007)
Geochemistry	Extended conference abstract		Iljina & Lahtinen (1991)
Geophysics	GTK databases		GTK databases
Exploration	FINPGE database		Iljina et al. (2009)

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

One reef-type prospect (SK reef) is known within the tract. This means that the minimum number of undiscovered reef-type deposits within the tract can be zero or one. The Kilvenjärvi block has been drilled through, but the other blocks have not. All estimators considered the existence of the Rytikangas reef in the Narkaus intrusion to be possible, but one of the estimators gave this a rather small probability. Since consensus was not reached, the calculated mean values of undiscovered deposits at 90th, 50th and 10th percentiles (Table 5) were used in the Monte Carlo simulations.

Table 5. Undiscovered deposit estimates, deposit numbers, and tract area for NarkausReefPGE.

Mean undiscovered deposit estimate					Summary statistics					Area (km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}	
1	2	2			1.6	0.46	28		1.6	12

Estimator	Estimated number of undiscovered deposits: N90	N50	N10	N05	N01
Estimator 1	1	2	2		
Estimator 2	1	2	2		
Estimator 3	1	1	2		
Mean	1	2	2		

Nxx = Estimated number of deposits associated with the xx^{th} percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were calculated by combining the undiscovered deposit estimates with the Finnish reef-type PGE grade model and the NarkausReefPGE tonnage model (Appendix 4) using the EMINERS software (Root et al. 1992, Duval 2004). Results of the Monte Carlo simulation are presented as cumulative frequency plots (Figure 2) and selected simulation results are reported in Table 6. The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralized rock.

Table 6. Results of Monte Carlo simulations of undiscovered resources in NarkauksReefPGE.

Material	At least the indicated amount at the probability of					Mean	Probability of mean or greater	Probability of zero
	0.95	0.9	0.5	0.1	0.05			
Pt (t)	0	15	120	590	950	260	0.27	0.06
Pd (t)	0	33	240	1,000	1,600	460	0.27	0.06
Au (t)	0	1	6	25	38	11	0.32	0.06
Ni (t)	0	9,500	50,000	160,000	210,000	71,000	0.35	0.06
Cu (t)	0	3,800	51,000	220,000	330,000	89,000	0.33	0.06
Rock (Mt)	0	14	70	200	250	90	0.38	0.06

t = metric tonnes; Mt = millions of tonnes.

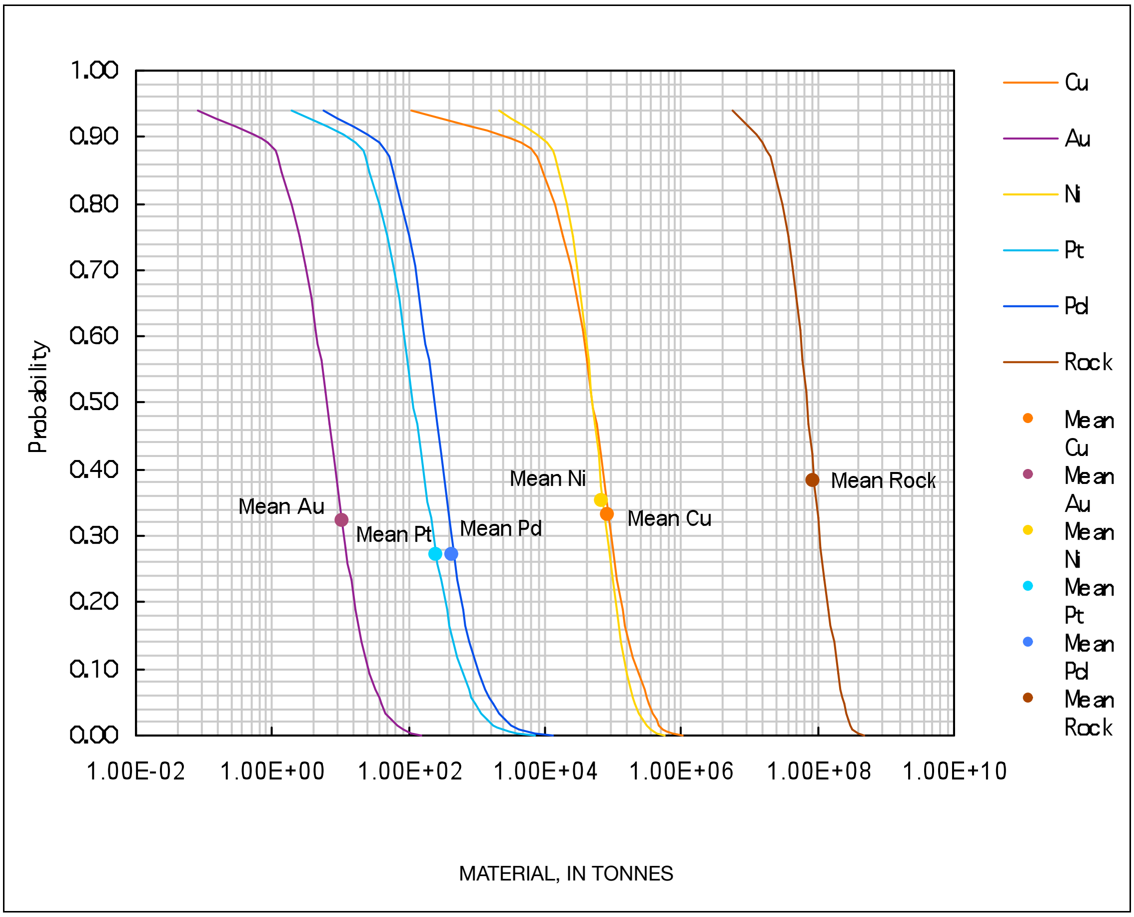

Figure 2. Cumulative frequency plot showing the results of Monte Carlo computer simulation of undiscovered resources in NarkausReefPGE.

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REEF-TYPE PGE ASSESSMENT FOR TRACT PenikatReefPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Reef-type PGE-Ni-Cu
Descriptive model: Finnish reef-type PGE-Ni-Cu (Appendix 3)
Grade-tonnage model: Finnish reef-type PGE-Ni-Cu grade model, PenikatPGE tonnage model (Appendix 4)

LOCATION AND RESOURCE SUMMARY

The Penikat layered intrusion is located in northern Finland in the municipalities of Simo, Keminmaa and Tervola, about 80 km SW from Rovaniemi and 25 km NE from Kemi. The 1:100 000 KKJ map sheets are 2543 and 2544. The UTM map sheets containing the intrusion are S4411, S4412 and S4421. The PGE resource assessment carried out for this report is summarised in Table 1.

Table 1. Summary of selected resource assessment results for PenikatReefPGE. Only well-delineated deposits are included

Date of assessment	Assessment depth (km)	Tract area (km²)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
01.09.2008	1	58	Pt	0	Pt	1,100	Pt	660
			Pd	0	Pd	2,000	Pd	1,300
			Au	0	Au	46	Au	34
			Ni	0	Ni	290,000	Ni	250,000
			Cu	0	Cu	370,000	Cu	290,000

t = metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The Penikat layered intrusion (Figure 1) dips to the NW with an angle of 40–70° to a depth of well beyond 1 km (Halkoaho 1993, Alapieti & Lahtinen 2002, Halkoaho et al. 2005). The extension of the intrusion to a great depth is indicated by a gravity survey performed by the University of Oulu (unpublished data). The middle and upper parts of the intrusion, at and above the contact between earlier boninitic-like (Cr-rich) and later tholeiitic magma units, are used to define the permissive tract. Hence, the permissive tract (Figure 2) follows the extent of this upper part of the intrusion projected to the surface from the depth of 1 km. The SE margin of the tract is defined by information from diamond-drill holes, and the NW margin by the projection of the hanging-wall contact of the intrusion at 1 km depth. The SW and NE contacts of the intrusion are defined by subvertical faults which also define the respective tract boundaries. The sources of information used in the delineation of the tract are summarised in Table 4.

Known deposits

No well-explored reef-type PGE deposits, with public information grades and tonnages, occur within the intrusion.

Prospects, mineral occurrences, and related deposit types

Three explored PGE reefs are known within the Penikat permissive tract: Sompujärvi (SJ) Reef at the contact between megacyclic units III and IV, Ala-Penikka (AP) Reef at the lower part of megacyclic unit IV, and Paasivaara (PV) Reef at the contact between megacyclic units IV and V (Table 2 and Figure 1). The SJ and AP reefs have been identified for almost the entire length of the intrusion from outcrop and drill core observations (Halkoaho 1993, Alapieti & Lahtinen 2002, Halkoaho et al. 2005). The PV Reef is present in other parts of the intrusion, except the Keski-Penikka Block and the northernmost end of the Sompujärvi Block (Figure 1).

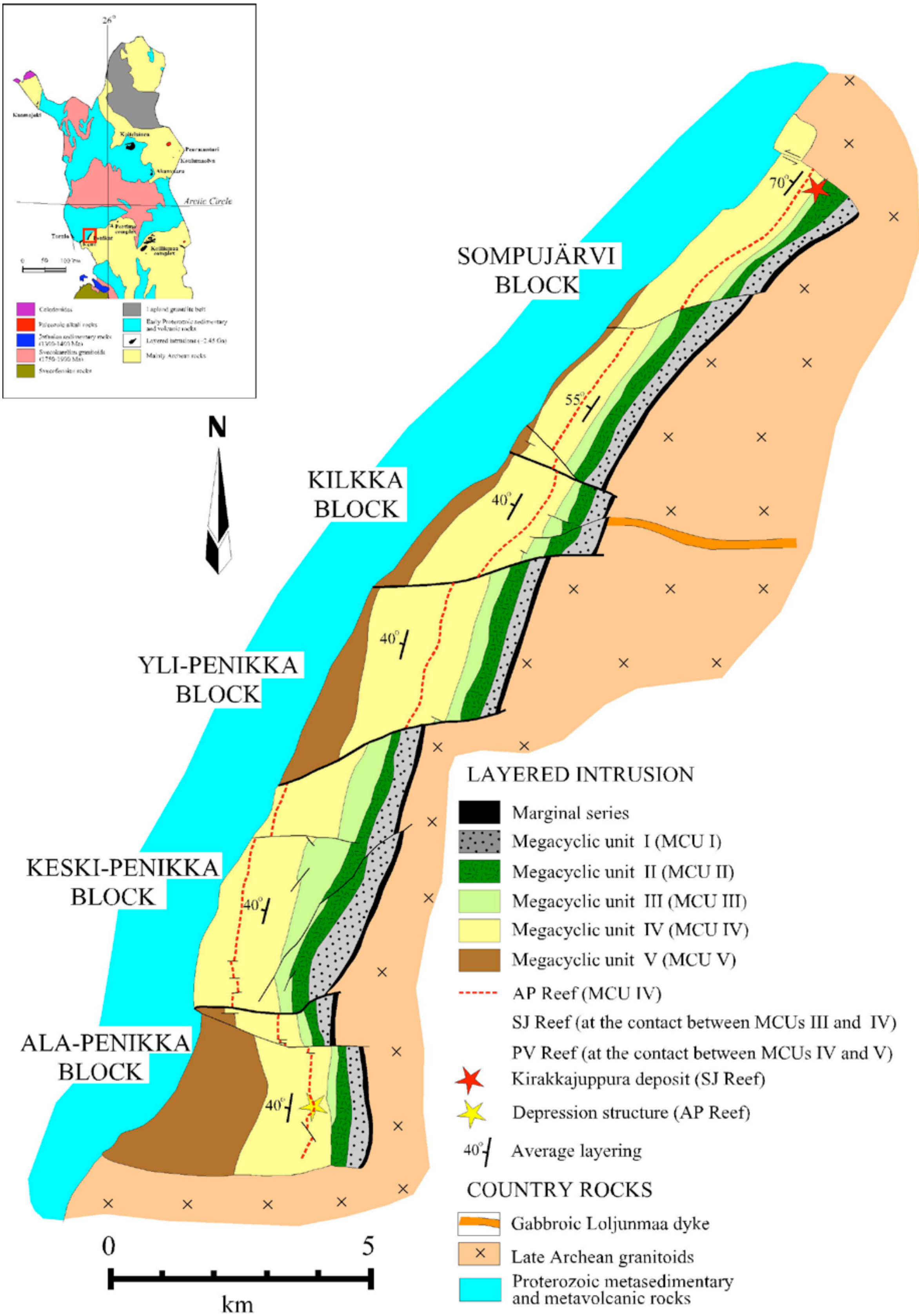

Figure 1. Generalised geological map of the Penikat Layered Intrusion showing the locations of the megacyclic units and PGE reefs. Note that the SJ Reef is located at the contact between megacyclic units III (light green) and IV (yellow), and the PV Reef at the contact between megacyclic units IV (yellow) and V (brown). Modified after Alapieti and Lahtinen (1986, 1989, 2002), Alapieti et al. (1990), Halkoaho (1993), and Halkoaho et al. (2005).

Table 2. Significant reef prospects and occurrences in the Penikat intrusion.

Name	X coordinate	Y coordinate	Age (Ga)	Comments (grade and tonnage data, if available)	Reference
SJ Reef	7318000	3416000	2.4	Coordinates from the best mineralized area. Average thickness roughly 1 m, grade 1-10 ppm (3 PGE+Au).	Alapieti & Lahtinen (2002), Halkoaho et al. (2005)
AP Reef	7304000	3409000	2.4	Coordinates from the best mineralized area. The normal AP Reef is roughly 0.2–0.4 m thick at about 5 ppm (3PGE+Au). In the pothole AP Reef, the best section is about 20 m at 0.3-12 ppm (3PGE+Au).	Alapieti & Lahtinen (2002), Halkoaho et al. (2005)
PV Reef	7304000	3407500	2.4	Coordinates taken from the best mineralized area. Average thickness about 1 m, grade <10 ppm (3 PGE+Au).	Alapieti & Lahtinen (2002), Halkoaho et al. (2005)

PGE grades from http://en.gtk.fi/ExplorationFinland/Commodities/PGE/nfin/penikat/penikat.html.

Exploration history

Exploration for chromium and nickel carried out by Outokumpu Oy in the area of the Penikat Layered Intrusion in the early 1960s eventually led to the discovery of low-grade sulphide occurrences in the hills of Ala-Penikkavaara and Paasivaara. In summer 1981, the geologists J. Lahtinen and P. Hautala and the geotechnician L. Nousiainen from the exploration team of Outokumpu Oy took new samples from outcrops of these occurrences to look for evidence of PGE mineralisation. All the samples contained detectable amounts of PGE, the best one from Ala-Penikkavaara as much as 4.5 ppm Pt, 14.6 ppm Pd and 1.0 ppm Au, and another from Paasivaara 3.7 ppm Pt and 2.9 ppm Pd. These samples led to the discovery of the Ala-Penikka and Paasivaara PGE reefs, respectively. Early in 1982, T. Alapieti from the University of Oulu and J. Lahtinen from Outokumpu Oy logged the holes drilled in the Penikat area by Outokumpu Oy in the 1960s and discovered the sulphur-poor Sompujärvi PGE reef. The Sompujärvi Reef was one of the principal targets for the Outokumpu Oy PGE exploration project in the 1980s. An extensive drilling programme carried out by Outokumpu covered the whole SJ Reef area, from the southern end of the Penikat Intrusion to its northern margin. In addition to extensive drilling, open-pit test mining was carried out during 1987–1988 in the Kirakkajuppura area at the northern end of the Penikat Intrusion. Department of Geology, University of Oulu carried out a PGE deposit research programme in the area in 1987–1989. Later, at the beginning of 2000, exploration started again through a joint venture between Outokumpu Oy and Gold Fields Ltd. Outokumpu left the joint venture in 2003 and in 2006, North American Palladium Ltd formed a new joint venture with Gold Fields Ltd. The exploration in the area still continues at the time of writing of this report. The exploration history for the Penikat intrusion is summarised in Table 3.

Table 3. Exploration history for the Penikat intrusion.

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Bedrock mapping	No	GTK	1960s–1970s
	Detailed bedrock mapping, outcrop sampling	Yes	Outokumpu / Lapin Malmi	
Geochemical surveys	Several till geochemical survey profiles	Yes	Outokumpu / Lapin Malmi	1980s
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	1990 and 1995
Ground geophysical surveys	Electromagnetic and magnetic surveys covering the whole intrusion.		Outokumpu / Lapin Malmi	1980s
Drilling	About 20 diamond drill holes, total about 3 km	No	Outokumpu	1960s
	About 10 diamond drill holes mainly bedrock related drilling	No	GTK	1975, 1982, 1999
	About 500 diamond drill holes, total about 50 km	Yes	Lapin Malmi	1980s
	Unknown number of drill holes	Yes	GFAP	2000–2001
Other	Ore mineralogical investigations on about 1550 polished thin sections. About 2000 whole-rock chemical analyses	Yes	University of Oulu & Lapin Malmi	1980s–1990s

GFAP = Gold Fields Arctic Platinum Oy and its precursor Arctic Platinum Partnership Ay.

Sources of information

Principal sources of information used by the assessment team for the delineation of PenikatReefPGE are listed in Table 4.

Table 4. Principal sources of information used by the assessment team for PenikatReefPGE.

Theme	Type of source	Scale	Citation
Geology	Regional bedrock mapping	1:100 000	Perttunen (1971, 1975, 1991)
	Detailed geological, mineralogical descriptions of the intrusion		Halkoaho (1993), Alapieti & Lahtinen (2002), Halkoaho et al. (2005)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
Mineral occurrences	Detailed geological, mineralogical descriptions of reef-type mineralisation		Halkoaho (1993), Alapieti & Lahtinen (2002), Halkoaho et al. (2005)
Geochemistry	Detailed geochemical descriptions of the intrusion and reef-type mineralisation		Halkoaho (1993), Alapieti & Lahtinen (2002), Halkoaho et al. (2005)
Geophysics	NA		
Exploration	General and detailed descriptions of exploration activities and results in the area		Halkoaho (1993), Alapieti & Lahtinen (2002)

NA= not available.

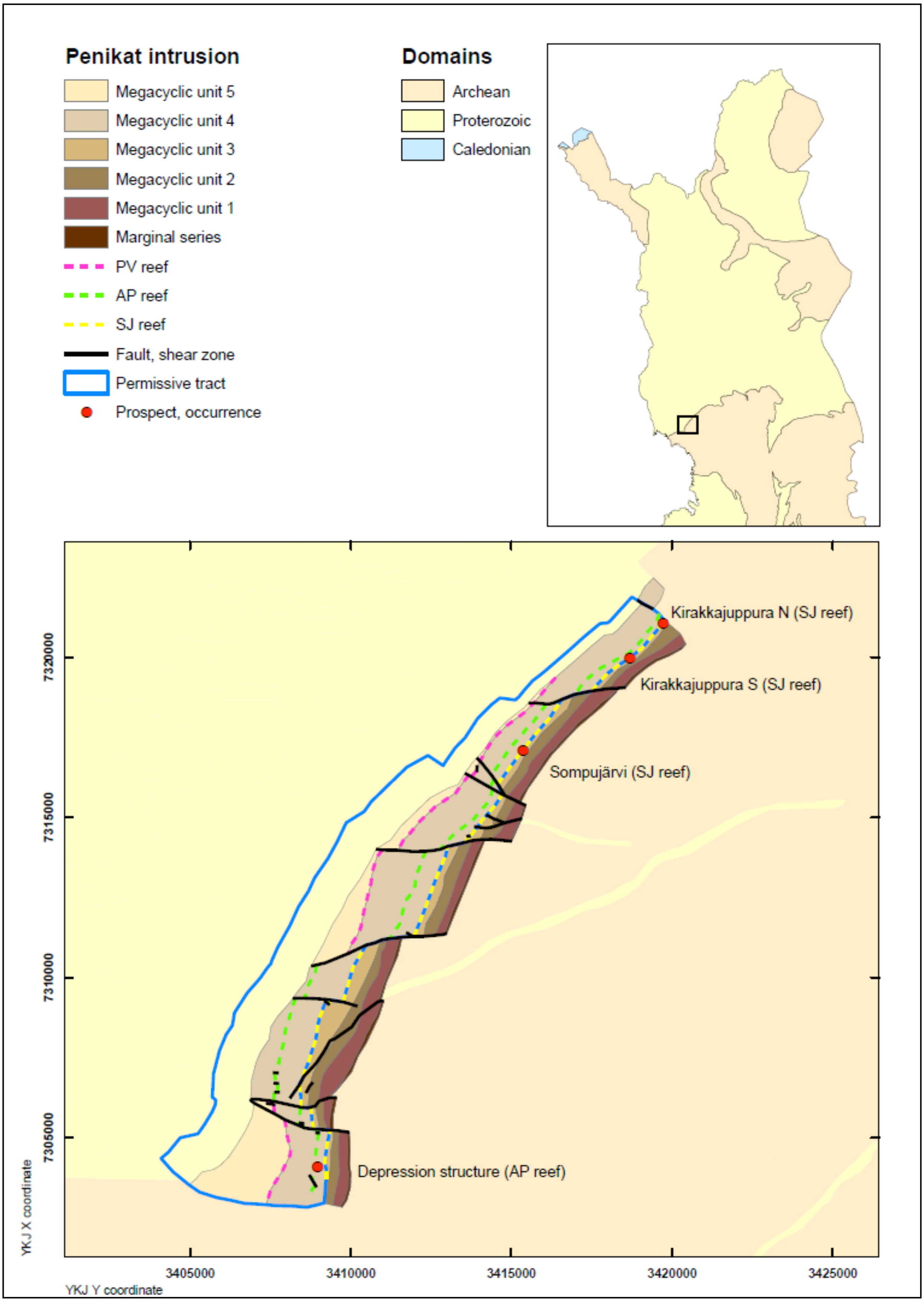

Figure 1. Location of the permissive tract PenikatReefPGE and significant prospects and occurrences (Table 2).

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

Three reef-type prospects (SJ, AP and PV Reef) are known within the tract, but no good quality resource estimates are available. This means that the minimum number of undiscovered reef-type deposits within the tract can be between zero and three. The intrusion is relatively well explored. Diamond-drilling profiles cover full sections across each block of the intrusion. There is a very minor possibility for additional reefs. Nevertheless, two of the estimators assigned a small probability for the existence of an additional, unknown reef at depth (Table 5). The third estimator disagreed with this and maintained that the probability for additional reefs is insignificant. The AP reef is very modest, but all estimators agreed on the possibility for more AP reef potholes, which could make also that reef economically viable.

Table 5. Undiscovered deposit estimates, deposit numbers, and tract area for PenikatReefPGE.

Mean undiscovered deposit estimate					Summary statistics					Area (km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}	
3	3	4			3.1	0.65	21	0	3.1	58

Estimator	Estimated number of undiscovered deposits N90	N50	N10	N05	N01
Estimator 1	3	3	4		
Estimator 2	3	3	4		
Estimator 3	3	3	3		
Mean	3	3	4		

Nxx = Estimated number of deposits associated with the xxth percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were calculated by combining the undiscovered deposit estimates with the Finnish reef-type PGE grade model and the PenikatReefPGE tonnage model (Appendix 4) using the EMINERS software (Root et al. 1992, Duval 2004). Selected simulation results are reported in Table 6. Results of the Monte Carlo simulation are presented as a cumulative frequency plots (Figure 3). The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralised rock.

Table 6. Results of Monte Carlo simulations of undiscovered resources in PenikatReefPGE.

Material	At least the indicated amount at the probability of					Mean	Probability of mean or greater	Probability of zero
	0.95	0.9	0.5	0.1	0.05			
Pt (t)	82	170	660	2,300	3,600	1,100	0.30	0.03
Pd (t)	190	360	1,300	4,100	6,100	2,000	0.30	0.03
Au (t)	4	9	34	96	130	46	0.36	0.03
Ni (t)	50,000	91,000	250,000	550,000	670,000	290,000	0.40	0.03
Cu (t)	27,000	65,000	290,000	800,000	1,000,000	370,000	0.38	0.03
Rock (Mt)	74	130	340	680	770	370	0.43	0.03

t = metric tonnes; Mt = millions of tonnes.

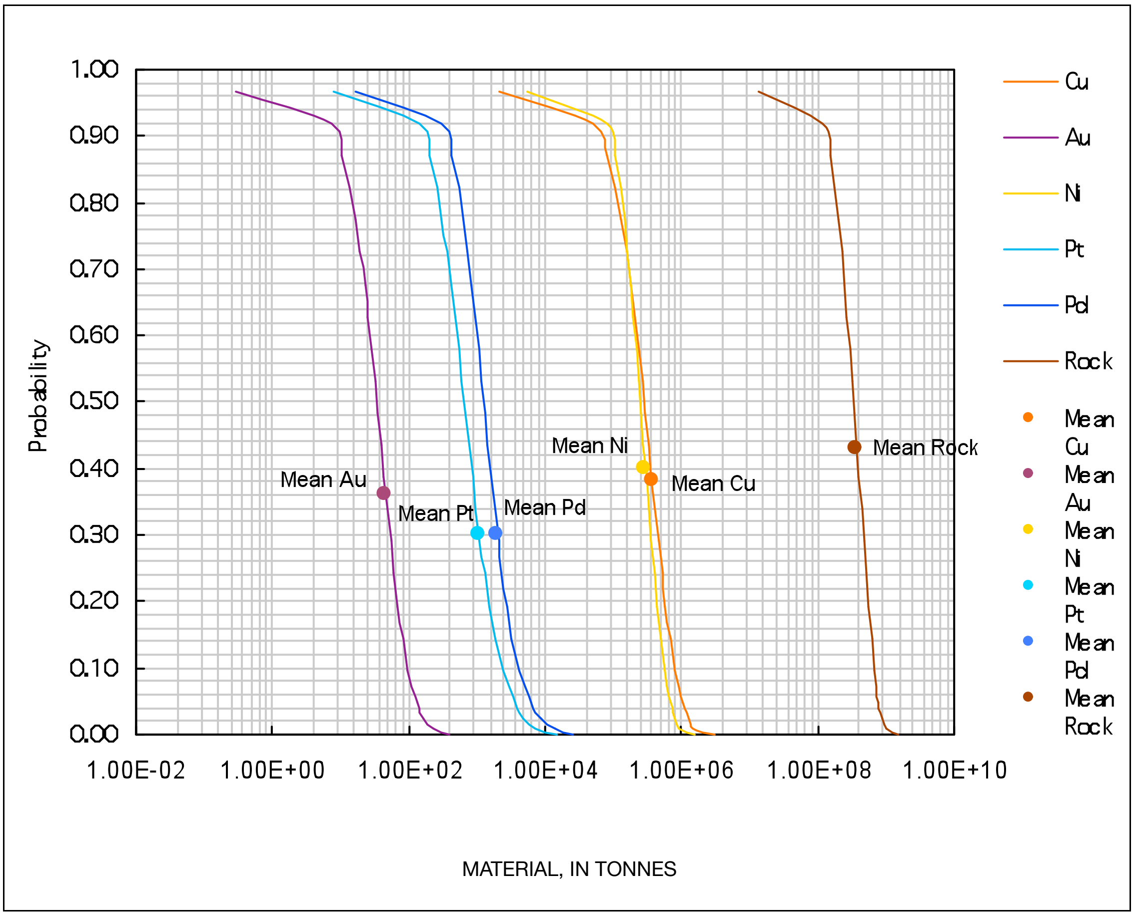

Figure 2. Cumulative frequency plot showing the results of Monte Carlo computer simulation of undiscovered resources in PenikatReefPGE.

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CONTACT-TYPE PGE ASSESSMENT FOR TRACT PintamoContactPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Contact-type Cu-Ni-PGE
Descriptive model: Fennoscandian contact-type Cu-Ni-PGE deposits (Appendix 1)
Grade and tonnage model: Fennoscandian contact-type Cu-Ni-PGE deposits (Appendix 2)

LOCATION AND RESOURCE SUMMARY

The Pintamo block of the Koillismaa Complex Western Intrusion is located in northern Finland in the municipality of Pudasjärvi, 150 km south from the town of Rovaniemi. The 1:100 000 KKJ map sheet is 3532. The UTM map sheets containing the block are S5113 and S5114. The PGE resource assessment carried out for this report is summarised in Table 1.

Table 1. Summary of selected resource assessment results for PintamoContactPGE.

Date of assessment	Assessment depth (km)	Tract area (km^2)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
02.10.2008	1	13	Pt	0	Pt	50	Pt	22
			Pd	0	Pd	210	Pd	83
			Au	0	Au	19	Au	9
			Ni	0	Ni	170,000	Ni	130,000
			Cu	0	Cu	320,000	Cu	210,000

t = metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The permissive tract delineated in Figure 1 is a surface projection of the basal contact zone of the Pintamo block of the ca. 2.45 Ga Koillismaa intrusion. Since the block has only recently been discovered, we assume the dip of layering, NW 30º, from the known dip of the Pirivaara block. We assume that the blocks of Pintamo and Pirivaara are distant exposed parts of the same original intrusion block, which presently are no longer in contact with each other. The permissive tract is delineated on the basis of an aeromagnetic anomaly (GTK low-altitude survey data), by which the lower contact of the block can be traced and which is assumed to continue down-dip to 1 km. The sources of information used in the delineation of the tract are summarised in Table 3.

Known deposits

No contact-type PGE deposits are known within the tract.

Prospects, mineral occurrences, and related deposit types

No contact-type PGE prospects are known from the tract.

Exploration history

The Pintamo block is the latest-discovered part of the Western Intrusion of the Koillismaa Layered Igneous Complex. Therefore, no detailed exploration has ever been performed in the area. The area has been included in a few regional-scale research, exploration and mapping projects. Types of exploration work carried out in the area, and known to us, are listed in Table 2.

Table 2. Exploration history for PintamoContactPGE

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Bedrock mapping	No	GTK	1996–2005
Geochemical surveys	Regional survey only	No	GTK	
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	1998
Ground geophysical surveys	No ground geophysical surveys in the area			
Drilling	No drilling within the intrusive block			
Other	Regional research and mapping programme in the KLIC region (Pintamo block not studied)	No	Univ Oulu	1971–1976
	Regional research and mapping programme in the KLIC region (Pintamo block not studied)	Yes	GTK	1996–2000

KLIC = Koillismaa Layered Igneous Complex.

Sources of information

Principal sources of information used by the assessment team for the delineation of PintamoContactPGE are listed in Tables 2 and 3.

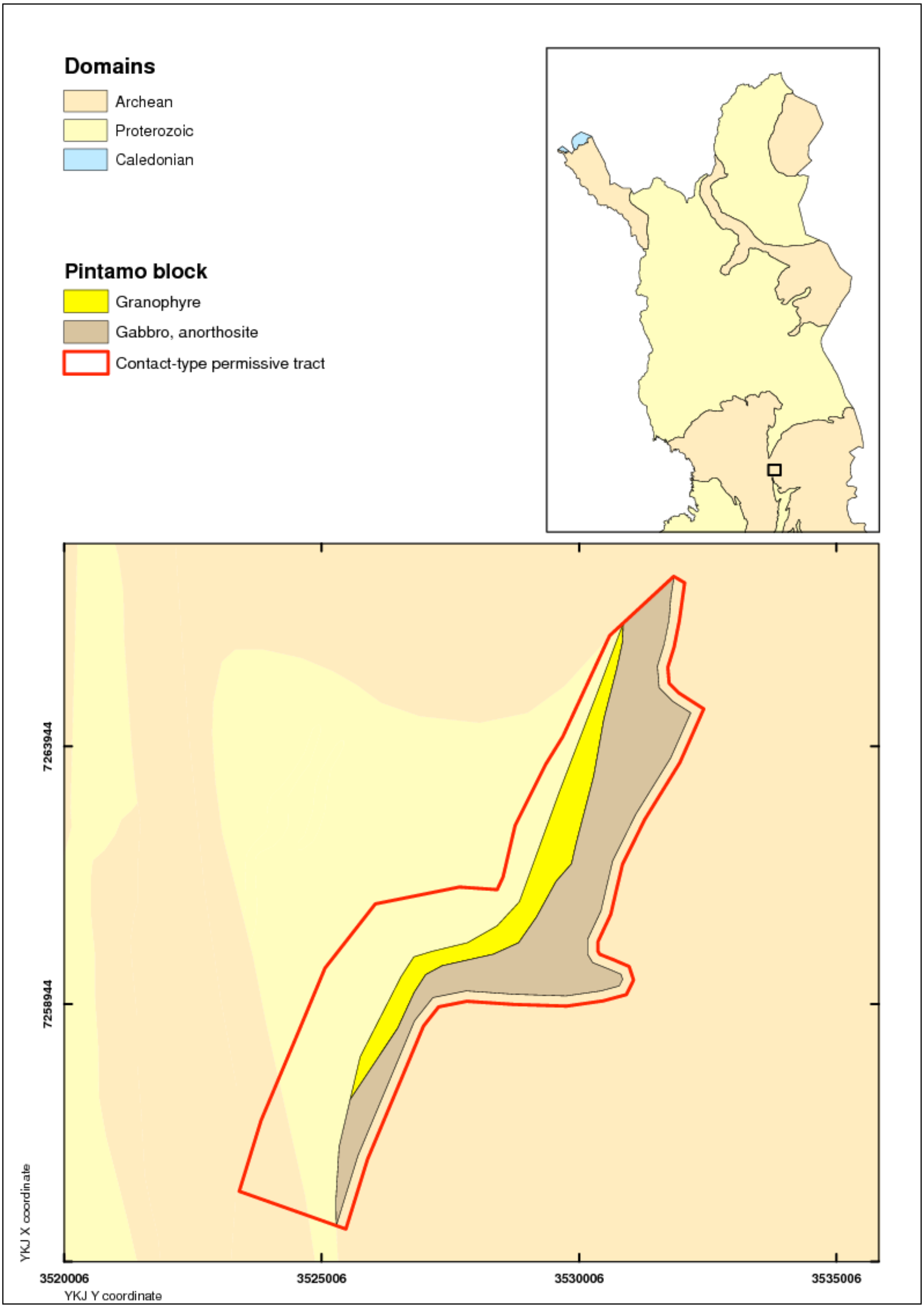

Figure 1. Location of the permissive tract PintamoContactPGE.

Table 3. Principal sources of information used by the assessment team for PintamoContactPGE.

Theme	Type of source	Scale	Citation
Geology	Geological description of the KLIC geology and then known mineral occurrences	1:150 000	Piirainen et al. (1978), Alapieti (1982), Iljina & Hanski (2005)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
	PhD on geology and reef-type mineralisation in the Western Koillismaa Intrusion		Karinen (2010)
Mineral occurrences	Not available		
Geochemistry	Not available		
Geophysics	Regional low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK databases
Exploration	Description of regional exploration activities in the area by Rautaruukki and Outokumpu companies.		Lahtinen (1983)
	Description of exploration activities in the region by GTK, general description on work by NAN		Iljina (2004)

KLIC = Koillismaa Layered Igneous Complex.
NAN = North Atlantic Natural Resources.

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

Geological factors that were used to estimate the number of undiscovered deposits included the geology of the intrusion, the distribution of the known deposits, mineralisation in the other parts of the Koillismaa Intrusion, and the available geophysical data (Table 3).

Not a single contact-type prospect is known within the tract. This means that the minimum number of undiscovered contact-type deposits within the tract is zero. As no detailed exploration has been carried out at Pintamo, most of the reasoning for the PGE potential was derived from analogies to other parts of the Koillismaa Intrusion. Pintamo was seen as similar to the Pirivaara Block, but being five times larger than the latter the potential for contact-type deposits was seen as much better. One estimator also commented that if Pintamo is as mineralised as other parts of Koillismaa, there should be at least one deposit. The deposit number estimation results are listed in Table 4.

Table 4. Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for PintamoContactPGE.

Mean of undiscovered deposit estimate					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
1	2	3			1.9	0.84	43	0	1.9	13	0.06

	Estimated number of undiscovered deposits				
Estimator	N90	N50	N10	N05	N01
Estimator 1	1	2	3		
Estimator 2	1	2	3		
Estimator 3	0	1	2		
Mean	1	2	3		

Nxx = Estimated number of deposits associated with the xxth percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; Deposit density = deposit density reported as the total number of deposits per km^2. N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were estimated by combining the means of estimated numbers of undiscovered contact-type PGE deposits with the Fennoscandian contact-type PGE grade and tonnage model (Appendix 2) using the EMINERS software (Root et al. 1992, Duval 2004). Selected simulation results are reported in Table 5. Results of the Monte Carlo simulation are presented as a cumulative frequency plots (Figure 2). The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralised rock.

Table 5. Results of Monte Carlo simulations of undiscovered resources in PintamoContactPGE.

Material	At least the indicated amount at the probability of					Mean	Probability of mean or greater	Probability of zero
	0.95	0.90	0.50	0.10	0.05			
Pt (t)	0	1	22	140	190	50	0.33	0.07
Pd (t)	0	2	83	620	960	210	0.29	0.07
Au (t)	0	0	9	53	77	19	0.29	0.07
Ni (t)	0	8 400	130 000	380 000	460 000	170 000	0.41	0.07
Cu (t)	0	11 000	210 000	770 000	960 000	320 000	0.39	0.07
Rock (Mt)	0	2	79	490	560	180	0.35	0.07

t = metric tonnes; Mt = millions of tonnes.

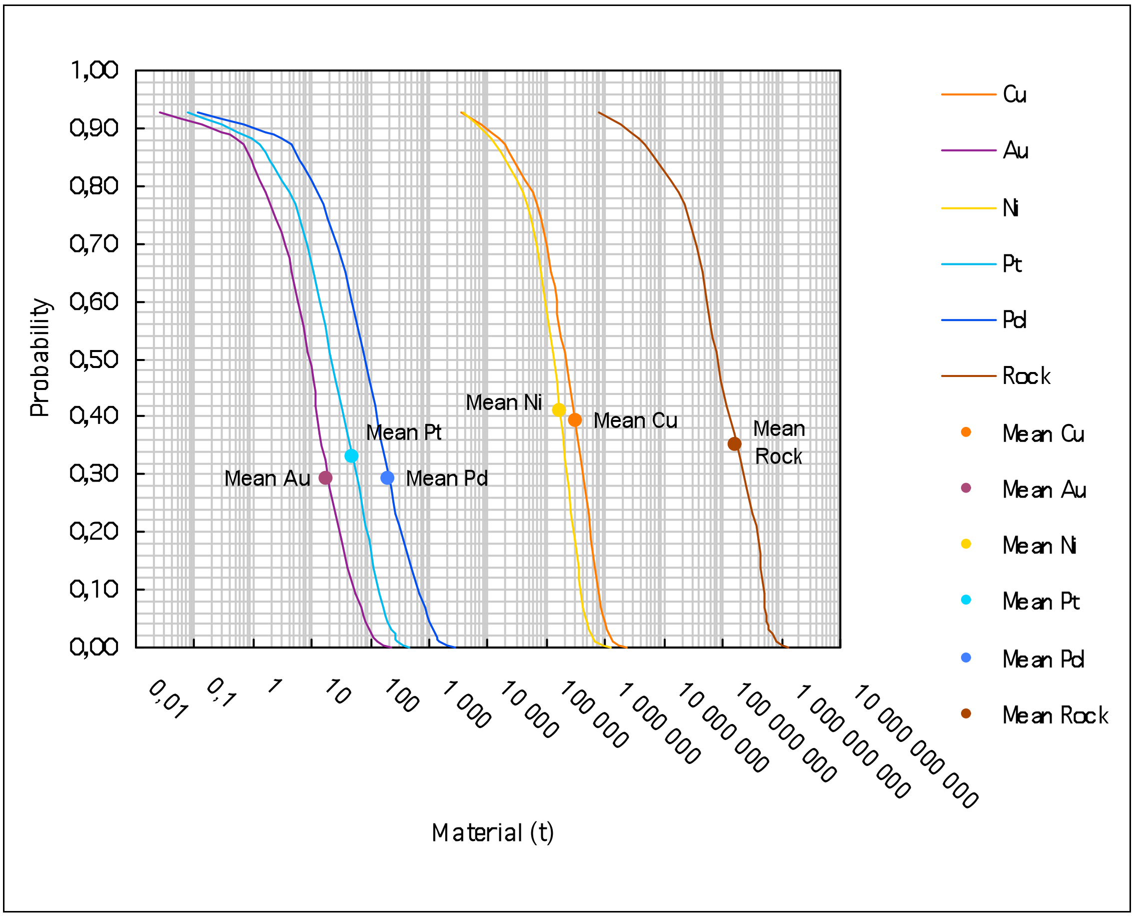

Figure 2. Cumulative frequency plot showing the results of Monte Carlo computer simulation of undiscovered resources in PintamoContactPGE.

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REEF-TYPE PGE ASSESSMENT FOR TRACT PintamoReefPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Reef-type PGE-Ni-Cu
Descriptive model: Finnish reef-type PGE-Ni-Cu (Appendix 3)
Grade-tonnage model: Finnish reef-type PGE-Ni-Cu grade model, PintamoReefPGE tonnage model (Appendix 4)

LOCATION AND RESOURCE SUMMARY

The Pintamo block of the Koillismaa Layered Intrusion Complex (KLIC) is in northern Finland, in the municipality of Pudasjärvi, 150 km south from the town of Rovaniemi. The 1:100 000 KKJ map sheet is 3532. The UTM map sheets containing the block are S5113 and S5114. The PGE resource assessment carried out for this report is summarised in Table 1.

Table 1. Summary of selected resource assessment results for PintamoReefPGE

Date of assessment	Assessment depth (km)	Tract area (km²)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
24.09.-01.10.2008	1	31	Pt	0	Pt	370	Pt	120
			Pd	0	Pd	680	Pd	250
			Au	0	Au	16	Au	7
			Ni	0	Ni	97,000	Ni	59,000
			Cu	0	Cu	120,000	Cu	50,000

t = metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The NE-trending Pintamo intrusive block has recently been discovered. The estimated 30º dip to the NW of the layering in the Pirivaara block is also assumed as the dip at Pintamo. This assumption was made as the Pirivaara block was assumed to be the NE continuation of the Pintamo block, although presently, these blocks are no longer in contact with each other. Also analogous with the Pirivaara block, we assume that the northern margin of the Pintamo block is a subvertical fault. Hence, the permissive tract for reef-type deposits of the Pintamo block roughly mtches the block's surface projection (Figure 1). The permissive tract is delineated on the basis of aeromagnetic anomaly (GTK low-altitude survey data). The sources of information used in the delineation of the tract are summarized in Table 3.

Known deposits

No reef-type PGE deposits are known from Pintamo.

Prospects, mineral occurrences, and related deposit types

No obvious reef-type PGE prospects are known from the tract.

Exploration history

The Pintamo block is the latest discovered of the blocks in the Koillismaa Intrusive Complex. Therefore, no detailed exploration has been performed in the area. The area has been included into a few regional-scale research, exploration and mapping projects. The types of exploration work related to the block are listed in Table 2.

Table 2. Exploration history for PintamoReefPGE.

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Bedrock mapping	No	GTK	1996–2005
Geochemical surveys	Regional survey only	No	GTK	
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	1998
Ground geophysical surveys	No ground geophysical surveys in the area			
Drilling	No drilling within the intrusive block			
Other	Regional research and mapping programme in the KLIC region (Pintamo block not studied)	No	Univ Oulu	1971–1976
	Regional research and mapping programme in the KLIC region (Pintamo block not studied)	Yes	GTK	1996–2000

KLIC = Koillismaa Layered Igneous Complex.

Sources of information

Principal sources of information used by the assessment team for the delineation of PintamoReefPGE are listed in Table 3.

Table 3. Principal sources of information used by the assessment team for PintamoReefPGE.

Theme	Type of source	Scale	Citation
Geology	Geological description of the KLIC geology and then known mineral occurrences	1:150 000	Piirainen et al. (1974, 1978), Juopperi (1977), Alapieti (1982)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
	PhD on geology and reef-type mineralisation in the Western Koillismaa Intrusion		Karinen (2010)
Mineral occurrences	Not available		
Geochemistry	Not available		
Geophysics	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK databases
Exploration	Description of exploration activities in the area by Rautaruukki and Outokumpu		Lahtinen (1983)
	Detailed description of exploration activities in the area by GTK, general description on work by NAN		Iljina (2004)

KLIC = Koillismaa Layered Igneous Complex.
NAN = North Atlantic Natural Recourses.

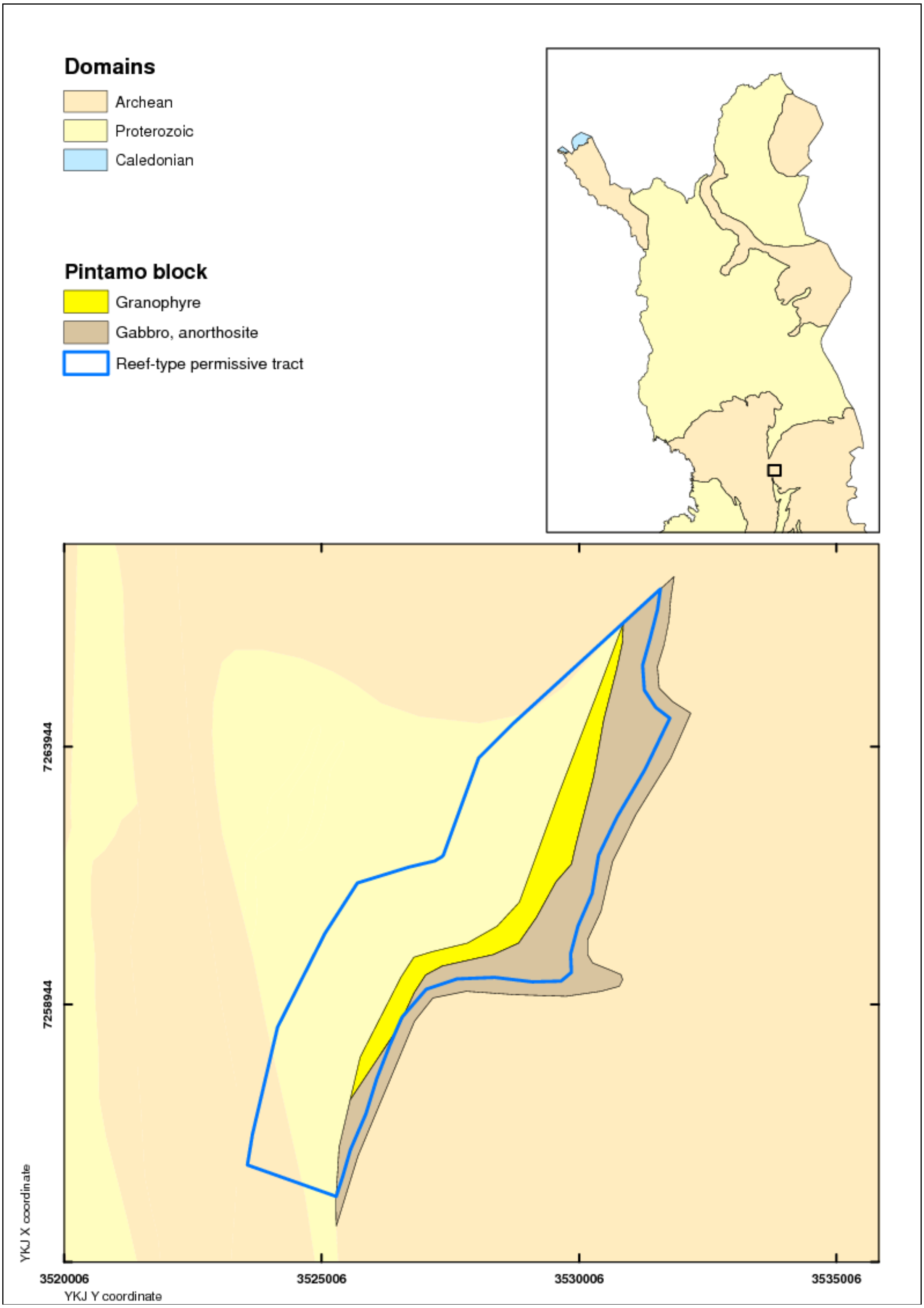

Figure 1. Location of the permissive tract PintamoReefPGE.

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

Not a single reef-type prospect is known within the tract. This means that the minimum number of undiscovered reef-type deposits within the tract is zero. The tract is relatively large. It is the most distal of all tracts of the Koillismaa Complex to the Feeder Dyke, in a location largely similar to the Kaukua tract. Hence, Pintamo may have a good potential for reef-type PGE mineralisation. The stratigraphic thickness of the intrusive block is relatively small, resulting in space for probably no more than one reef. Nevertheless, one of the estimators assumed a possibility of two undiscovered reefs at the N50 level of probability. As no consensus was reached in discussion, mean values for undiscovered deposit numbers had to be calculated and used in the Monte Carlo simulations (Table 4).

Table 4. Undiscovered deposit estimates, deposit numbers, and tract area for PintamoReefPGE.

Mean undiscovered deposit estimate					Summary statistics					Area (km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}	
1	1	1			0.93	0.17	18	0	0.93	31

Estimator	N90	N50	N10	N05	N01
	Estimated number of undiscovered deposits				
Estimator 1	1	1	1		
Estimator 2	1	2	2		
Estimator 3	1	1	1		
Mean	1	1	1		

Nxx = Estimated number of deposits associated with the xxth percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were calculated by combining the undiscovered deposit estimates with the Finnish reef-type PGE grade model and the PintamoReefPGE tonnage model (Appendix 4) using the EMINERS software (Root et al. 1992, Duval 2004). Selected simulation results are reported in Table 5. Results of the Monte Carlo simulation are presented as a cumulative frequency plots (Figure 2). The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralised rock.

Table 5. Results of Monte Carlo simulations of undiscovered resources in PintamoReefPGE.

Material	At least the indicated amount at the probability of					Mean	Probability of mean or greater	Probability of zero
	0.95	0.9	0.5	0.1	0.05			
Pt (t)	0	14	120	850	1,500	370	0.22	0.07
Pd (t)	0	32	250	1,500	2,600	680	0.23	0.07
Au (t)	0	1	7	38	60	16	0.28	0.07
Ni (t)	0	10,000	59,000	230,000	330,000	97,000	0.33	0.07
Cu (t)	0	2,800	50,000	320,000	510,000	120,000	0.29	0.07
Rock (Mt)	0	15	83	280	410	120	0.35	0.07

t = metric tonnes; Mt = millions of tonnes.

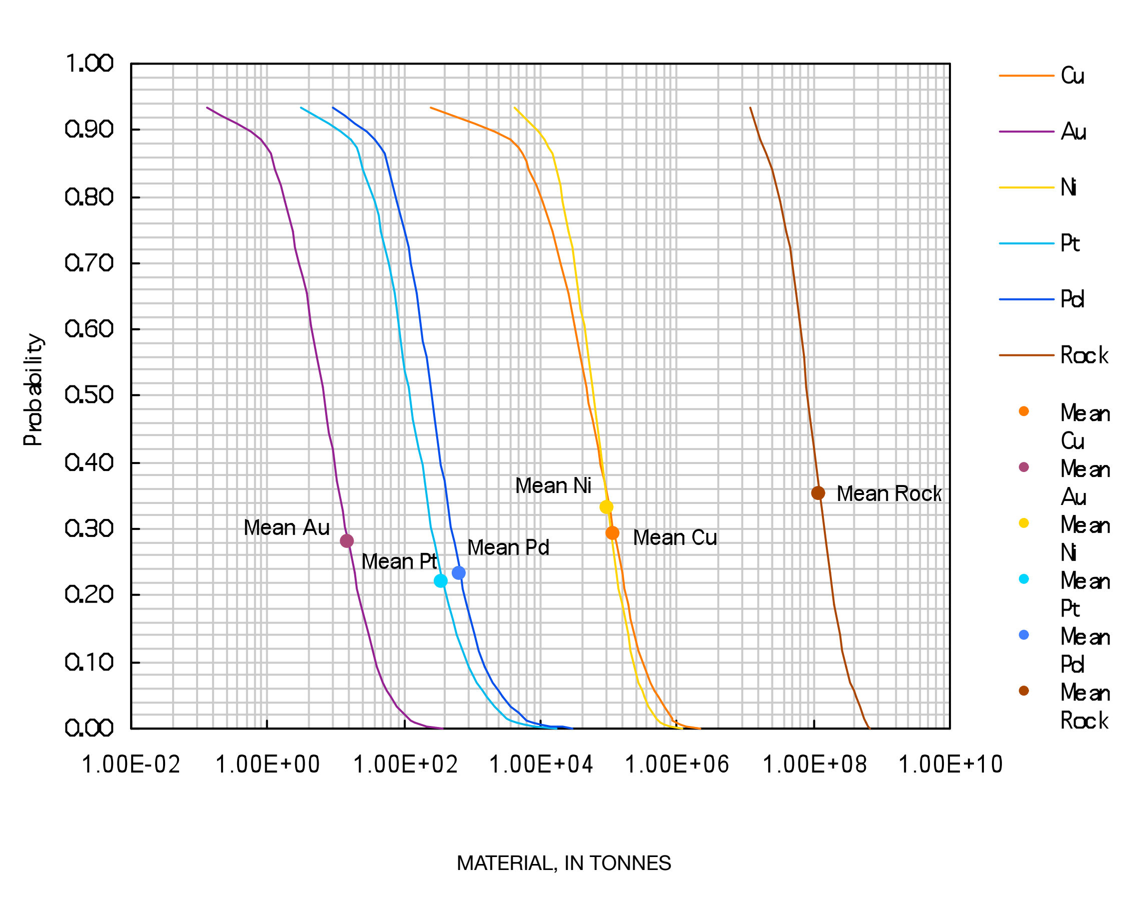

Figure 2. Cumulative frequency plot showing the results of Monte Carlo computer simulation of undiscovered resources in PintamoReefPGE.

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CONTACT-TYPE PGE ASSESSMENT FOR TRACT PirivaaraContactPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Contact-type Cu-Ni-PGE
Descriptive model: Fennoscandian contact-type Cu-Ni-PGE deposits (Appendix 1)
Grade and tonnage model: Fennoscandian contact-type Cu-Ni-PGE deposits (Appendix 2)

LOCATION AND RESOURCE SUMMARY

The Pirivaara block of the Koillismaa Complex Western Intrusion is located in northern Finland in the municipality of Taivalkoski, 135 km south-southeast from the town of Rovaniemi. The 1:100 000 KKJ map sheet is 3532. The UTM map sheet containing the block is S5123. The PGE resource assessment carried out for this report is summarised in Table 1.

Table 1. Summary of selected resource assessment results for PirivaaraContactPGE.

Date of assessment	Assessment depth (km)	Tract area (km²)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
28.08.–02.10.2008	1	2.7	Pt	0	Pt	18	Pt	2
			Pd	0	Pd	75	Pd	6
			Au	0	Au	7	Au	1
			Ni	0	Ni	62,000	Ni	23,000
			Cu	0	Cu	110,000	Cu	30,000

t = metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The permissive tract delineated in Figure 1 is a surface projection of the basal contact zone of the Pirivaara block. The dip of igneous layering in the block is 30º to the northwest. The northern margin of the Pintamo block is in deep subvertical fault to rocks of the Archaean basement and the permissive track therefore matches the surface projection of the block. With this dip the marginal series, including possible contact type deposits, can be projected down to the depth of 800–900 m to the fault in the NW part of the block. On the surface, the delineation is based on a geological map by Räsänen et al. (2004), one drill hole (Oulu University research project), geophysical information (GTK low-altitude and regional gravity survey data) and a structural model by Karinen & Salmirinne (2001). The sources of information used in the delineation of the tract are summarised in Tables 2 and 3.

Known deposits

No contact-type PGE deposits are known within the tract.

Prospects, mineral occurrences, and related deposit types

No obvious contact-type PGE prospects are known from the tract.

Exploration history

Little detailed exploration has been performed in the Pirivaara area. Mapping, the drilling of one hole and glacial erratic boulder surveys have been performed during regional-scale exploration programmes. The types of exploration work carried out in the area, and known to us, are listed in Table 2.

Table 2. Exploration history for PirivaaraContactPGE

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Not available			
Geochemical surveys	Not available			
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	1998
Ground geophysical surveys	Regional gravity survey, local magnetic and VLF-R survey		GTK	1999–2001, 2003, 2004
Drilling	One diamond-drill hole, 272.30 m	No	Univ Oulu	1973
Other	Regional research and mapping programme in the KLIC region	No	Univ Oulu	1971–1976
	Regional research and exploration programme in the KLIC region	Yes	GTK	1996–2000

KLIC = Koillismaa Layered Igneous Complex.

Sources of information

Principal sources of information used by the assessment team for the delineation of PirivaaraContactPGE are listed in Table 3.

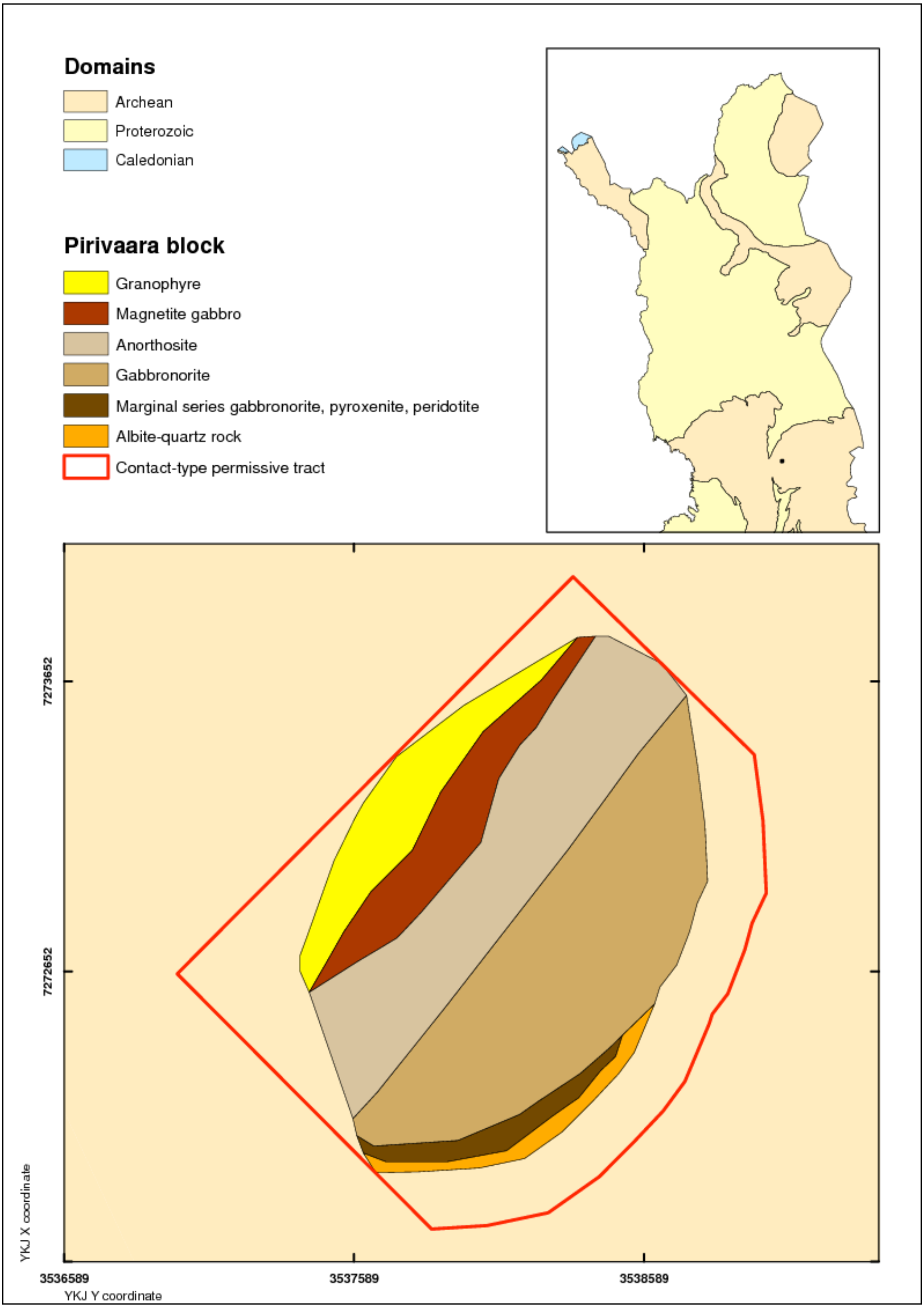

Figure 1. Location of the permissive tract PirivaaraContactfPGE.

Table 3. Principal sources of information used by the assessment team for PirivaaraContactPGE.

Theme	Type of source	Scale	Citation
Geology	Geological description of the KLIC geology and then known mineral occurrences	1:150 000	Piirainen et al. (1974, 1978), Juopperi (1977), Alapieti (1982), Iljina & Hanski (2005)
	Geological map of the KLIC region	1:200 000	Räsänen et al. (2004)
	Geological description of the KLIC geology and the known mineral occurrences		Iljina (2004)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
	PhD on geology and reef-type mineralisation in the Western Koillismaa Intrusion		Karinen (2010)
Exploration	Description of exploration activities in the area by GTK		Iljina et al. (2005)
Geophysics	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK databases

KLIC = Kollismaa Layered Igneous Complex.

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

Geological factors that were used to estimate the number of undiscovered deposits included the geology of the intrusion, the distribution of the known deposits, and the available geophysical and drilling data (Tables 2 and 3).

No contact-type prospects are known within the tract. This means that the minimum number of undiscovered contact-type deposits within the tract is zero. The hole drilled did not intersect the marginal series. This leaves room for perhaps one contact-type deposit. In addition, glacial erratic boulders detected from the region indicate a mineralised marginal series in the area. A near consensus was reached between the estimators for the number of undiscovered contact-type PGE deposits at Pirivaara; the mean only had to be used for the percentile N50 in the Monte Carlo simulations. The deposit number estimation results are listed in Table 4.

Table 4. Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for PirivaaraContactPGE.

Mean undiscovered deposit estimate					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
0	1	1			0.70	0.41	58	0	0.70	2.7	0.26

Estimator	Estimated number of undiscovered deposits				
	N90	N50	N10	N05	N01
Estimator 1	0	0	1		
Estimator 2	0	1	1		
Estimator 3	0	1	1		
Mean	0	1	1		

Nxx = Estimated number of deposits associated with the xx^{th} percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; Deposit density = deposit density reported as the total number of deposits per km^2. N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were estimated by combining the means of estimated numbers of undiscovered contact-type PGE deposits with the Fennoscandian contact-type PGE grade and tonnage model (Appendix 2) using the EMINERS software (Root et al. 1991, Duval 2004). Selected simulation results are reported in Table 5. Results of the Monte Carlo simulation are presented as a cumulative frequency plots (Figure 2). The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralised rock.

Table 5. Results of Monte Carlo simulations of undiscovered resources in PirivaaraContactPGE.

Material	At least the indicated amount at the probability of					Mean	Probability of mean or greater	Probability of zero
	0.95	0.90	0.50	0.10	0.05			
Pt (t)	0	0	2	55	100	18	0.22	0.30
Pd (t)	0	0	6	200	420	75	0.21	0.30
Au (t)	0	0	1	17	35	7	0.24	0.30
Ni (t)	0	0	23,000	180,000	250,000	62,000	0.34	0.30
Cu (t)	0	0	30,000	370,000	540,000	110,000	0.29	0.30
Rock (Mt)	0	0	9	240	400	64	0.23	0.30

t = metric tonnes; Mt = millions of tonnes.

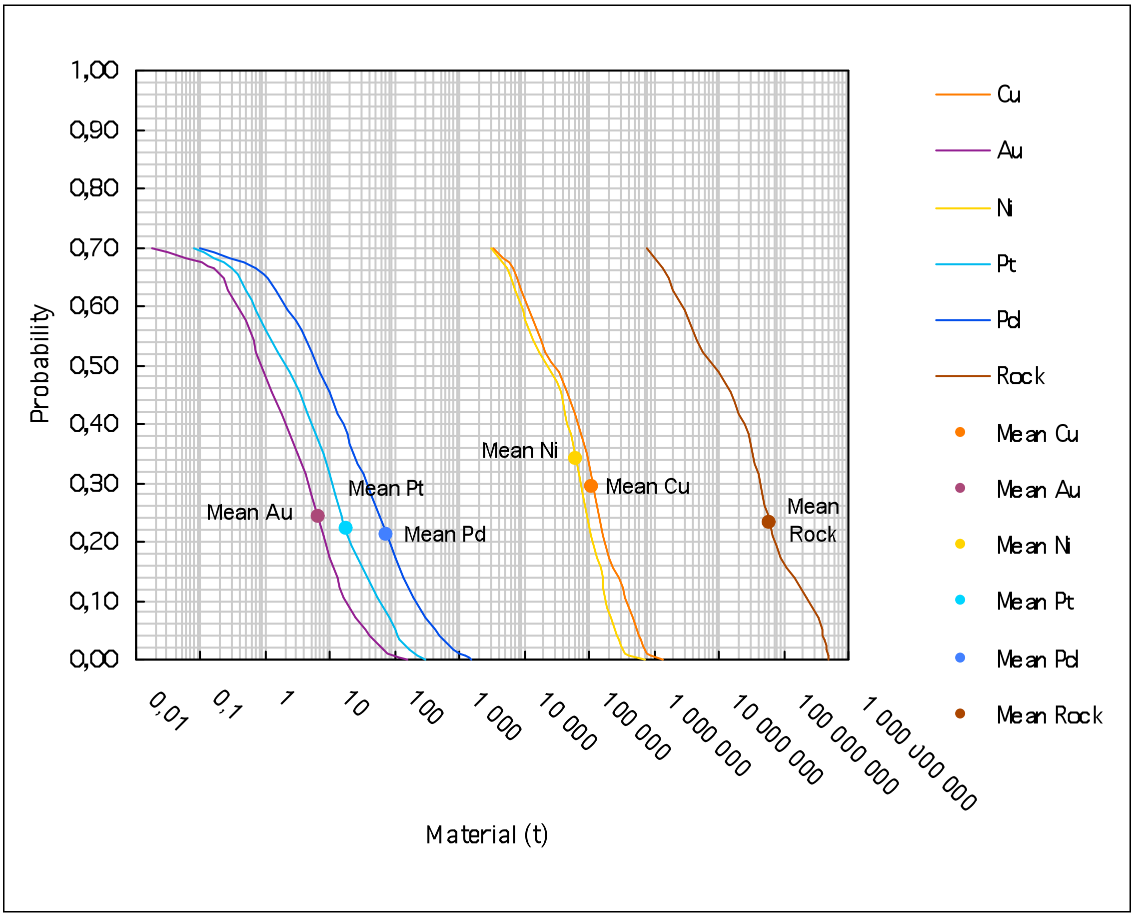

Figure 2. Cumulative frequency plot showing the results of Monte Carlo computer simulation of undiscovered resources in PirivaaraContactPGE.

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REEF-TYPE PGE ASSESSMENT FOR TRACT PirivaaraReefPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Reef-type PGE-Ni-Cu
Descriptive model: Finnish reef-type PGE-Ni-Cu (Appendix 3)
Grade-tonnage model: Finnish reef-type PGE-Ni-Cu grade model, PirivaaraReefPGE tonnage model (Appendix 4)

LOCATION AND RESOURCE SUMMARY

The Pirivaara block of the Koillismaa Complex Western Intrusion is located in northern Finland in the municipality of Taivalkoski, 135 km south-southeast from the town of Rovaniemi. The 1:100 000 KKJ map sheet is 3532. The UTM map sheet containing the block is S5123. The PGE resource assessment carried out for this report is summarised in Table 1.

Table 1. Summary of selected resource assessment results for PirivaaraReefPGE

Date of assessment	Assessment depth (km)	Tract area (km²)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
24.09.–01.10.2008	1	2.1	Pt	0	Pt	5	Pt	0
			Pd	0	Pd	9	Pd	0
			Au	0	Au	0	Au	0
			Ni	0	Ni	1,400	Ni	0
			Cu	0	Cu	1,700	Cu	0

t – metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The Western Intrusion of the Koillismaa Complex has been attributed to a Cr-poor magma type (Lahtinen et al. 1989). Therefore, the whole layered series of the Pirivaara block has the potential for PGE reefs. The dip of igneous layering in the block is 30º to the northwest. Since the northern margin of the block is a subvertical fault, the permissive tract (Figure 1) for reef-type deposits in the block roughly matches the block´s surface projection. With the dip of 30°, the depth extent of the block is 800–900 m. The permissive tract delineation is based on the geological map by Räsänen et al. (2004), one drill hole, geophysical information and a structural model by Karinen & Salmirinne (2001). The sources of information used in the delineation of the tract are summarised in Table 3.

Known deposits

No reef-type PGE deposits are known from Pirivaara.

Prospects, mineral occurrences, and related deposit types

The PGE reef described in the reports Porttivaara-PyhitysReefPGE and SyöteReefPGE has also been detected in a few outcrops of the Pirivaara block. No chemical composition data are available from these outcrops, however.

Exploration history

Little detailed exploration has been performed in the Pirivaara area. Mapping, the drilling of one hole, and glacial erratic boulder surveys have been carried out during regional-scale exploration programmes. The types of exploration work carried out in the area, and known to us, are listed in Table 2.

Table 2. Exploration history for PirivaaraReefPGE.

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Not available			
Geochemical surveys	Not available			
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	1998
Ground geophysical surveys	Regional gravity survey, local magnetic and VLF-R survey		GTK	1999–2001, 2003, 2004
Drilling	One diamond-drill hole, 272.30 m	No	Univ Oulu	1973
Other	Regional research and mapping programme in the KLIC region	No	Univ Oulu	1971–1976
	Regional research and exploration programme in the KLIC region	Yes	GTK	1996–2000

KLIC = Koillismaa Layered Igneous Complex.

Sources of information

Principal sources of information used by the assessment team for the delineation of PirivaaraReefPGE are listed in Table 3.

Table 3. Principal sources of information used by the assessment team for PirivaaraReefPGE.

Theme	Type of source	Scale	Citation
Geology	Geological description of the KLIC geology and then known mineral occurrences	1:150 000	Piirainen et al. (1974, 1978), Juopperi (1977), Alapieti (1982)
	Geological map of the KLIC region	1:200 000	Räsänen et al. (2004)
	Geological description of the KLIC geology and the known mineral occurrences		Iljina (2004)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
	PhD on geology and reef-type mineralisation in the Western Koillismaa Intrusion		Karinen (2010)
Exploration	Description of exploration activities in the area by GTK		Iljina et al. (2005)
Geophysics	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK databases

KLIC = Kollismaa Layered Igneous Complex.

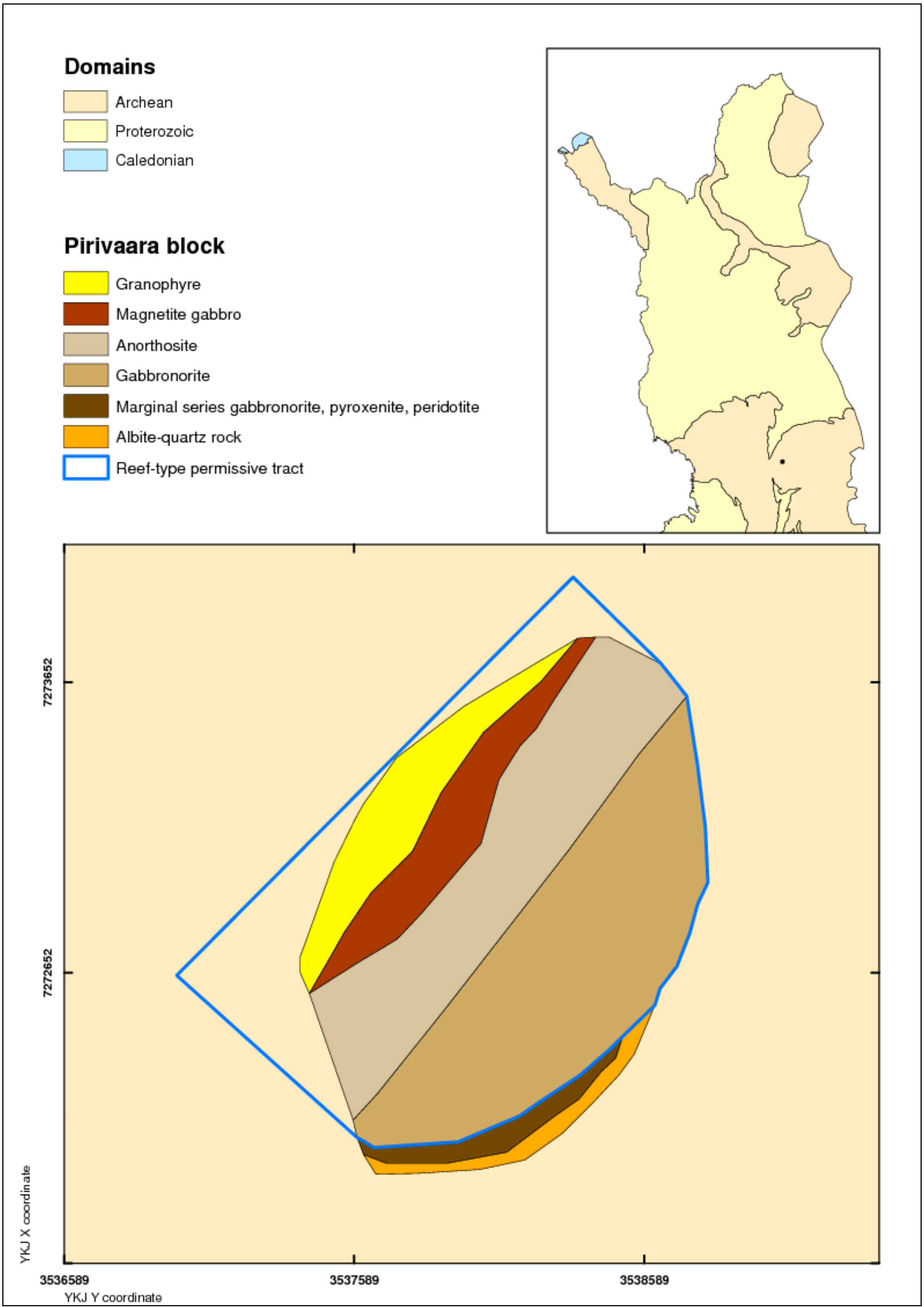

Figure 1. Location of the permissive tract PirivaaraReefPGE.

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

Geological factors that were used to estimate the number of undiscovered deposits included the geology of the Pirivaara intrusive block, the distribution of the known occurrences, and the available geophysical and drilling data (Tables 2 and 3).

Not a single reef-type prospect is known within the tract. This means that the minimum number of undiscovered reef-type deposits within the tract is zero. The estimators agreed that, as the known indications are minor and the block is small, there is only a relatively small possibility for an economic reef-type PGE deposit to occur at Pirivaara (Table 4).

Table 4. Undiscovered deposit estimates, deposit numbers, and tract area for PirivaaraReefPGE.

Consensus undiscovered deposit estimate					Summary statistics					Area (km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}	
0	0	1			0.30	0.50	170	0	0.30	2.1

	Estimated number of undiscovered deposits				
Estimator	N90	N50	N10	N05	N01
Estimator 1	0	0	1		
Estimator 2	0	0	1		
Estimator 3	0	0	1		
Consensus	0	0	1		

Nxx = Estimated number of deposits associated with the xxth percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were calculated by combining the undiscovered deposit estimates with the Finnish reef-type PGE grade model and the PirivaaraReefPGE tonnage model (Appendix 4) using the EMINERS software (Root et al. 1992, Duval 2004). Selected simulation results are reported in Table 5. Results of the Monte Carlo simulation are presented as cumulative frequency plots (Figure 2). The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralised rock.

Table 5. Results of Monte Carlo simulations of undiscovered resources in PirivaaraReefPGE.

Material	At least the indicated amount at the probability of					Mean	Probability of mean or greater	Probability of zero
	0.95	0.9	0.5	0.1	0.05			
Pt (t)	0	0	0	10	22	5	0.16	0.71
Pd (t)	0	0	0	20	43	9	0.17	0.71
Au (t)	0	0	0	1	1	0	0.17	0.71
Ni (t)	0	0	0	4,000	7,400	1,400	0.19	0.71
Cu (t)	0	0	0	4,100	9,800	1,700	0.16	0.71
Rock (Mt)	0	0	0	6	10	2	0.21	0.71

t = metric tonnes; Mt = millions of tonnes.

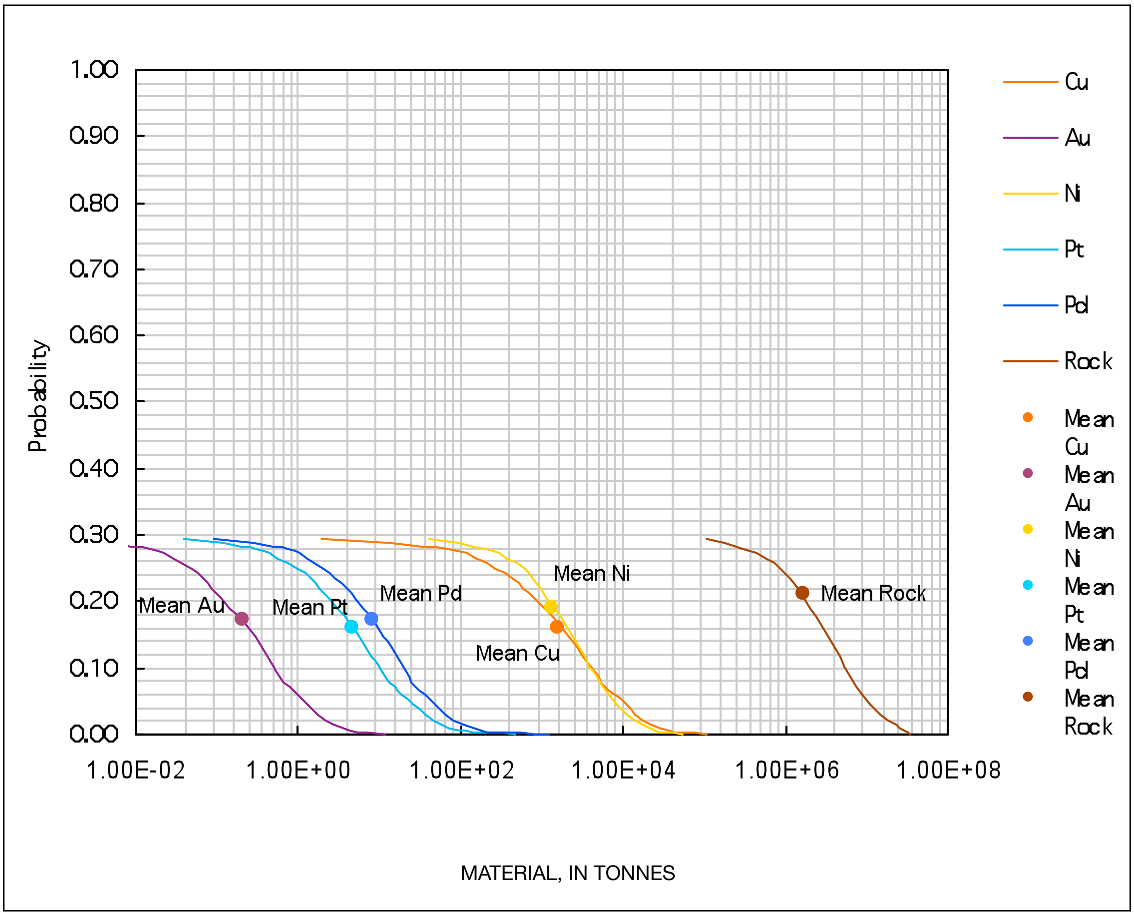

Figure 2. Cumulative frequency plot showing the results of Monte Carlo computer simulation of undiscovered resources in PirivaaraReefPGE.

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REEF-TYPE PGE ASSESSMENT FOR TRACT PorttivaaraPyhitysReefPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Reef-type PGE-Ni-Cu
Descriptive model: Finnish reef-type PGE-Ni-Cu (Appendix 3)
Grade-tonnage model: Finnish reef-type PGE-Ni-Cu grade model, PorttivaaraPyhitysReefPGE tonnage model (Appendix 4)

LOCATION AND RESOURCE SUMMARY

Both the Porttivaara and Pyhitys blocks of the Koillismaa Complex Western Intrusion are located in northern Finland in the municipalities of Posio and Taivalkoski, about 130 km southeast from the city of Rovaniemi. The 1:100 000 KKJ map sheets are 3541 and 3543. The UTM map sheets containing the blocks are S5213 and S5231. The PGE resource assessment carried out for this report is summarised in Table 1.

Table 1. Summary of selected resource assessment results for PorttivaaraPyhitysReefPGE

Date of assessment	Assessment depth (km)	Tract area (km²)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
26.09–02.10..2008	1	115	Pt	0	Pt	730	Pt	320
			Pd	0	Pd	1,300	Pd	650
			Au	0	Au	31	Au	17
			Ni	0	Ni	190,000	Ni	140,000
			Cu	0	Cu	250,000	Cu	140,000

t – metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The WSW-trending Porttivaara and Pyhitys blocks dip to the NNW at 45°. One reef-type permissive tract covers both of these blocks, which are in physical contact with each other. The results of a gravity survey indicate that the blocks continue to at least 1 km depth; most of drilling in the area extends to the depth of 150 m. In the east and west, the block and the tract are terminated by a fault; especially in the northernmost parts, the blocks are bounded by subvertical faults. Hence, the permissive tract roughly matches the surface projection of the blocks (Figure 1). The tract delineation is based on a geological map by Räsänen et al. (2004), drilling, geophysical information (local gravity survey) and a structural model by Karinen & Salmirinne (2001). The sources of information used in the delineation of the tract are summarised in Table 4.

Known deposits

No well-delineated reef-type PGE deposits are known from the block areas.

Prospects, mineral occurrences, and related deposit types

One partially investigated prospect is known from the western part of the Porttivaara block (Table 2). According to current knowledge, the prospect belongs to the same reef unit investigated by Isohanni (1976) in the Rometölväs area of the Syöte block.

Table 2. Significant prospects and occurrences in PorttivaaraPyhitysReefPGE.

Name	X coordinate	Y coordinate	Age (Ma)	Comments (grade and tonnage data, if available)	Reference
Baabelinälkky	7297572	3540241	2.45	0.5% Cu, 0.2% Ni, 24 ppb Au, 77 ppb Pd, 263 ppb Pt; drill core B1	Isohanni (1976)

The deposit age is derived from the assumed age of the Porttivaara and Pyhitys blocks based on age data from the Complex (Alapieti 1982).

Exploration history

Exploration commenced in the Porttivaara area in the 1960s when Outokumpu started to map and drill Ni-Cu targets in the Koillismaa Complex area. Attention was drawn to the area by Ni- and Cu-rich sulphide-bearing glacial erratic boulders found in the 1960s. Suomen Malmi Oy found the Baabelinälkky and Rometölväs occurrences in 1966. These areas were drilled by the Koillismaa Research Project of the University of Oulu in 1973. The rest of work in the tract area has mostly been related to the exploration of contact-type deposits in the marginal series. Hence, some of the work listed in Table 3 is actually related to exploration of the latter type. Types of exploration work carried out in the tract area, and known to us, are listed in Table 3.

Table 3. Exploration history for PorttivaaraPyhitysReefPGE.

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Detailed bedrock mapping, outcrop sampling	A few cases*	Outokumpu	1960s
	Bedrock mapping	No?	Suomen Malmi	1966
Geochemical surveys	Not available			
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	1998
	Low-altitude airborne magnetic and electromagnetic survey		NAN	2000
	Low-altitude airborne electromagnetic survey TDEM (Time Domain Electromagnetic Survey)		Akkerman-Nortec	2006
Ground geophysical surveys	Gravity survey line		Univ Oulu	1971
	IP, VLF-R and magnetic surveys		GTK	1976, 1997–2000
	Regional gravity survey		GTK	1999–2001, 2003, 2004 2000–2001
	Magnetic and IP survey		NAN	
Drilling	Four short diamond-drill holes, total 120.35 m.	Some	Oulu University	1973
	Three diamond-drill holes, total 844.46 m. (Target was the down-dip extent of contact-type mineralisation)	Some	Outokumpu	1965, 1989
	Two diamond-drill holes, total 280.30 m. (Target was the down-dip extent of contact-type mineralisation)	Yes	GTK	1998
	11 diamond-drill holes, total 1441.10 m. (Target was the down-dip extent of contact-type mineralisation)	Yes	NAN	2000–2001
	Two long drill holes, total 899.45 m (Target was the down-dip extent of contact-type mineralisation)	Yes	Akkerman-Nortec	2007
Other	Regional research and mapping programme in the KLIC region	No	Univ. Oulu	1971–1976
	Regional research and exploration programme in the KLIC region	Yes	GTK	1996–2000

* PGE analysed in the early 1980s from parts of the 1960s drill core.
NAN = North Atlantic Natural Resources.
Akkerman-Nortec= Akkerman exploration B. V. – Nortec Ventures Joint Venture.
KLIC = Koillismaa Layered Igneous Complex.

Sources of information

Principal sources of information used by the assessment team for the delineation of PorttivaaraPyhitys-ReefPGE are listed in Table 4.

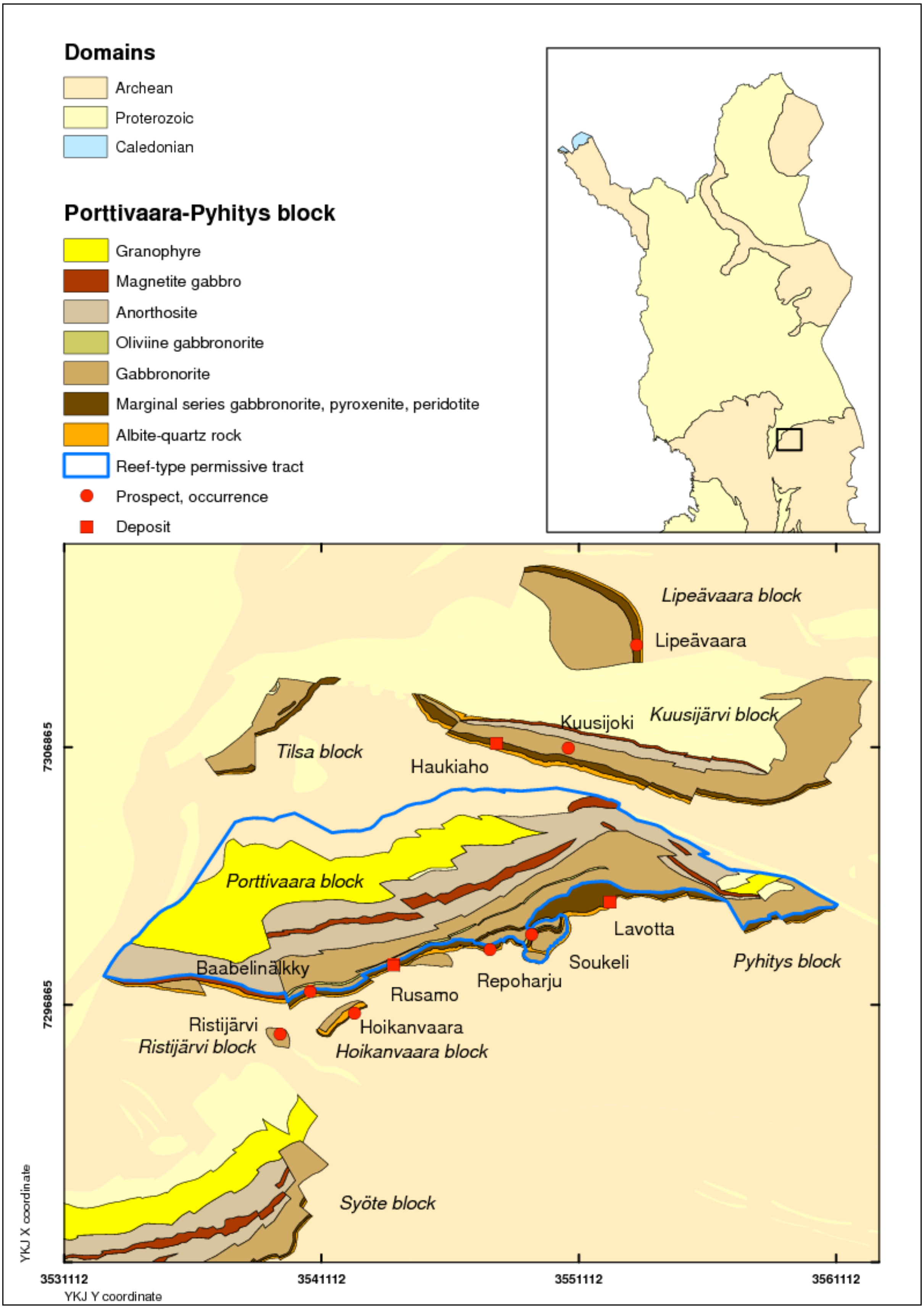

Figure 1. Location of the permissive tract Porttivaara-PyhitysReefPGE.

Table 4. Principal sources of information used by the assessment team for PorttivaaraPyhitysReefPGE.

Theme	Type of source	Scale	Citation
Geology	Geological description of the KLIC geology and then known mineral occurrences	1:150 000	Piirainen et al. (1974, 1978), Juopperi (1977), Alapieti (1982), Lahtinen (1985), Iljina (2004)
	Geological map of the KLIC region	1:200 000	Räsänen et al. (2004)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
	PhD on geology and reef-type mineralisation in the Western Koillismaa Intrusion		Karinen (2010)
Mineral occurrences	Description of mineralised localities		Isohanni (1976), Lahtinen (1983, 1985), Iljina (2004)
Geochemistry	Not available		
Geophysics	Magnetic, VLF-R and IP survey		Iljina (2004)
Exploration	Detailed description of exploration activities in the area		Isohanni (1976), Lahtinen (1983, 1985), Iljina (2004), Nortec (2007)

KLIC = Koillismaa Layered Igneous Complex.

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

Geological factors that were used to estimate the number of undiscovered deposits included the geology of the intrusion, the distribution of the known deposits, and the available geophysical and drilling data (Tables 3 and 4).

One reef-type prospect is known within the tract (Table 2). This means that the minimum number of undiscovered reef-type deposits within the tract can be zero or one. The estimators agreed that at the N50 probability level there may well be two deposits. Only at the N10 probability level did the estimators slightly disagree on the number of undiscovered reef-type PGE deposits within the Porttivaara-Pyhitys tract (Table 5).

Table 5. Undiscovered deposit estimates, deposit numbers, and tract area for PorttivaaraPyhitysReefPGE.

Mean undiscovered deposit estimate					Summary statistics					Area (km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}	
1	2	2			2	0.46	28	0	2	115

	Estimated number of undiscovered deposits				
Estimator	N90	N50	N10	N05	N01
Estimator 1	1	2	2		
Estimator 2	1	2	2		
Estimator 3	1	2	3		
Mean	1	2	2		

Nxx = Estimated number of deposits associated with the xx^{th} percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were calculated by combining the undiscovered deposit estimates with the Finnish reef-type PGE grade model and the PorttivaaraPyhitysReefPGE tonnage model (Appendix 4) using the EMINERS software (Root et al. 1992, Duval 2004). Selected simulation results are reported in Table 6. Results of the Monte Carlo simulation are presented as cumulative frequency plots (Figure 2). The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralized rock.

Table 6. Results of Monte Carlo simulations of undiscovered resources in PorttivaaraPyhitysReefPGE.

Material	At least the indicated amount at the probability of					Mean	Probability of mean or greater	Probability of zero
	0.95	0.9	0.5	0.1	0.05			
Pt (t)	0	33	320	1,700	2,800	730	0.26	0.07
Pd (t)	0	77	650	2,900	4,700	1,300	0.27	0.07
Au (t)	0	2	17	75	110	31	0.31	0.07
Ni (t)	0	22,000	140,000	430,000	550,000	190,000	0.36	0.07
Cu (t)	0	8,600	140,000	600,000	890,000	250,000	0.33	0.07
Rock (Mt)	0	34	190	560	700	250	0.38	0.07

t = metric tonnes; Mt = millions of tonnes.

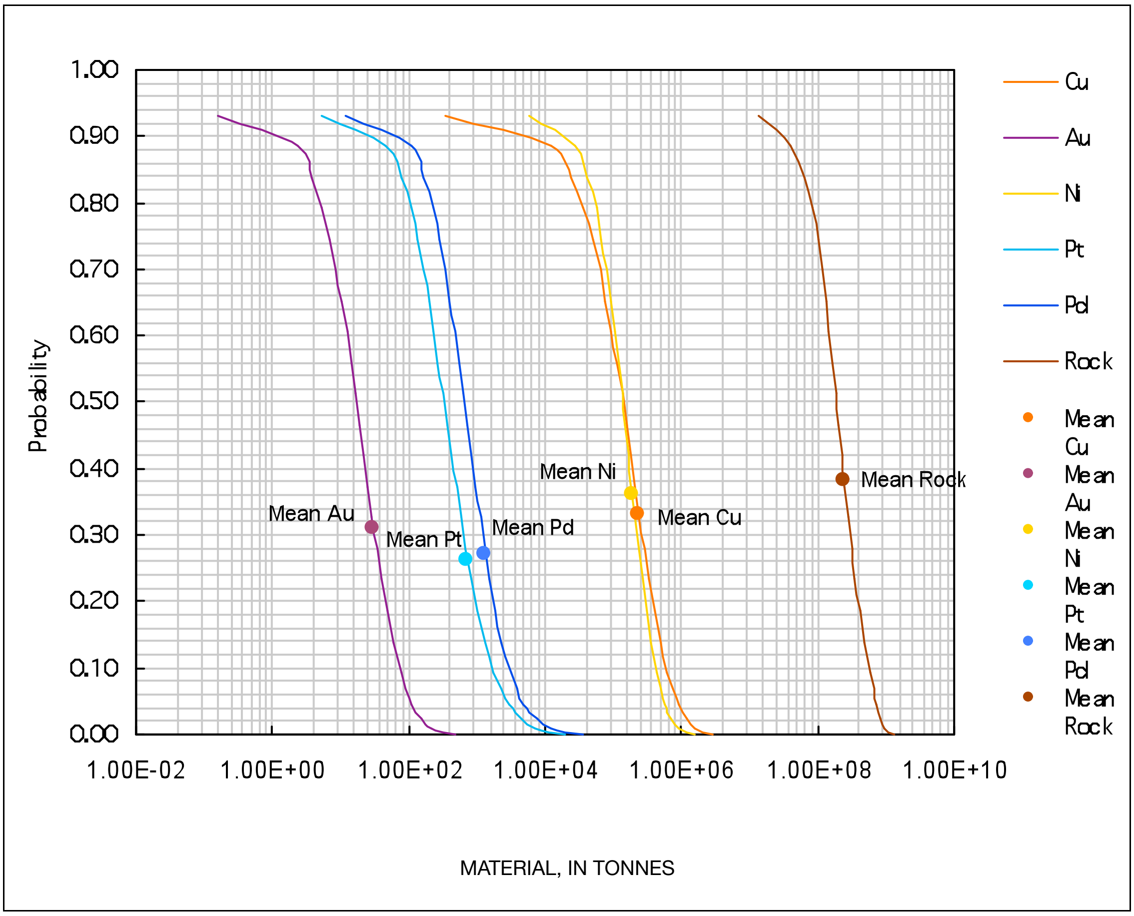

Figure 2. Cumulative frequency plot showing the results of Monte Carlo computer simulation of undiscovered resources in PorttivaaraPyhitysReefPGE.

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CONTACT-TYPE PGE ASSESSMENT FOR TRACT PorttivaaraContactPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Contact-type Cu-Ni-PGE
Descriptive model: Fennoscandian contact-type Cu-Ni-PGE deposits (Appendix 1)
Grade and tonnage model: Fennoscandian contact-type Cu-Ni-PGE deposits (Appendix 2)

LOCATION AND RESOURCE SUMMARY

The Porttivaara block of the Koillismaa Complex Western Intrusion is located in northern Finland in the municipalities of Posio and Taivalkoski, about 130 km southeast from the city of Rovaniemi. The 1:100 000 KKJ map sheets are 3541 and 3543. The UTM map sheets containing the block are S5213 and S5231. The PGE resource assessment carried out for this report is summarised in Table 1.

Table 1. Summary of selected resource assessment results for PorttivaaraContactPGE.

Date of assessment	Assessment depth (km)	Tract area (km^2)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
29.08.–02.10.2008	1	44	Pt	0.95	Pt	69	Pt	39
			Pd	1.4	Pd	290	Pd	140
			Au	0.83	Au	25	Au	15
			Ni	9,900	Ni	240,000	Ni	210,000
			Cu	14,000	Cu	440,000	Cu	340,000

t = metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The permissive tract delineated in Figure 1 is a surface projection of the basal contact zone of the Porttivaara block, which dips to the NNW at 45°. The results of a gravity survey indicate that the block continues to at least 1 km depth; most of the drilling at Porttivaara has only extended to the depth of 150 m. In the east and west, the block, and hence the tract, is terminated by a fault. The tract delineation is based on a geological map by Räsänen et al. (2004), drilling (Outokumpu, Rautaruukki, GTK and NAN), geophysical information (local gravity survey) and a structural model by Karinen & Salmirinne (2001). The sources of information used in the delineation of the tract are summarized in Table 5.

Known deposits

Two well-studied contact-type, disseminated PGE deposits are known within the tract (Table 2 and Figure 1). The Lavotta deposit is characterized by extensive repetition of igneous layering, and comprises a sheet-like repeated section of contact-type mineralisation.

Table 2. Known contact-type PGE deposits in PorttivaaraContactPGE.

Name	X coordinate	Y coordinate	Age (Ma)	Tonnage (Mt)	Grade					Contained PGE (t)		Reference
					Cu (%)	Ni (%)	Pt (g/t)	Pd (g/t)	Au (g/t)			
Lavotta	7300850	3552300	2.45	3.0	0.26	0.21	0.1	0.3	0.05	Pt	0.3	Lahtinen (1983)
										Pd	0.9	Lahtinen (1983)
Rusamo	7298400	3543900	2.45	1.5	0.5	0.24	0.46	0.19	0.15	Pt	0.3	Lahtinen (1983)
										Pd	0.7	Lahtinen (1983)

Ma – millions of years; Mt – millions of metric tonnes; t – metric tonne; g/t – grams per metric tonne. The contained PGE is given in metric tonnes and computed as tonnage * grade. Deposit ages are derived from the assumed age of the Porttivaara block based on age data from the Complex (Alapieti 1982).

Prospects, mineral occurrences, and related deposit types

Two contact-type PGE prospects are known within the tract (Table 3 and Figure 1), Soukeli and Repoharju (Pärjänoja). These prospects are incompletely delineated and no representative grade or tonnage information is available. In addition, there is at least one reef with PGE potential in the Porttivaara Block.

Table 3. Significant prospects and occurrences in PorttivaaraContactPGE.

Name	X coordinate	Y coordinate	Age (Ma)	Comments (grade and tonnage data, if available)	Reference
Soukeli	7299900	3550250	2.45		Kujanpää (1966)
Repoharju	7299200	3546850	2.45		Kujanpää (1966), Inkinen (1978)

Deposit ages are derived from the assumed age of the Porttivaara block based on age data from the Complex (Alapieti 1982).

Exploration history

Exploration commenced in the area in the 1960s when Outokumpu started to map and drill Ni-Cu targets in the Koillismaa Complex. Attention was drawn to the area by Ni- and Cu-rich sulphide-bearing glacial erratic boulders found in the 1960s. The first indications on contact-type deposits in outcrops and drill cores were discovered by Outokumpu in the 1960s, at Rusamo. In the early 1970s, Rautaruukki drilled the Lavotta deposit. GTK drilled and carried out ground geophysical surveys in the area in 1996–2000 and NAN in 2000–2001 (Iljina 2004). In 2006, the Akkerman-Nortec JV commenced an airborne survey in the western part of the Porttivaara Block, and continued exploration by drilling two deep holes near Lavotta in 2007 (Akkerman 2008). These two drill holes are not inside the PorttivaaraContactPGE permissive tract. Nevertheless, they are mentioned in Table 4, because their collars are located very close to the tract and their target was contact-type mineralisation. The types of exploration work carried out in the permissive tract area, and known to us, are listed in Table 4.

Table 4. Exploration history for PorttivaaraContactPGE

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Detailed bedrock mapping, outcrop sampling	A few cases*	Outokumpu Oy,	1960s, 1990s
	Bedrock mapping	No	Suomen Malmi Oy	1966
Geochemical surveys	None available			
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	1998
	Low-altitude airborne magnetic and electromagnetic survey		NAN	2000
	Low-altitude airborne magnetic and TDEM (Time Domain Electromagnetic Survey)		Akkerman-Nortec	2006
Ground geophysical surveys	Gravity survey lines		Univ. Oulu	1971
	IP, VLF-R and magnetic surveys		GTK	1997–2000
	Regional gravity survey		GTK	1999–2001, 2003, 2004
	Magnetic, IP and TEM surveys		NAN	2000–2001
Drilling	36 diamond-drill holes along the strike of the marginal series rocks, total 11500 m.	Some	Outokumpu	1963–1966
	Four short diamond-drill holes, total 120.35 m.	Some	Univ. Oulu	1973
	17 diamond-drill holes at Lavotta, total 4575 m.	Yes	Rautaruukki	1975
	19 diamond-drill holes along the strike of the marginal series rocks, total 2126 m.	Yes	GTK	1998–1999
	27 diamond-drill holes where 14 at Lavotta, total 3360 m.	Yes	NAN	2000–2001
	6. Two diamond-drill holes at Lavotta, total 899.45 m.	Yes	Akkerman-Nortec	2007
Other	Regional research and mapping programme in the KLIC region	No	Univ. Oulu	1971–1976
	Regional research and exploration programme in the KLIC region	Yes	GTK	1996–2000

*PGE reanalysed in the early 1980s from part of the 1960s drill core.
NAN = North Atlantic Natural Resources.
Akkerman-Nortec = Akkerman Exploration B. V. – Nortec Ventures Joint Venture.
KLIC = Koillismaa Layered Igneous Complex.

Sources of information

Principal sources of information used by the assessment team for the delineation of PorttivaaraContactPGE are listed in Tables 4 and 5.

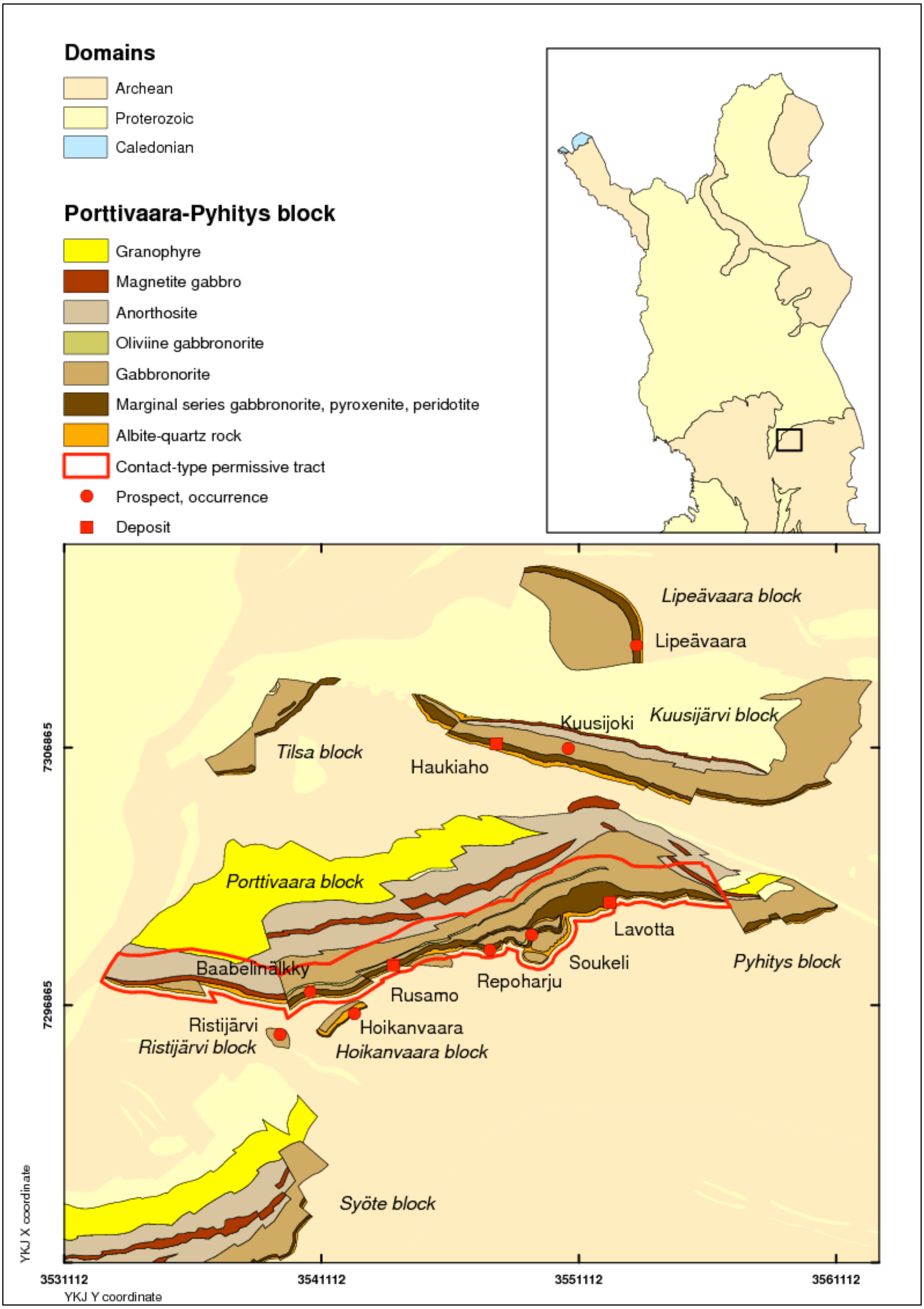

Figure 1. Location of the permissive tract PorttivaaraContactPGE.

Table 5. Principal sources of information used by the assessment team for PorttivaaraContactPGE.

Theme	Type of source	Scale	Citation
Geology	Geological description of the KLIC geology and then known mineral occurrences	1:150 000	Piirainen et al. (1974, 1978), Juopperi (1977), Alapieti (1982), Lahtinen (1985)
	Geological description of the KLIC geology and the known mineral occurrences		Iljina (2004)
	Geological map of the KLIC region	1:200 000	Räsänen et al. (2004)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
	PhD on geology and reef-type mineralisation in the Western Koillismaa Intrusion		Karinen (2010)
Mineral occurrences	Description of mineralised localities		Kujanpää (1966), Inkinen (1978), Iljina (2004)
Geochemistry	Not available		
Geophysics	Magnetic, VLF-R and IP survey		Iljina (2004)
Exploration	Detailed description of exploration activities in the area by GTK, review of work done by Outokumpu, Rautaruukki and NAN		Kujanpää (1966), Inkinen (1978), Lahtinen (1983), Iljina (2004)
	Description of exploration activities in the area by Akkerman-Nortec JV		Nortec (2006, 2007a, 2007b), Akkerman (2008)

KLIC = Kollismaa Layered Igneous Complex.
NAN = North Atlantic Natural Resources.

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

Geological factors that were used to estimate the number of undiscovered deposits included the geology of the intrusion, the distribution of the known deposits, and the available geophysical and drilling data (Tables 4 and 5).

Two reasonably well-defined contact-type deposits and two prospects are known within the tract (Tables 2 and 3). Of the latter, the Repoharju occurrence is regarded as so small that it will most probably never become a mineable deposit. On the other hand, the Soukeli occurrence may turn out to be large enough for mining. This means that the number of undiscovered contact-type deposits within the tract is at least one. Another feature favourable for mineralisation is the relatively large horizontal size and depth extent of the intrusive block. Another favourable factor may be the fact that, between the present surface and 1 km depth, the basal contact has three down-dip bends, each of which may host a sizeable contact-type PGE deposit. On the other hand, the eastern and western ends of the tract are known to have only low PGE concentrations. The deposit number estimation results are listed in Table 6.

Table 6. Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for PorttivaaraContactPGE.

Mean of undiscovered deposit estimate					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
1	3	4			2.6	1.1	43	2	4.6	44	0.11

	Estimated number of undiscovered deposits				
Estimator	N90	N50	N10	N05	N01
Estimator 1	0	2	4		
Estimator 2	1	3	5		
Estimator 3	2	3	4		
Mean	1	3	4		

Nxx = Estimated number of deposits associated with the xxth percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; Deposit density = deposit density reported as the total number of deposits per km^2. N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were estimated by combining the means of estimated numbers of undiscovered contact-type PGE deposits with the Fennoscandian contact-type PGE grade and tonnage model (Appendix 2) using the EMINERS software (Root et al. 1991, Duval 2004). Selected simulation results are reported in Table 7. Results of the Monte Carlo simulation are presented as cumulative frequency plots (Figure 2). The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralized rock.

Table 7. Results of Monte Carlo simulations of undiscovered resources in PorttivaaraContactPGE.

Material	At least the indicated amount at the probability of					Mean	Probability of mean or greater	Probability of zero
	0.95	0.90	0.50	0.10	0.05			
Pt (t)	0	1	39	180	250	69	0.35	0.06
Pd (t)	0	4	140	800	1 200	290	0.31	0.06
Au (t)	0	1	15	67	91	25	0.33	0.06
Ni (t)	0	15,000	210,000	510,000	610,000	240,000	0.43	0.06
Cu (t)	0	21,000	340,000	970,000	1,200,000	440,000	0.42	0.06
Rock (Mt)	0	5	150	580	740	250	0.39	0.06

t = metric tonnes; Mt = millions of tonnes.

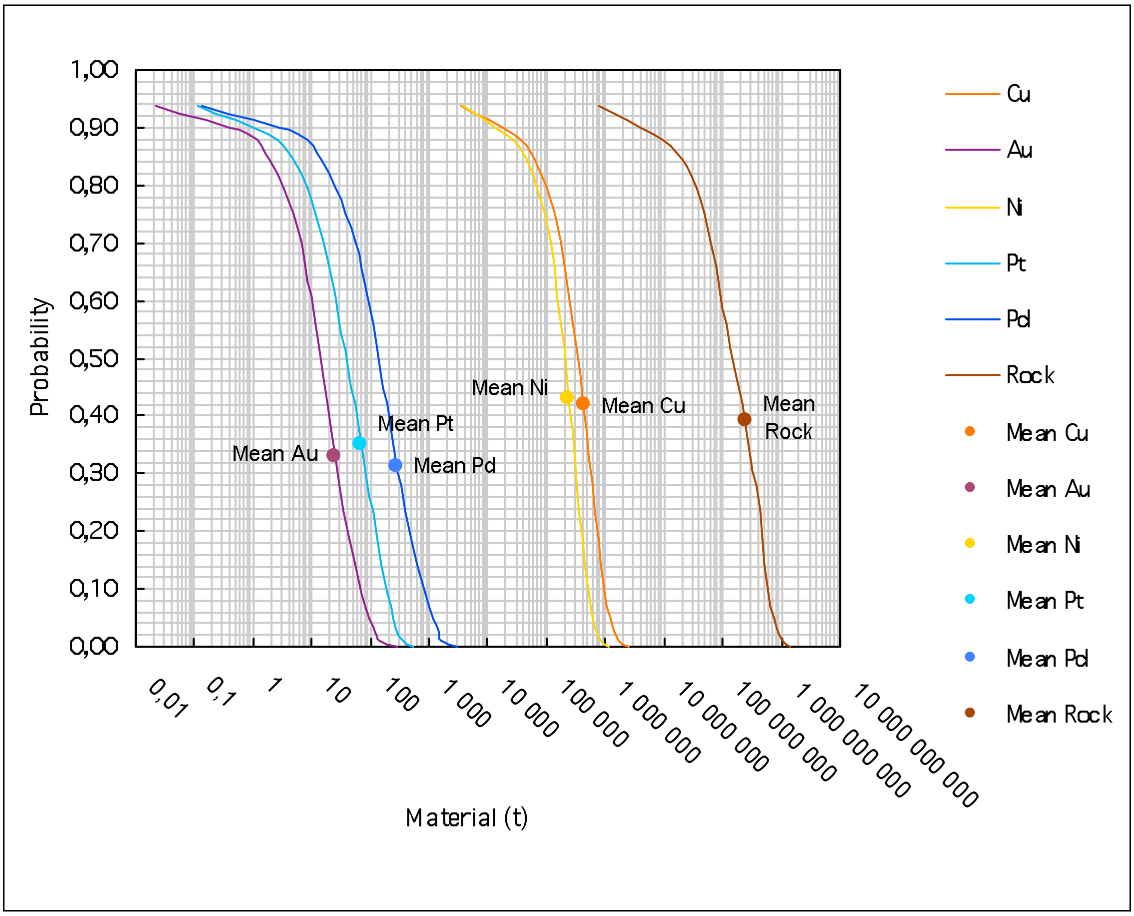

Figure 2. Cumulative frequency plot showing the results of Monte Carlo computer simulation of undiscovered resources in PorttivaaraContactPGE.

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CONTACT-TYPE PGE ASSESSMENT FOR TRACT PyhitysContactPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Contact-type Cu-Ni-PGE
Descriptive model: Fennoscandian contact-type Cu-Ni-PGE deposits (Appendix 1)
Grade and tonnage model: Fennoscandian contact-type Cu-Ni-PGE deposits (Appendix 2)

LOCATION AND RESOURCE SUMMARY

The Pyhitys block of the Western Intrusion of the Koillismaa Layered Igneous Complex is located in northern Finland in the municipality of Taivalkoski, 140 km ESE from Rovaniemi. The 1:100 000 KKJ map sheets are 3541 and 3543. The UTM map sheets containing the block are S5213 and S5231. The PGE resource assessment carried out for this report is summarised in Table 1.

Table 1. Summary of selected resource assessment results for PyhitysContactPGE.

Date of assessment	Assessment depth (km)	Tract area (km²)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
28.08.–01.10.2008	1	4.0	Pt	0	Pt	8	Pt	0
			Pd	0	Pd	31	Pd	0
			Au	0	Au	3	Au	0
			Ni	0	Ni	26,000	Ni	0
			Cu	0	Cu	48,000	Cu	0

t – metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The permissive tract delineated in Figure 1 is a surface projection of the basal contact zone of the 2.45 Ga Pyhitys Block. The dip of igneous layering in the block is 15–30º to the NNW. The Pyhitys block seems only to extend to the depth of 300 m. On the surface, the delineation is based on a geological map by Räsänen et al. (2004), drilling by GTK, geophysical information (low-altitude airborne magnetic survey and ground surveys by GTK) and a structural model by Karinen & Salmirinne (2001). The sources of information used in the delineation of the tract are summarised in Tables 2 and 3.

Known deposits

No contact-type PGE deposits are known within the tract.

Prospects, mineral occurrences, and related deposit types

No obvious contact-type PGE prospects are known from the tract.

Exploration history

Exploration commenced in the Pyhitys Block area in the 1960s when Outokumpu started to map and drill Ni-Cu targets in the Koillismaa Complex area. Attention was drawn to the region by Ni- and Cu-rich sulphide-bearing glacial erratic boulders found in the 1960s. The marginal Series of the Pyhitys Block has been drilled by GTK and later, in 2007, by Akkerman-Nortec with one deep hole in the northernmost part of the block. This drill site is not located inside the permissive tract, but is still included in Table 4, since the target of the drilling was the down-dip continuation of contact-type mineralisation. This drilling revealed that the block is very shallow, only about 300 m in thickness. Exploration has also revealed that the marginal series at Pyhitys is richer in Ni than is typical for the marginal series elsewhere at Koillismaa. The types of exploration work carried out in the area, and known to us, are listed in Table 2.

Table 2. Exploration history for PyhitysContactPGE

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Detailed bedrock mapping, outcrop sampling	Yes	Outokumpu	1960s
	Detailed bedrock mapping, outcrop sampling	Yes	GTK	1996–2000
Geochemical surveys	Apparently none has been performed			
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	1998
	Airborne TDEM survey		Akkerman – Nortec	2007
Ground geophysical surveys	VLF-R, magnetic, and IP surveys in the Lehtovaara subarea		GTK	1997–1999
Drilling	12 diamond-drill holes, 1663.70 m	Yes	GTK	1998
	1 drill hole 671.30 m	Yes	Akkerman – Nortec	2007
Other	Regional research and mapping programme in the KLIC region	No	Univ. Oulu	1971–1976
	Regional research and exploration programme in the KLIC region	Yes	GTK	1996–2000

Akkerman–Nortec = Akkerman Exploration–Nortec Ventures Joint Venture.
KLIC = Koillismaa Layered Igneous Complex.

Sources of information

Principal sources of information used by the assessment team for the delineation of PyhitysContactPGE are listed in Table 3.

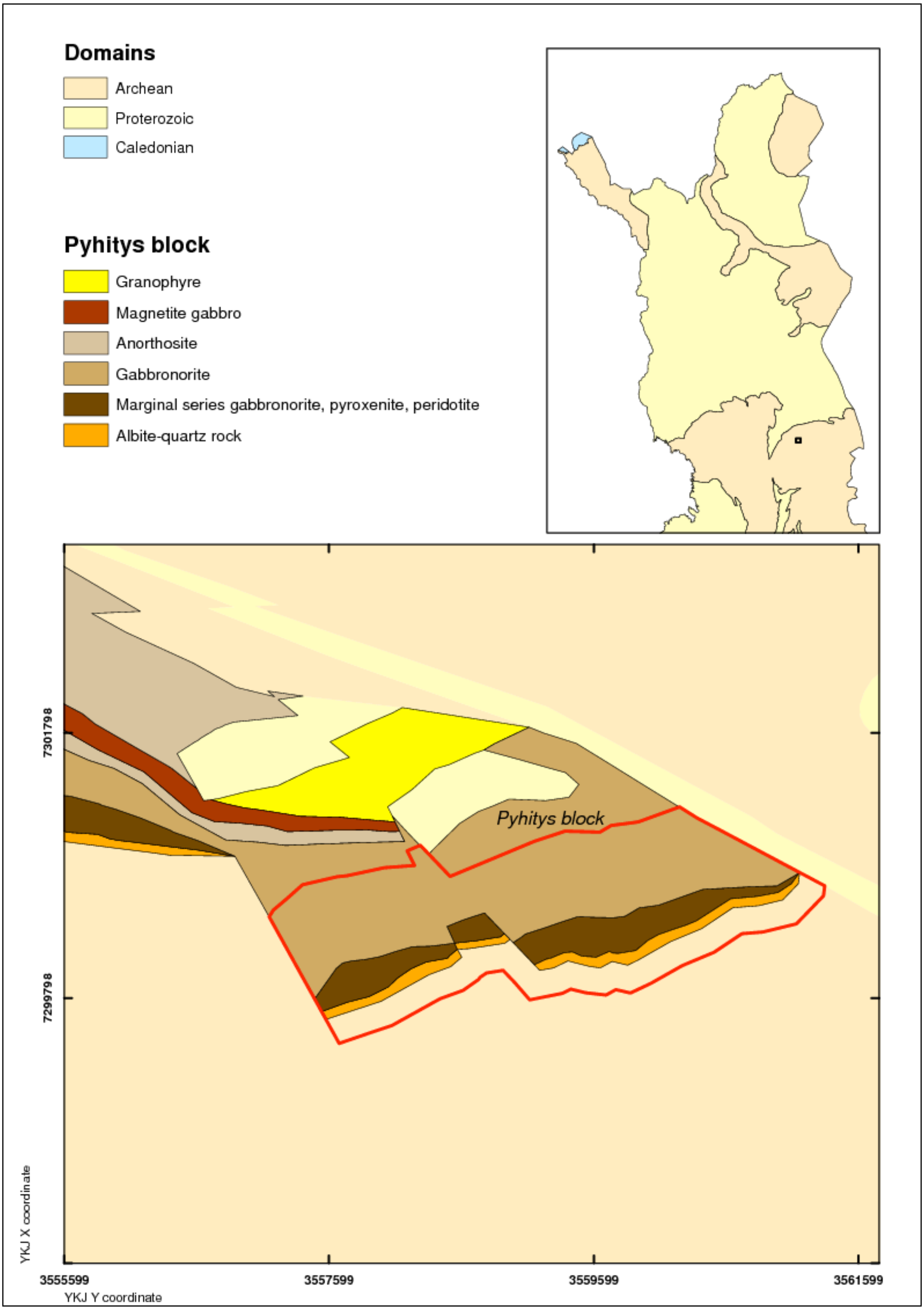

Figure 1. Location of the permissive tract PyhitysContactPGE.

Table 3. Principal sources of information used by the assessment team for PyhitysContactPGE.

Theme	Type of source	Scale	Citation
Geology	Geological description of the KLIC geology and then known mineral occurrences		Alapieti (1982), Iljina (2004)
	Geological map of the KLIC region	1:200 000	Räsänen et al. (2004)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
	PhD on geology and reef-type mineralisation in the Western Koillismaa Intrusion		Karinen (2010)
Mineral occurrences	NA		
Geochemistry	NA		
Geophysics	Ground-geophysical surveys; airborne TDEM survey		Iljina (2004), Nortec Ventures (2007)
Exploration	Summary report on exploration activities by Outokumpu		Lahtinen (1983)
	Detailed description of exploration activities in the area by GTK		Iljina (2004)

NA = not available.
KLIC = Kollismaa Layered Igneous Complex.

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

Geological factors that were used to estimate the number of undiscovered deposits included the geology of the intrusion, the distribution of the known deposits, and the available geophysical and drilling data (Tables 2 and 3).

No contact-type prospects are known within the tract. This means that the minimum number of undiscovered contact-type deposits within the tract is zero. A consensus was reached between the estimators: Poor detected PGE concentrations and the small size of the tract suggest poor prospects for undiscovered deposits. Roughly at the centre of the bottom of the intrusive block, there might be a small possibility for a deposit. The deposit number estimation results are listed in Table 4.

Table 4. Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for PyhitysContactPGE.

Consensus of undiscovered deposit estimate					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
0	0	1			0.30	0.50	170	0	0.30	4.0	0.075

Estimator	Estimated number of undiscovered deposits				
	N90	N50	N10	N05	N01
Estimator 1	0	0	1		
Estimator 2	0	0	1		
Estimator 3	0	0	1		
Consensus	0	0	1		

Nxx = Estimated number of deposits associated with the xxth percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; Deposit density = deposit density reported as the total number of deposits per km^2. N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were estimated by combining the means of estimated numbers of undiscovered contact-type PGE deposits with the Fennoscandian contact-type PGE grade and tonnage model (Appendix 2) using the EMINERS software (Root et al. 1992, Duval 2004). Selected simulation results are reported in Table 5. Results of the Monte Carlo simulation are presented as cumulative frequency plots (Figure 2). The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralized rock.

Table 5. Results of Monte Carlo simulations of undiscovered resources in PyhitysContactPGE.

Material	At least the indicated amount at the probability of					Mean	Probability of mean or greater	Probability of zero
	0.95	0.90	0.50	0.10	0.05			
Pt (t)	0	0	0	15	47	8	0.15	0.71
Pd (t)	0	0	0	63	170	31	0.13	0.71
Au (t)	0	0	0	7	15	3	0.15	0.71
Ni (t)	0	0	0	95,000	170,000	26,000	0.20	0.71
Cu (t)	0	0	0	140,000	340,000	48,000	0.19	0.71
Rock (Mt)	0	0	0	57	200	27	0.17	0.71

t = metric tonnes; Mt = millions of tonnes.

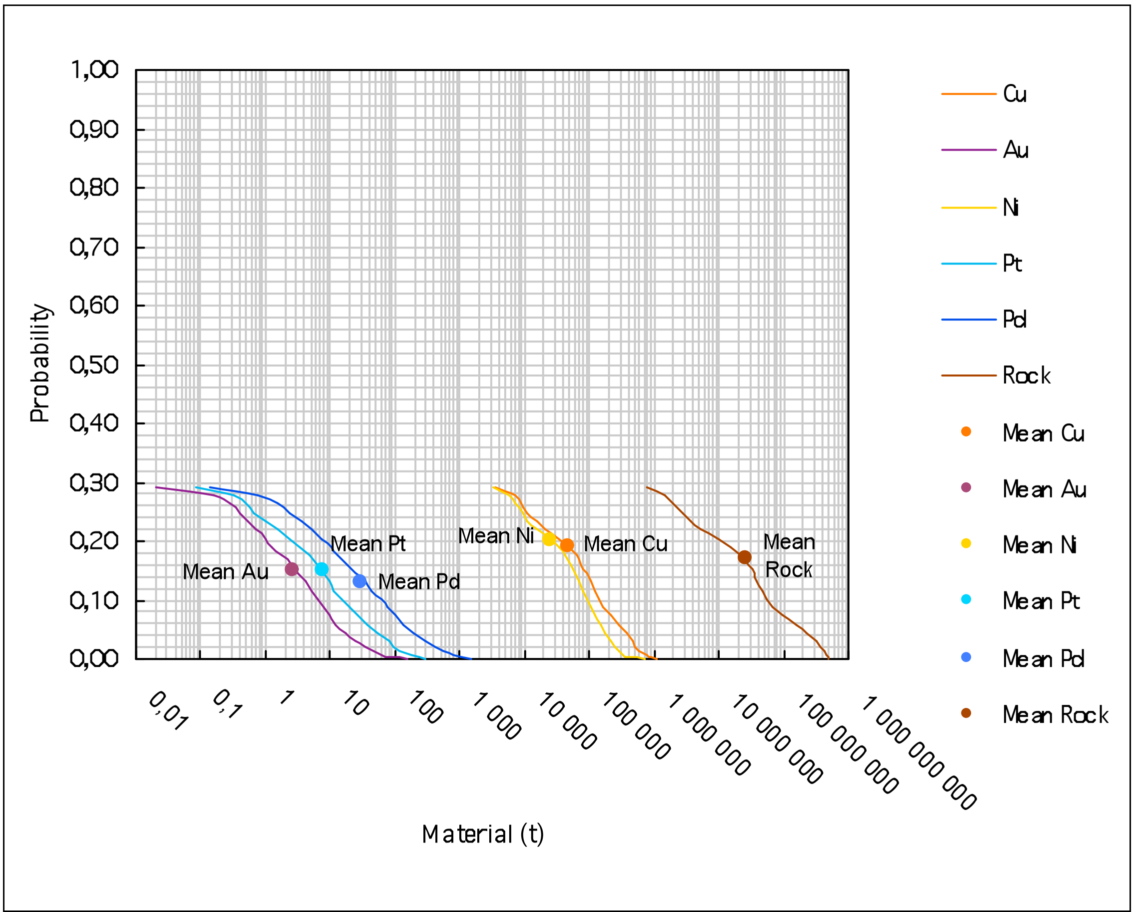

Figure 2. Cumulative frequency plot showing the results of Monte Carlo computer simulation of undiscovered resources in PyhitysContactPGE.

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CONTACT-TYPE PGE ASSESSMENT FOR TRACT RistijärviContactPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Contact-type Cu-Ni-PGE
Descriptive model: Fennoscandian contact-type Cu-Ni-PGE deposits (Appendix 1)
Grade and tonnage model: Fennoscandian contact-type Cu-Ni-PGE deposits (Appendix 2)

LOCATION AND RESOURCE SUMMARY

The Ristijärvi block of the 2.45 Ga Western Intrusion of the Koillismaa Complex is located in northern Finland in the municipality of Taivalkoski, 130 km southeast from the city of Rovaniemi. The 1:100 000 KKJ map sheets is 3541.The UTM map sheet containing the block is S5213. The PGE resource assessment carried out for this report is summarised in Table 1.

Table 1. Summary of selected resource assessment results for RistijärviContactPGE.

Date of assessment	Assessment depth (km)	Tract area (km^2)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
28.08–02.10.2008	1	1.2	Pt	0	Pt	0	Pt	0
			Pd	0	Pd	0	Pd	0
			Au	0	Au	0	Au	0
			Ni	0	Ni	0	Ni	0
			Cu	0	Cu	0	Cu	0

t = metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geologic criteria

The permissive tract delineated in Figure 1 is a surface projection of the basal contact zone of the Ristijärvi block. The geophysical anomalies indicate that the block is very shallow. Therefore, the permissive tract is delineated along the contact on the present erosion surface of the block. The delineation is based on a geological map by Räsänen et al. (2004), drilling (GTK in 1999) and geophysical information (local geophysical surveys performed by the GTK in 1998). The sources of information used in the delineation of the tract are summarized in Tables 3 and 4.

Known deposits

No contact-type PGE deposits are known within the tract.

Prospects, mineral occurrences, and related deposit types

One contact-type PGE prospect is known within the tract (Table 2 and Figure 1), the Ristijärvi occurrence at the southern margin of the block, in the typical marginal series rocks. It is incompletely delineated and no representative grade or tonnage information is available.

Table 2. Significant prospects and occurrences in RistijärviContactPGE.

Name	X coordinate	Y coordinate	Age (Ma)	Comments (grade and tonnage data, if available)	Reference
Ristijärvi (Ristivaara)	7295700	3539500	2.45		Iljina (2003)

The deposit age is derived from the assumed age of the Kaukua block based on age data from the Koillismaa Complex (Alapieti 1982).

Exploration history

Exploration in the Ristijärvi block area started in the mid-1960s when Outokumpu Oy commenced a mapping and drilling programme at Koillismaa. The Ristijärvi block was not drilled during that campaign, but was drilled later, in 1998, by GTK. The types of exploration work carried out at Ristijärvi, and known to us, are listed in Table 3.

Table 3. Exploration history for RistijärviContactPGE.

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Detailed bedrock mapping, outcrop sampling	Yes	Outokumpu	1965
Geochemical surveys	Not available			
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	1998
Ground geophysical surveys	Magnetic, VLF-R and IP survey		GTK	1998-2000
Drilling	Four diamond-drill holes, total 426.10 m	Yes	GTK	1998
Other	Regional research and mapping programme in the KLIC region.	No	Univ. Oulu	1971–1976
	Regional research and exploration programme in the KLIC region.	Yes	GTK	1996–2000

KLIC = Koillismaa Layered igneous Complex.

Sources of information

Principal sources of information used by the assessment team for the delineation of RistijärviContactPGE are listed in Table 4.

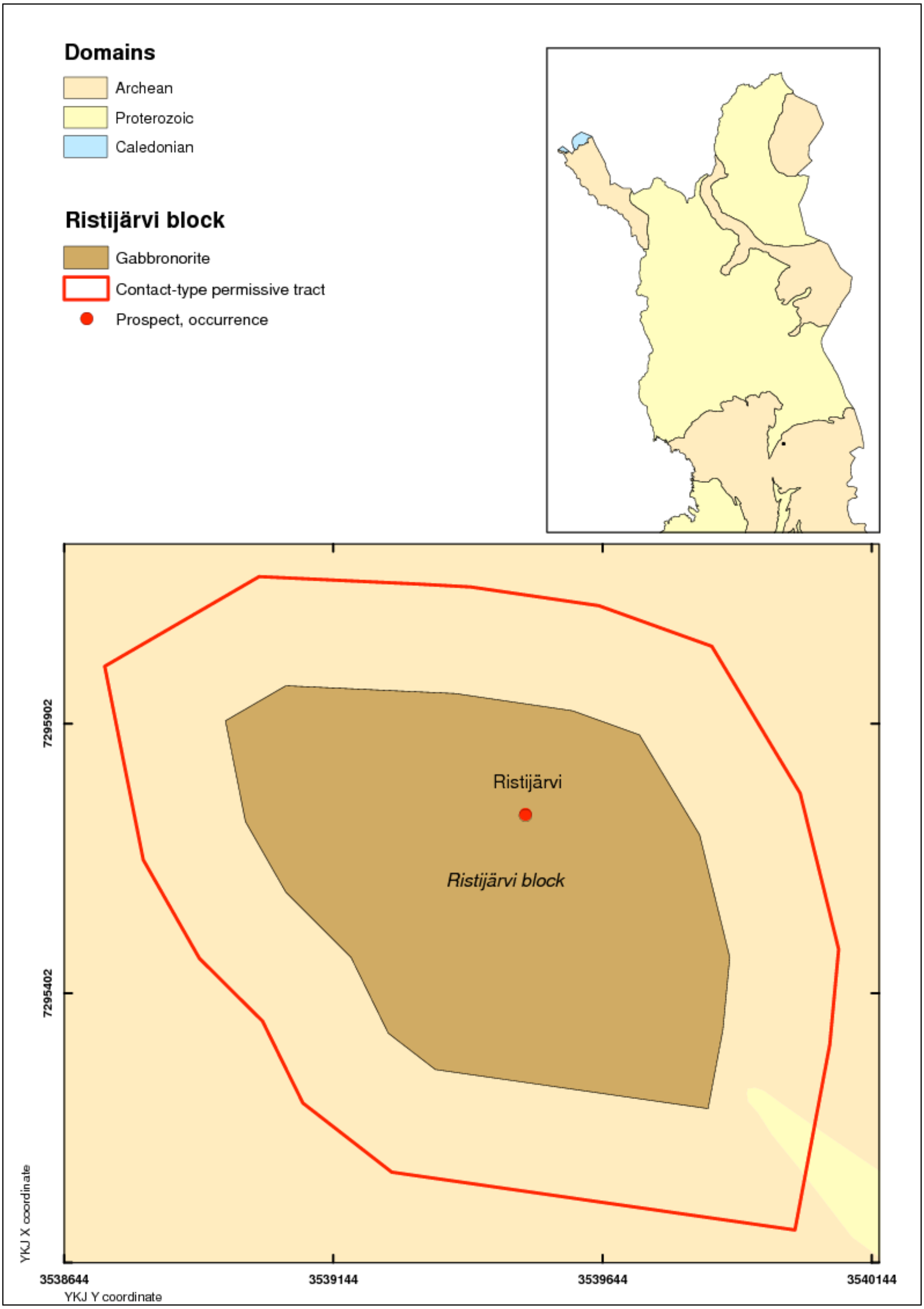

Figure 1. Location of the permissive tract RistijärviContactPGE.

Table 4. Principal sources of information used by the assessment team for RistijärviContactPGE.

Theme	Type of source	Scale	Citation
Geology	Geological description of the KLIC geology and the known mineral occurrences		Alapieti (1982), Iljina (2004), Iljina & Hanski (2005)
	Geological map of the KLIC region	1:200 000	Räsänen et al. (2004)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
	PhD on geology and reef-type mineralisation in the Western Koillismaa Intrusion		Karinen (2010)
Mineral occurrences	Description of the Ristijärvi PGE occurrence		Iljina (2003, 2004)
Geochemistry	Not available		
Geophysics	Geophysical surveys		Iljina (2004)
Exploration	Detailed description of exploration activities in the area by GTK		Iljina (2003, 2004)

KLIC = Kollismaa Layered Igneous Complex.

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

Geological factors that were used to estimate the number of undiscovered deposits included the geology of the intrusion, the distribution of the known deposits, and the available geophysical and drilling data (Tables 3 and 4).

One contact-type prospect is known from the tract (Table 2). This occurrence is, however, regarded as very small. In addition, the Ristijärvi block has a small horizontal and depth extent, and drilling and other types of exploration seem to cover the area so well that the estimators regarded the possibilities of finding a mineable deposit in the area as very small (Table 5).

Table 5. Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for RistijärviContactPGE.

Mean undiscovered deposit estimate					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
0	0	0			0	0			0	1.2	0

	Estimated number of undiscovered deposits				
Estimator	N90	N50	N10	N05	N01
Estimator 1	0	0	1		
Estimator 2	0	0	0		
Estimator 3	0	0	0		
Mean	0	0	0		

Nxx = Estimated number of deposits associated with the xx^{th} percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; Deposit density = deposit density reported as the total number of deposits per km^2. N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were not estimated, because the result of the assessment workshop suggested a zero mean probability for a deposit to occur within the tract.

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REEF-TYPE PGE ASSESSMENT FOR TRACT RistijärviReefPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Reef-type PGE-Ni-Cu
Descriptive model: Finnish reef-type PGE-Ni-Cu (Appendix 3)
Grade-tonnage model: Finnish reef-type PGE-Ni-Cu grade model, RistijärviReefPGE tonnage model (Appendix 4)

LOCATION AND RESOURCE SUMMARY

The Ristijärvi block of the Western intrusion of the Koillismaa Complex is located in northern Finland in the municipality of Taivalkoski, 130 km southeast from the city of Rovaniemi. The 1:100 000 KKJ map sheet is 3541.The UTM map sheet containing the block is S5213. The PGE resource assessment carried out for this report is summarised in Table 1.

Table 1. Summary of selected resource assessment results for RistijärviReefPGE

Date of assessment	Assessment depth (km)	Tract area (km²)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
29.08.2008	1	0.5	Pt	0	Pt	0	Pt	0
			Pd	0	Pd	0	Pd	0
			Au	0	Au	0	Au	0
			Ni	0	Ni	0	Ni	0
			Cu	0	Cu	0	Cu	0

t = metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

Airborne and local ground geophysical surveys indicate that the Ristijärvi intrusive block is very small and shallow. The block dips to the NW with an angle of about 50 degrees. Since the layered series of the Koillismaa Western Intrusion has been attributed to the Cr-poor magma type (Lahtinen et al. 1989), we assume the entire layered series potential for a PGE reef. Hence, the permissive tract (Figure 1) matches the surface projection the block. The delineation is based on a geological map by Räsänen et al. (2004), drilling and geophysical information. The sources of information used in the delineation of the tract are summarized in Table 3.

Known deposits

There are no well-explored reef-type PGE deposits within the Ristijärvi permissive tract.

Prospects, mineral occurrences, and related deposit types

There are no reef-type prospects within the Ristijärvi permissive tract.

Exploration history

Exploration in the Ristijärvi block area started in the mid-1960s when Outokumpu Oy commenced a mapping and drilling programme. The Ristijärvi block was not drilled during that programme, but was drilled later, in 1998, by GTK. The types of exploration work carried out in the area, and known to us, are listed in Table 2.

Table 2. Exploration history for RistijärviReefPGE.

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Detailed bedrock mapping, outcrop sampling	Yes	Outokumpu	1965
Geochemical surveys	Not available			
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	1998
Ground geophysical surveys	Magnetic, VLF-R and IP survey		GTK	1998–2000
Drilling	Four diamond-drill holes, total 426.10 m	Yes	GTK	1998
Other	Regional research and mapping programme in the KLIC region.	No	Univ. Oulu	1971–1976
	Regional research and exploration programme in the KLIC region.	Yes	GTK	1996–2000

KLIC = Koillismaa Layered igneous Complex.

Sources of information

Principal sources of information used by the assessment team for the delineation of RistijärviReefPGE are listed in Table 3.

Table 3. Principal sources of information used by the assessment team for RistijärviReefPGE.

Theme	Type of source	Scale	Citation
Geology	Geological description of the KLIC geology and the known mineral occurrences		Alapieti (1982), Iljina (2004), Iljina & Hanski (2005)
	Geological map of the KLIC region	1:200 000	Räsänen et al. (2004)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
	PhD on geology and reef-type mineralisation in the Western Koillismaa Intrusion		Karinen (2010)
Mineral occurrences	Description of the Ristijärvi PGE occurrence		Iljina (2003, 2004)
Geochemistry	Not available		
Geophysics	Geophysical surveys		Iljina (2004)
Exploration	Detailed description of exploration activities in the area by GTK		Iljina (2003, 2004)

KLIC = Koillismaa Layered Igneous Complex.

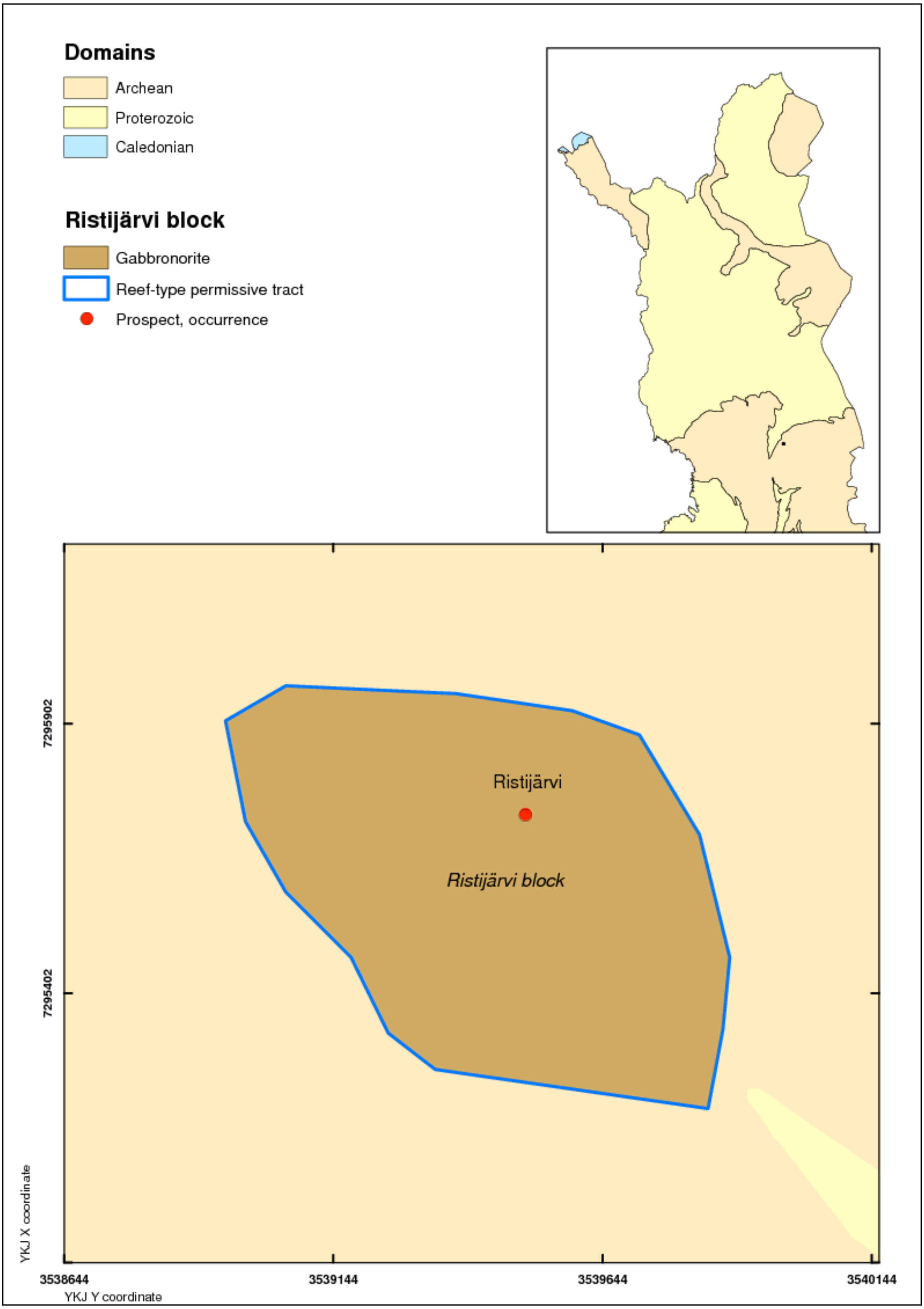

Figure 1. Location of the permissive tract RistijärviReefPGE.

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

Geological factors that were used to estimate the number of undiscovered deposits included the geology of the intrusion, the distribution of the known deposits, and the available geophysical and drilling data (Tables 2 and 3). The Ristijärvi block has a small horizontal and depth extent, and drilling and other types of exploration seem to cover the area so well that all the estimators regarded the possibilities of finding a mineable reef-type deposit in the area as negligible (Table 4).

Table 4. Undiscovered deposit estimates, deposit numbers, and tract area for RistijärviReefPGE.

Consensus of undiscovered deposit estimate					Summary statistics					Area (km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}	
0	0	0			0	0			0	0.5

Estimator	Estimated number of undiscovered deposits N90	N50	N10	N05	N01
Estimator 1	0	0	0		
Estimator 2	0	0	0		
Estimator 3	0	0	0		
Consensus	0	0	0		

Nxx = Estimated number of deposits associated with the xx^{th} percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were not estimated, because the result of the assessment workshop suggested a zero mean probability for a deposit to occur within the tract.

REFERENCES

Alapieti, T. 1982. The Koillismaa layered igneous complex, Finland – its structure, mineralogy and geochemistry, with emphasis on the distribution of chromium. Geological Survey of Finland, Bulletin 319. 116 p. + 1 map. Available online at: http://arkisto.gtk.fi/bul/bt319.pdf

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CONTACT-TYPE PGE ASSESSMENT FOR TRACT SuhankoContactPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Contact-type Cu-Ni-PGE
Descriptive model: Fennoscandian contact-type Cu-Ni-PGE deposits (Appendix 1)
Grade and tonnage model: Fennoscandian contact-type Cu-Ni-PGE deposits (Appendix 2)

LOCATION AND RESOURCE SUMMARY

The Suhanko layered intrusion is located in northern Finland in the municipality of Ranua, 45 km south-southwest from Rovaniemi. The 1:100 000 KKJ map sheets are 3522, 3524, 3611 and 3613. The UTM map sheets containing the intrusion are S4442 and T4331. The Suhanko intrusion denotes the single Suhanko body excluding the separate Konttijärvi body, which in some publications has been included in the Suhanko intrusion. The PGE resource assessment carried out for this report is summarised in Table 1.

Table 1. Summary of selected resource assessment results for SuhankoContactPGE

Date of assessment	Assessment depth (km)	Tract area (km²)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
22.05.–29.08.2008	1	35	Pt	28	Pt	93	Pt	64
			Pd	130	Pd	380	Pd	220
			Au	15	Au	34	Au	21
			Ni	120 000	Ni	320 000	Ni	290 000
			Cu	270 000	Cu	580 000	Cu	500 000

t = metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The permissive tract delineated in Figure 1 is a surface projection of the basal contact zone of the Suhanko intrusion, plus a 200 m buffer zone. On the surface, the delineation is based on unpublished geological maps by Iljina. At depth, the tract delineation is based on detailed gravity, electrical and electromagnetic measurements and a high resolution reflection seismic survey (Ketola 1982, Pernu et al. 1986, Rekola 1986, Iljina & Salmirinne 2008). The geophysical interpretation has been verified and adjusted by information from drilling, including one hole down to about 700 m in vertical depth within the Suhanko intrusion.

It is possible that at some area in the deepest, central part of the intrusion, an earlier megacyclic unit, possibly corresponding to MCU I or II of the Narkaus intrusion, which is just 20 km away from the Suhanko intrusion, forms the lowermost part of the intrusion. In such a case, the central part of the intrusion could not host contact-type deposits. However, due to the 200 m buffer zone, the tract also there contains possible offset type deposits, which are grouped together with the contact-type deposits in the descriptive model. Hence, no area from the central part of the Suhanko intrusion is excluded from the permissive tract. The sources of information used in the delineation of the tract are summarized in Table 5.

Known deposits

Erratically distributed, disseminated, PGE-enriched base metal sulphide occurrences, normally 10–30 m thick, are encountered throughout the Suhanko intrusion marginal series (Iljina 1994). The PGE concentrations generally vary from weakly anomalous to about 2 ppm, and up to over 10 ppm in places at Ahmavaara. The Ahmavaara deposit has some reef-type characteristics, but due to its location close to the base of the intrusion, it has been taken as a contact-type deposit. Three other contact-type PGE deposits are known within the tract: Niittylampi, Suhanko, and Vaaralampi (Table 2 and Figure 1). The deposit outlines for Ahmavaara and Konttijärvi in Figure 1 represent the extents of the planned open pits (Purich et al. 2007). For Suhanko, Vaaralampi and Niittylampi, the deposit outlines are deduced from Reino et al. (1978).

According to the spatial rule used in the definition of a contact-type PGE deposit, all ore bodies closer than 1 km to each other are counted as one deposit. Hence, from the viewpoint of the deposit model, two contact-type PGE deposits are known within the tract: Ahmavaara-Suhanko and Vaaralampi-Niittylampi. All four deposits are listed separately in Table 2, but in the assessment procedure, two known deposits were assigned to the tract.

The Niittylampi, Suhanko, and Vaaralampi deposits consist of massive sulphides with PGE grades, but the Ahmavaara deposit includes both massive and disseminated styles of mineralisation. Hence, the tonnages and concentrations given in Table 2 refer to massive sulphide ore in the cases of Niittylampi, Suhanko, and Vaaralampi, whereas those of the Ahmavaara include both massive and disseminated ore. In the massive sulphide part of Ahmavaara, the Pd concentration is 6.4 ppm and Pt 0.87 ppm (Lahtinen 1987).

There seems to be a general structural control for mineralisation at Suhanko, as all known massive sulphide deposits occur in areas where the basal contact of the intrusion is horizontal or has only a gentle dip (Iljina 1994). So far, no deposits have been detected in areas where the basal contact is steep.

Table 2. Known contact-type PGE deposits in SuhankoContactPGE. Only well-delineated deposits are included.

Name	X coordinate (YKJ)	Y coordinate (YKJ)	Age (Ga)	Tonnage (Mt)	Grade					Contained PGE (t)		Reference
					Cu (%)	Ni (%)	Pt (g/t)	Pd (g/t)	Au (g/t)			
Ahmavaara	7334600	3456700	2.44	187.8	0.17	0.07	0.17	0.82	0.10	Pt Pd	33.6 159.8	Puritch et al. (2007)
Niittylampi	7334750	3463950	2.44	0.85	0.49	0.67	0.30	0.70	0.01	Pt Pd	0.3 0.6	Lahtinen (1991)
Suhanko	7334700	3459200	2.44	1.0	0.31	0.20	0.20	1.0	0.04	Pt Pd	0.2 1.0	Lahtinen (1991)
Vaaralampi	7334000	3462900	2.44	6.0	0.20	0.31	0.20	0.55	0.06	Pt Pd	1.2 3.3	Lahtinen (1991)

Ga = billions of years; Mt = millions of metric tonnes; t = metric tonne; g/t = grams per metric tonne.
Contained PGE is computed as tonnage x grade.
Deposit ages are derived from the assumed age of the Suhanko intrusion based on age data from other layered intrusions in the Archaean-Proterozoic boundary zone (Alapieti 1982, Perttunen & Vaasjoki 2001).

Prospects, mineral occurrences, and related deposit types

One significant contact-type massive base metal-PGE prospect, in addition to those listed in Table 2, is known within the tract, the Yli-Portimojärvi occurrence at the eastern margin of the Suhanko intrusion (Table 3 and Figure 1). The occurrence consists of massive sulphides at the base of the marginal series and near the top of it, 165 m above the base, but no exact grade or tonnage information is available. Other PGE occurrences known in the Suhanko intrusion include the Rytikangas reef in the layered series, the PGE concentrations near the roof of the intrusion, and a platinum-anomalous pyroxenitic pegmatite pipe in the western limb of the intrusion.

Table 3. Significant prospects and occurrences in SuhankoContactPGE.

Name	X coordinate	Y coordinate	Age (Ma)	Comments (grade and tonnage data, if available)	Reference
Yli-Portimojärvi	7338000	3462500	2.44	Possibly 1–2 Mt @ about 0.5 ppm PGE, no decisive data is available	Iljina, pers. comm. (2009)

Exploration history

Exploration commenced in the Suhanko area in the early 1960s when Outokumpu Oy started to map and drill the marginal series targets in the area. Attention was drawn to the area by sulphide-bearing glacial erratic boulders. Within a few years, the Yli-Portimojärvi, Niittylampi, Vaaralampi and Suhanko proper massive sulphide deposits were found. The Ahmavaara deposit was discovered in 1986 by drilling. The exploration campaigns also revealed that all the deposits, except Ahmavaara, are rather low in Ni, Cu, and PGE. Later, at the beginning of 2000, exploration started again through a joint venture between Outokumpu Oy and Gold Fields Ltd. Outokumpu dropped out from the joint venture in 2003 and in 2006, North American Palladium Ltd formed a new joint venture with Gold Fields Ltd. Later, in August 2008, North American Palladium Ltd left the project. The exploration in the area has ceased at the time of writing of this report, but the deposits are still held by Gold Fields Ltd. The types of exploration work carried out in the area, and known to us, are listed in Table 4.

Table 4. Exploration history for SuhankoContactPGE.

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Detailed bedrock mapping, outcrop sampling	Yes	Outokumpu Oy	1960s–1980s
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric surveys		GTK	1982, 1986, 1987, 1992
Ground-geophysical surveys	Slingram, magnetic, IP, gravity, and other surveys		University of Oulu; Outokumpu Oy	1960s to 1980s
Geochemical surveys	None known			
Drilling	Over 100 diamond-drill holes 189 diamond drill holes, 13617 m 1053 diamond drill holes, 119963 m	No Yes Yes	Outokumpu Oy Outokumpu Oy GFAP	1964–1978 1981–1995 2000–

GFAP = Gold Fields Arctic Platinum Oy and its precursor, Arctic Platinum Partnership Ay.

Sources of information

The principal sources of information used here are listed in the Table 5. The source references comprise various in-house company reports and one Ph.D. study, in addition to excursion guidebooks.

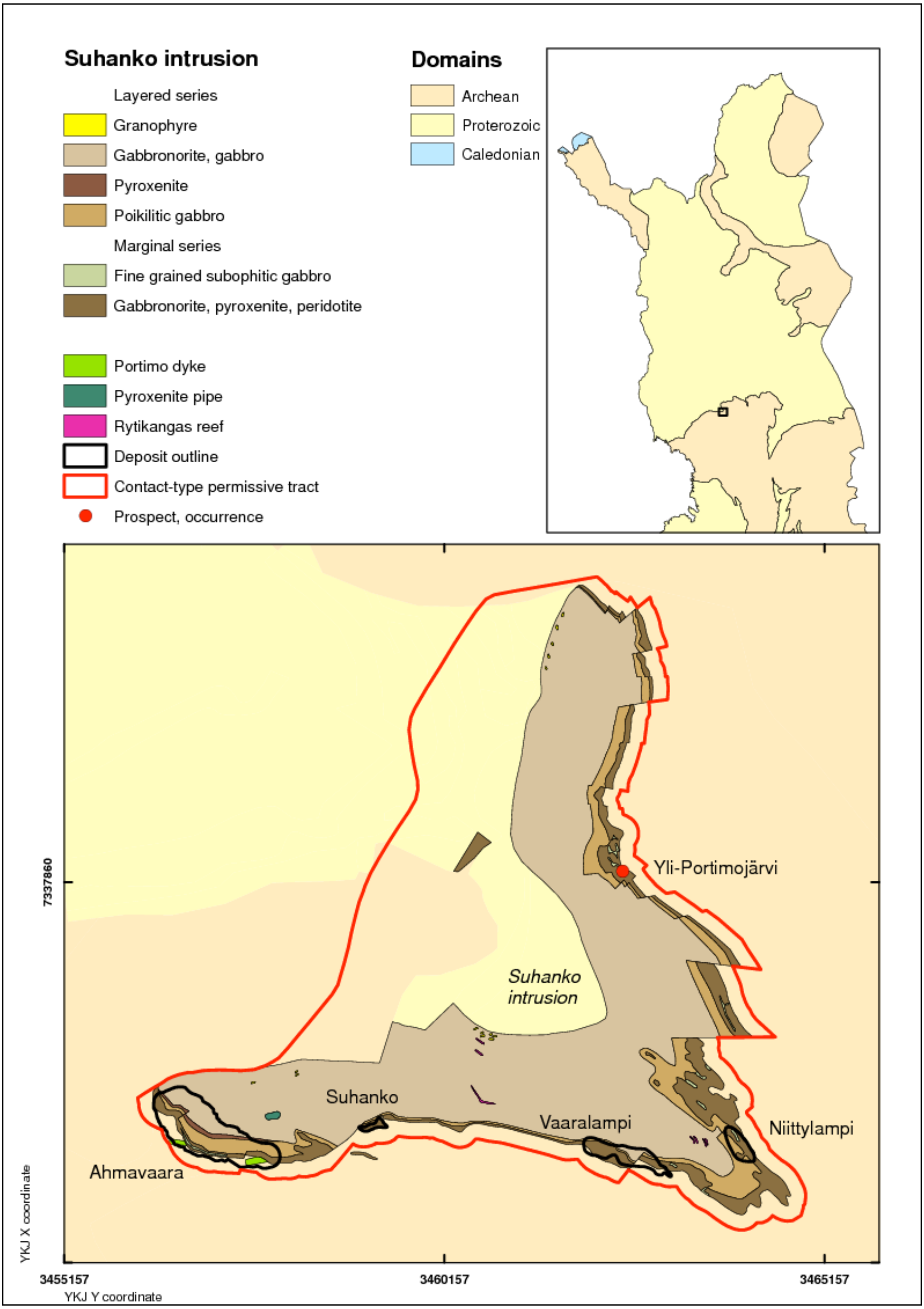

Figure 1. Location of the permissive tract SuhankoContactPGE. The map is compiled from unpublished maps by Iljina and Gold Fields Arctic Platinum Oy.

Table 5. Principal sources of information used by the assessment team for SuhankoContactPGE.

Theme	Type of source	Scale	Citation
Geology	PhD thesis on Portimo intrusion geology and mineral occurrences. Excursion guidebooks		Iljina (1994, 2005, 2007), Iljina & Lee (2005)
	Geological map of the Portimo complex	1:100 000–1:20 000	Iljina (1994), Iljina (unpublished)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
Mineral occurrences	PhD thesis on Portimo intrusion geology and mineral occurrences. Excursion guidebooks.		Iljina (1994, 2005, 2007, 2008)
	Suhanko occurrences preliminary assessment		Reino et al. (1978), Lahtinen (1987), Eerola et al. (1990), Lahtinen (1991)
	Suhanko NI 43-101 Scoping Study		Puritch et al. (2007)
Geophysics	Magnetic, electric, electromagnetic and gravity surveys at Suhanko, Vaaralampi and Niittylampi		Ketola (1982, Pernu et al. (1986), Rekola (1986)
	High resolution reflection seismic measurements.		Iljina & Salmirinne (2008)
Exploration	General description of exploration activities in the area.		Reino et al. (1978), Lahtinen (1983), Lahtinen (1987), Lahtinen (1991), Puritch et al. (2007)

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

The existence of two known contact-type deposits (Ahmavaaara-Suhanko, Vaaralampi-Niittylampi) and one significant prospect (Yli-Portimojärvi) systematically along the exposed margin of the Suhanko intrusion at the present erosion surface suggests the potential for further deposits within the marginal series at depth. This is further supported by the fact that erratically distributed disseminations of PGE-bearing base metal sulphides are encountered throughout the Suhanko intrusion marginal series. The existence of other types of PGE occurrences mentioned above also testifies to the PGE potential of the entire Suhanko intrusion. Exploration has concentrated on the known deposits and their immediate surroundings; at depth, the basal contact of the intrusion has not been systematically explored by drilling.

Based on the average distance between the known contact-type deposits along the margin of the Suhanko intrusion, we calculated that there could be up to one deposit per 3 km^2 within the permissive tract. The calculated area of the basal contact of the intrusion is 34 km^2, and area of the surface projection of the permissive tract is 31.2 km^2. Hence, the maximum number of undiscovered deposits that could exist within the tract is 9.

Despite discussions, consensus was not reached on the estimated number of undiscovered deposits. This was mostly due to the differing opinions of the estimators concerning the likelihood of existence and possible spatial extent of an earlier megacyclic unit at the lowermost, central part of the intrusion. Within the area of this unit, the probability of existence of undiscovered deposits would be diminished. After discussions, mean values of the estimates were used as inputs to the Eminers software.

The mean value of the estimated number of undiscovered deposits at various probability levels and the values given by individual estimators are presented in Table 6. The expected number of deposits, its standard deviation, and the coefficient of variation, also given in Table 6, were calculated by the Eminers software from the undiscovered deposit estimates using a regression equation (Singer & Menzie 2005).

Table 6. Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for SuhankoContactPGE.

Mean of undiscovered deposits					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
2	4	5			3.6	1.2	33	4	7.6	35	0.22

	Estimated number of undiscovered deposits				
Estimator	N90	N50	N10	N05	N01
Estimator 1	2	4	5		
Estimator 2	2	4	6		
Estimator 3	2	3	5		
Mean	2	4	5		

Nxx = Estimated number of deposits associated with the xxth percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; Deposit density = deposit density reported as the total number of deposits per km^2. N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were estimated by combining the means of undiscovered contact-type PGE deposit estimates at various probability levels with the Fennoscandian contact-type PGE grade and tonnage model (Appendix 2) using the Eminers software (Root et al. 1992, Duval 2004). Selected simulation results are reported in Table 7. Results of the Monte Carlo simulation are presented as cumulative frequency plots (Figure 2). The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralized rock.

Table 7. Results of Monte Carlo simulations of undiscovered resources in SuhankoContactPGE.

Material	At least the indicated amount at the probability of					Mean	Probability of mean or greater	Probability of zero
	0.95	0.90	0.50	0.10	0.05			
Pt (t)	1	6	64	220	280	93	0.38	0.04
Pd (t)	2	19	220	1,000	1,400	380	0.33	0.04
Au (t)	0	3	21	84	110	34	0.35	0.04
Ni (t)	10,000	60,000	290,000	610,000	730,000	320,000	0.45	0.04
Cu (t)	13,000	86,000	500,000	1,200,000	1,400,000	580,000	0.43	0.04
Rock (Mt)	3	28	260	720	900	330	0.43	0.04

t = metric tonnes; Mt = millions of tonnes.

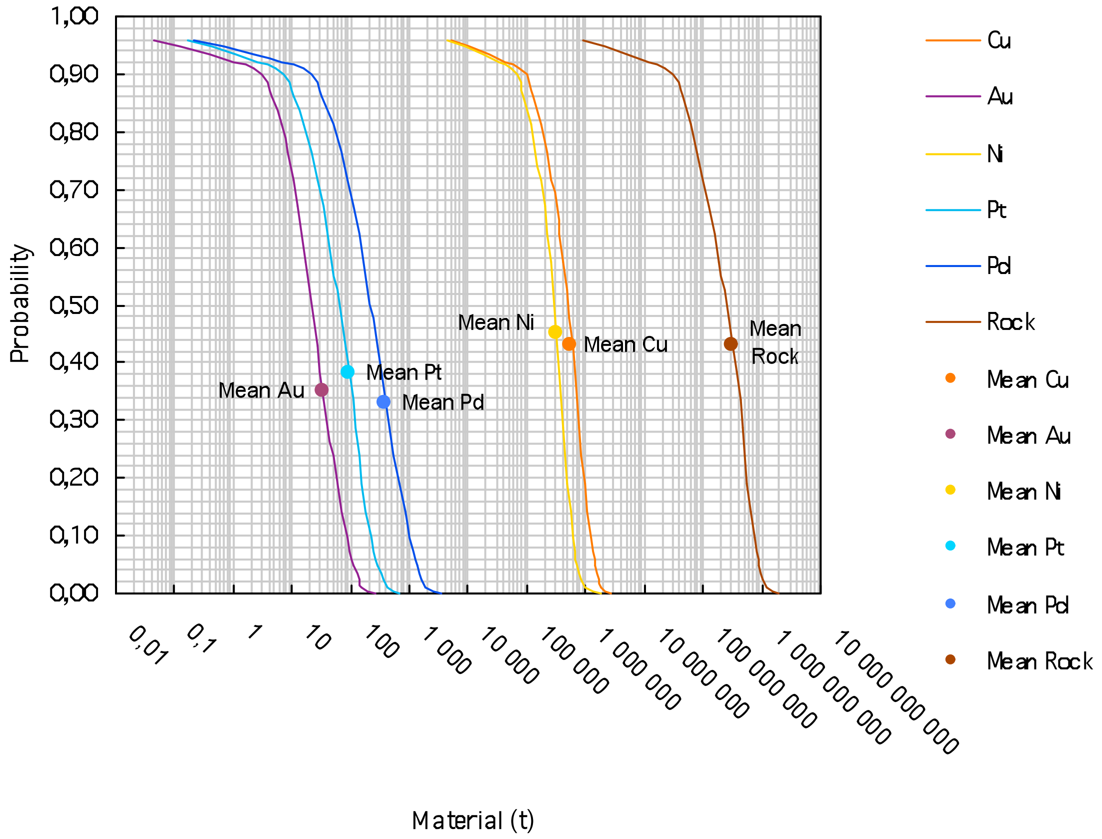

Figure 2. Cumulative frequency plot showing the results of Monte Carlo computer simulation of undiscovered resources in Suhanko-ContactPGE.

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REEF-TYPE PGE ASSESSMENT FOR TRACT SuhankoReefPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Reef-type PGE-Ni-Cu
Descriptive model: Finnish reef-type PGE-Ni-Cu (Appendix 3)
Grade-tonnage model: Finnish reef-type PGE-Ni-Cu grade model, SuhankoReefPGE tonnage model (Appendix 4)

LOCATION AND RESOURCE SUMMARY

The Suhanko layered intrusion is located in northern Finland in the municipality of Ranua, 45 km south-southwest from Rovaniemi. The 1:100 000 KKJ map sheets are 3522, 3524, 3611 and 3613. The UTM map sheets containing the intrusion are S4442 and T4331. The Suhanko intrusion denotes the single Suhanko body excluding the separate Konttijärvi body, which in some publications has been included into the Suhanko intrusion. The PGE resource assessment carried out for this report is summarised in Table 1.

Table 1. Summary of selected resource assessment results for SuhankoReefPGE.

Date of assessment	Assessment depth (km)	Tract area (km²)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
22.05.–29.08.2008	1	23	Pt	0	Pt	490	Pt	240
			Pd	0	Pd	890	Pd	470
			Au	0	Au	21	Au	13
			Ni	0	Ni	130,000	Ni	100,000
			Cu	0	Cu	170,000	Cu	100,000

t = metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

Most of the Suhanko intrusion is subhorizontal; in the northern parts there is a gentle dip to the west and in the western parts to the north. The permissive tract (Figure 1) has been drawn to cover the middle and upper part of the intrusion stratigraphy. The depth extent of the intrusion has been interpreted using a regional gravity survey (4 points/km^2), magnetic ground surveys and a high resolution reflection seismic survey. Interpretation of the thickness of the intrusion has locally been verified by drilling (Iljina & Salmirinne 2008). The sources of information used in the delineation of the tract are summarised in Table 4.

Known deposits

There are no well-explored reef-type PGE deposits within the Suhanko permissive tract. A note should be made that the Ahmavaara deposit at the western end of the intrusion may, in fact, be a reef-type deposit located close to the base of the intrusion, but which due to this location has been included in this work in the contact-type assessment.

Prospects, mineral occurrences, and related deposit types

Reef-type PGE occurrences at Suhanko include four poikilitic leucogabbro-anorthosite layers. The lowermost of these, the Rytikangas Reef (RK), locally has high grades and thickness, and hence is possibly economic (Table 2). In addition, mixed granophyre-gabbropegmatite dykes and irregular segregations have been found to carry PGE up to a few ppm at Suhanko.

Table 2. Significant prospects and occurrences in SuhankoReefPGE.

Name	X coordinate	Y coordinate	Age (Ma)	Comments (grade and tonnage data, if available)	Reference
RK Reef	7335200	3460200	2.45	At least locally a few g/t PGE	Iljina (1994)

Exploration history

Exploration commenced in the Suhanko area in the early 1960s when Outokumpu Oy started to map and drill the marginal series targets in the area. Attention was drawn to the area by sulphide-bearing glacial erratic boulders. Within a few years, a set of contact-type deposits were found. Exploration for the reef-type PGE deposits started in the mid-1980s by outcrop mapping and reanalysis of old drill cores. This work resulted in the discovery of the RK Reef. This reef was subsequently investigated by diamond drilling (Table 3).

Table 3. Exploration history for Suhanko intrusion.

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Detailed bedrock mapping, outcrop sampling	Yes	Outokumpu	1980s
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric surveys		GTK	1982, 1986, 1987, 1992
Ground-geophysical surveys	Slingram, magnetic, IP, gravity, and other surveys		Univ. Oulu, Outokumpu	1980s
Geochemical surveys	None known			
Drilling	About 10 diamond-drill holes, 800 m	Yes	Outokumpu	1988–
	Several diamond-drill holes	Yes	GFAP	1990 2000–

Drilling listed only refers to work on reef-type mineralisation.

GFAP = Gold Fields Arctic Platinum Oy and its precursor, Arctic Platinum Partnership Ay.

Sources of information

The principal sources of information used by the assessment team for the delineation of SuhankoReefPGE are listed in Table 4.

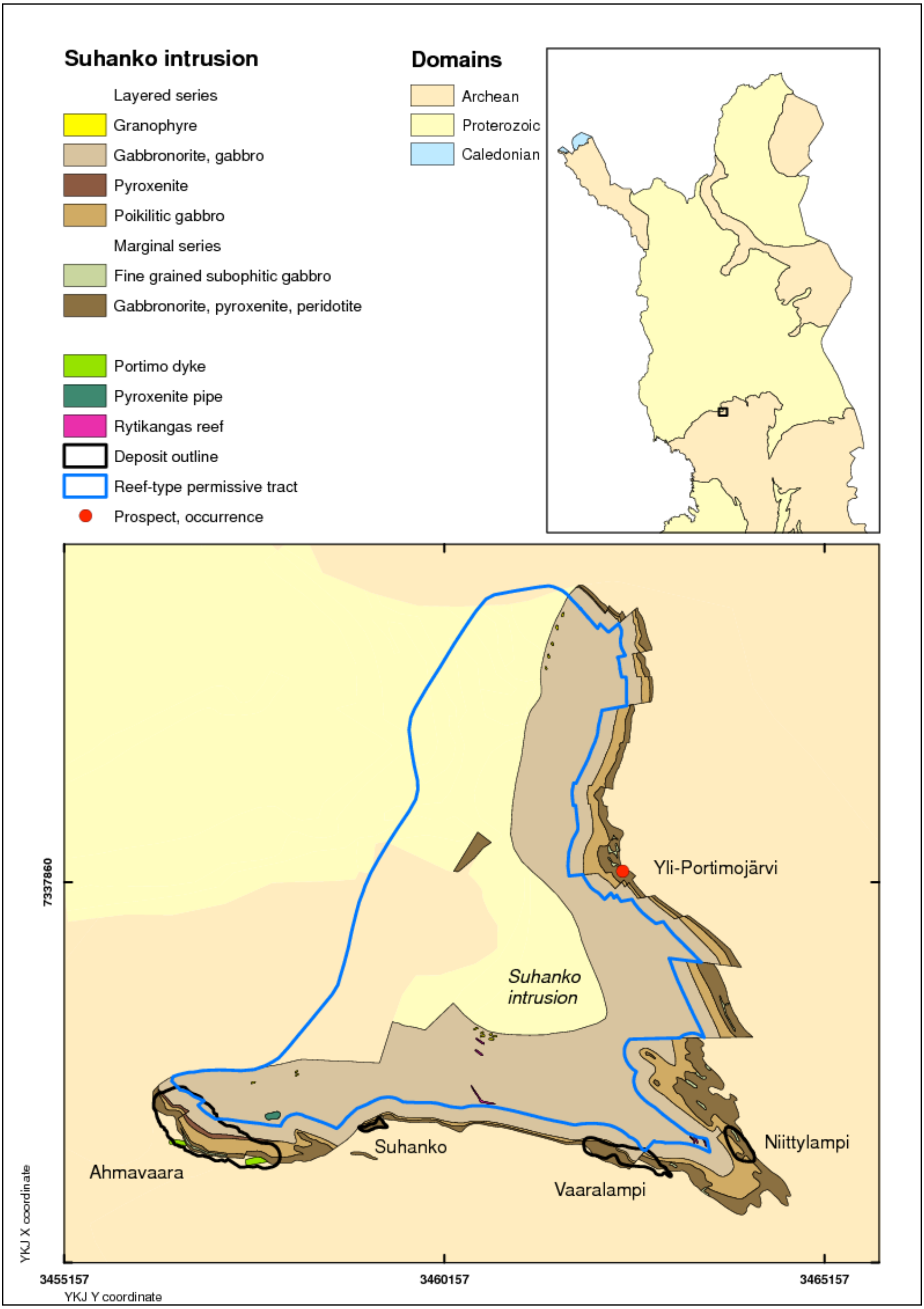

Figure 1. Location of the permissive tract SuhankoReefPGE.

Table 4. Principal sources of information used by the assessment team for SuhankoReefPGE.

Theme	Type of source	Scale	Citation
Geology	PhD thesis on Portimo intrusion geology and mineral occurrences. Excursion guidebooks		Iljina (1994, 2005, 2007)
	Geological map of the Portimo complex	1:100 000–1:20 000	Iljina (1994), Iljina (unpublished)
Mineral occurrences	PhD thesis on Portimo intrusion geology and mineral occurrences. Excursion guidebooks.		Iljina (1994, 2005, 2007, 2008)
	Suhanko occurrences preliminary assessment		Reino et al. (1978)
	Preliminary assessment		Lahtinen (1987)
Geophysics	Magnetic, electric, electromagnetic and gravity surveys at Suhanko, Vaaralampi and Niittylampi		Ketola (1982), Pernu et al. (1986), Rekola (1986)
	High resolution reflection seismic measurements.		Iljina & Salmirinne (2008)
Exploration	General description of exploration activities in the area.		Reino et al. (1978), Lahtinen (1983), Lahtinen (1987), Puritch et al. (2007)

NA = not available.

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

Geological factors that were used to estimate the number of undiscovered deposits included the geology of the intrusion, the distribution of the known occurrences, and the available geophysical and drilling data (Tables 3 and 4).

Consensus was reached between the estimators in assessing of the number of undiscovered deposits (Table 5). The numbers of undiscovered deposits include the RK Reef and indications of another reef at the boundary between two megacyclic units in the deep central part of the intrusion.

Table 5. Undiscovered deposit estimates, deposit numbers, and tract area for SuhankoReefPGE.

Consensus undiscovered deposit estimate					Summary statistics					Area (km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}	
2	2	2			1.9	0.22	12		1.9	23

Estimator	N90	N50	N10	N05	N01
	Estimated number of undiscovered deposits				
Estimator 1	2	2	2		
Estimator 2	2	2	2		
Estimator 3	2	2	2		
Consensus	2	2	2		

Nxx = Estimated number of deposits associated with the xx^{th} percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were calculated by combining the undiscovered deposit estimates with the Finnish reef-type PGE grade model and the SuhankoReefPGE tonnage model (Appendix 4) using the EMINERS software (Root et al. 1992, Duval 2004). Selected simulation results are reported in Table 6. Results of the Monte Carlo simulation are presented as cumulative frequency plots (Figure 2). The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralized rock.

Table 6. Results of Monte Carlo simulations of undiscovered resources in SuhankoReefPGE.

Material	At least the indicated amount at the probability of					Mean	Probability of mean or greater	Probability of zero
	0.95	0.9	0.5	0.1	0.05			
Pt (t)	19	51	240	1,100	1,800	490	0.27	0.04
Pd (t)	48	110	470	2,000	3,000	890	0.28	0.04
Au (t)	1	3	13	48	67	21	0.32	0.04
Ni (t)	16,000	30,000	100,000	280,000	360,000	130,000	0.37	0.04
Cu (t)	5,200	17,000	100,000	400,000	550,000	170,000	0.33	0.04
Rock (Mt)	24	45	140	360	430	170	0.39	0.04

t = metric tonnes; Mt = millions of tonnes.

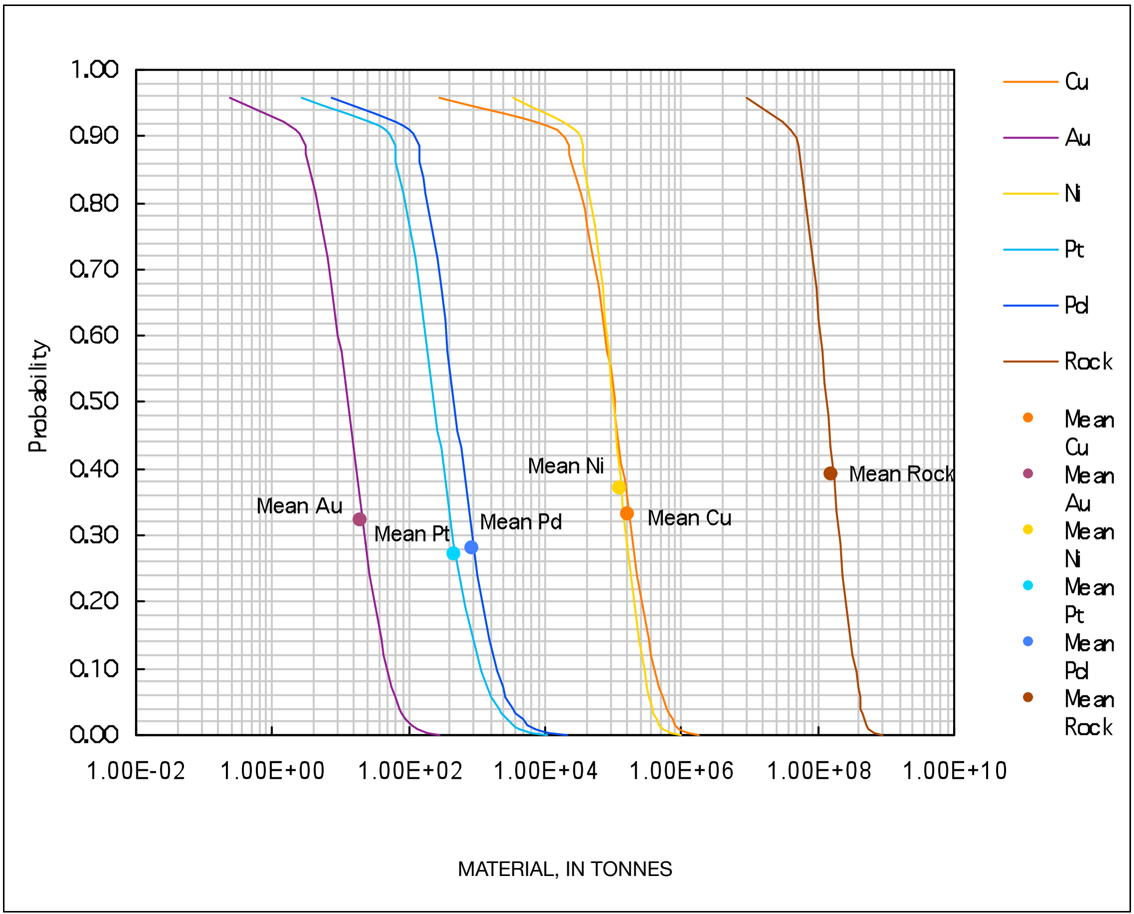

Figure 2. Cumulative frequency plot showing the results of Monte Carlo computer simulation of undiscovered resources in SuhankoReefPGE.

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CONTACT-TYPE PGE ASSESSMENT FOR TRACT SyöteContactPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Contact-type Cu-Ni-PGE
Descriptive model: Fennoscandian contact-type Cu-Ni-PGE deposits (Appendix 1)
Grade and tonnage model: Fennoscandian contact-type Cu-Ni-PGE deposits (Appendix 2)

LOCATION AND RESOURCE SUMMARY

The Syöte block of the Western Intrusion of the Koillismaa Complex locates in the northern Finland in the municipalities of Pudasjärvi and Taivalkoski, about 130 km NE from the city of Oulu and 130 km SE from the city of Rovaniemi. Within the 1:100 000 map sheets the tract SyöteContactPGE lies in the sheets 3532, 3541 and 3543. In the UTM sheets the block locates in the sheets S5123 and S5124. The PGE resource assessment carried out for this report is summarised in Table 1.

Table 1. Summary of selected resource assessment results for SyöteContactPGE

Date of assessment	Assessment depth (km)	Tract area (km²)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
26.08.–30.09.2008	1	62	Pt	0	Pt	75	Pt	43
			Pd	0	Pd	310	Pd	150
			Au	0	Au	28	Au	16
			Ni	0	Ni	260,000	Ni	230,000
			Cu	0	Cu	480,000	Cu	370,000

t = metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The permissive tract shown in Figure 1 is a surface projection of the basal contact zone of the Syöte block. On the surface, the tract delineation is based on a geological map by Räsänen et al. (2004) and on information gathered by diamond drilling (by GTK). The entire SE margin of the Syöte block is a fault and shear zone (Iljina 2004). Drilling and gravity data indicate that the intrusive block dips at 20–30° to the NW and extends beyond 1 km depth. The sources of information used in the delineation of the tract are summarised in Table 4.

Known deposits

No contact-type PGE deposits are known within the tract.

Prospects, mineral occurrences, and related deposit types

One offset-type occurrence has been detected in outcrop (but not in drill core) from the permissive tract (Table 2). Diamond drill cores show that the SE contact of the block, where the Lehtovaara prospect is located, is strongly deformed. Low-grade contact-type mineralisation has also been detected in the Lehtovaara area of the Syöte block.

Table 2. Significant prospects and occurrences in SyöteContactPGE

Name	X coordinate	Y coordinate	Age (Ma)	Comments (grade and tonnage data, if available)	Reference
Lehtovaara	7284750	3536750	2.45*	1.78 g/t Au, 4.72 g/t Pd, 1.91 g/t Pt, 1.4% Ni, 8.7% Cu; analysis from a grab sample	Iljina (2004)

*The deposit age is derived from the assumed age of the Syöte Block based on age data from the Koillismaa Complex (Alapieti 1982).

Exploration history

Exploration commenced in the Syöte area in 1960 when GTK started regional exploration at Koillismaa. This was soon followed by Outokumpu and briefly (1980) by Rautaruukki who mapped and did outcrop sampling in the area. Attention was drawn to the area by sulphide-bearing glacial erratic boulders detected by GTK in 1960. In 1996, GTK returned to the Koillismaa area and operated until 2002. The Lehtovaara area was studied by ground geophysics and diamond drilling. NAN operated in the Southern Syöte area, about 10 km SW from the Lehtovaara prospect, in 2001 with low-altitude airborne magnetic, ground geophysics and by drilling one diamond drill core. The exploration work carried out in the area is listed in Table 3.

Table 3. Exploration history for SyöteContactPGE.

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Detailed bedrock mapping, outcrop sampling.	Some	Outokumpu	1960s
	Bedrock mapping.	No	Suomen Malmi Oy	1966
	Bedrock mapping.	Yes	Rautaruukki Oy	1980s
Geochemical surveys	Not available			
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	1998
	Low-altitude airborne magnetic and electromagnetic survey		NAN	2000
Ground geophysical surveys	Gravity survey line		Univ Oulu	1971
	VLF-R, magnetic, and IP surveys at Lehtovaara		GTK	1996
	Magnetic, IP and TEM		NAN	2001
	Regional gravity survey		GTK	1999–2001, 2003, 2004
Drilling	4 Diamond drill cores 524,15 m	No*	Univ. Oulu	1973
	35 diamond-drill holes, total about 2000 m	Yes	GTK	1997
	1 diamond-drill hole, total 197.70 m	Yes	NAN	2001
Other	Regional research and mapping programme in the KLIC region.	No	Univ. Oulu	1971–1976
	Regional research and exploration programme in the KLIC region.	Yes	GTK	1996–2000

*Analysed later by GTK.
NAN = North Atlantic Natural Resources.
KLIC = Koillismaa Layered Igneous Complex.

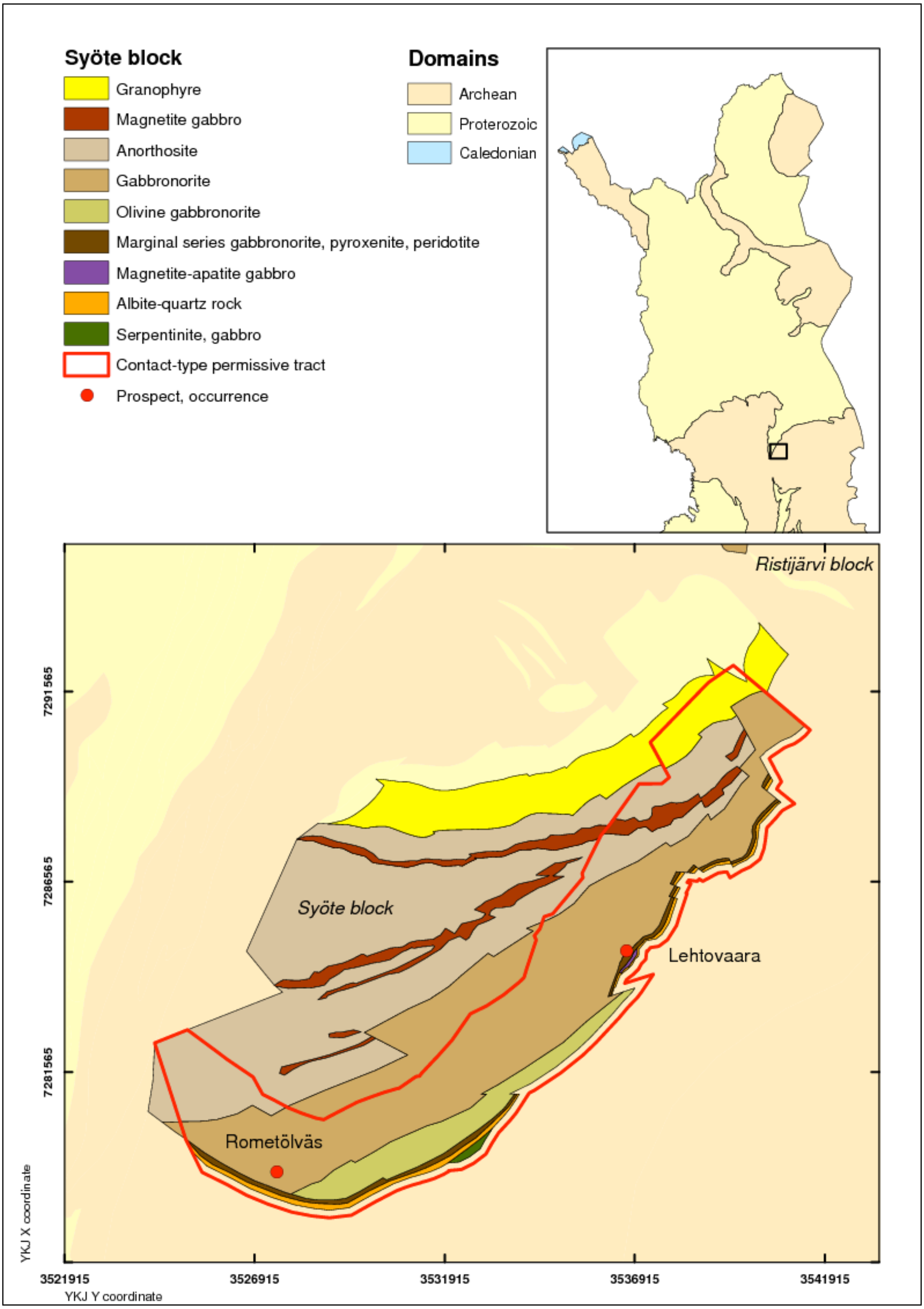

Figure 1. Location of the permissive tractSyöteContactPGE.

Sources of information

Principal sources of information used by the assessment team for delineation of the Syöte Contact tract are listed in Table 4.

Table 4. Principal sources of information used by the assessment team for SyöteContactPGE

Theme	Type of source	Scale	Citation
Geology	Geological description of the KLIC and then known mineral occurrences		Piirainen et al. (1974, 1978), Juopperi (1977), Alapieti (1982)
	Geological and mineralogical description of the Syöte intrusive block		Alapieti et al. (1979)
	Geological description of the KLIC and the known mineral occurrences		Iljina (2004)
	Geological map of the KLIC region	1:200 000	Räsänen et al. (2004)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
	PhD on geology and reef-type mineralisation in the Western Koillismaa Intrusion		Karinen (2010)
Mineral occurrences	Description of mineralised localities		Iljina (2004)
Geochemistry	Not available		
Geophysics	Magnetic and IP survey		Iljina (2004)
Exploration	Description of exploration activities in the area by Rautaruukki and Outokumpu		Lahtinen (1983)
	Detailed description of exploration activities in the area by GTK, general description of work by NAN		Iljina (2004)

KLIC = Kollismaa Layered Igneous Complex.

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

Geological factors that were used to estimate the number of undiscovered deposits included the geology of the intrusion, the distribution of the known deposits, and the available geophysical and drilling data (Tables 3 and 4).

By surface area, Syöte is the largest block of the Koillismaa Intrusion. This is due to the low-angled dip of the block and to the extensive repetition of the igneous sequence within the block, as indicated by several layers of magnetite gabbro at Syöte. These features also make the permissive tract large and increase its potential for contact-type PGE deposits. On the other hand, the 3D-model for the intrusive (Karinen & Salmirinne 2001) suggests that the Syöte Block is a continuation of the western part of the Porttivaara Block, which is not very prospective for PGE. Only one offset-type and a low-grade contact-type occurrence are known within the Syöte permissive tract. This means that the minimum number of undiscovered contact-type deposits within the tract is zero. As there are a number of positive and negative indications of PGE potential within the block, no consensus between the estimators was achieved, and a mean had to be calculated to be used in the tonnage and grade simulations. In addition to the estimates given below (Table 5), the indications of offset mineralisation and the extensive deformation at and around the SE contact zone suggest a possibility of a significant offset-style occurrence at Syöte (Iljina 2004).

Table 6. Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for SyöteContactPGE.

Mean undiscovered deposit estimate					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
1	3	5			2.9	1.5	51	0	2.9	62	0.048

Estimator	Estimated number of undiscovered deposits				
	N90	N50	N10	N05	N01
Estimator 1	1	3	4		
Estimator 2	2	4	6		
Estimator 3	1	2	4		
Mean	1	3	5		

Nxx = Estimated number of deposits associated with the xxth percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; Deposit density = deposit density reported as the total number of deposits per km^2. N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were estimated by combining the means of estimated numbers of undiscovered contact-type PGE deposits with the Fennoscandian contact-type PGE grade and tonnage model (Appendix 2) using the EMINERS software (Root et al. 1992, Duval 2004). Selected simulation results are reported in Table 6. Results of the Monte Carlo simulation are presented as cumulative frequency plots (Figure 2). The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralized rock.

Table 6. Results of Monte Carlo simulations of undiscovered resources in SyöteContactPGE

Material	At least the indicated amount at the probability of					Mean	Probability of mean or greater	Probability of zero
	0.95	0.90	0.50	0.10	0.05			
Pt (t)	0	1	43	200	260	75	0.37	0.07
Pd (t)	0	3	150	870	1 200	310	0.32	0.07
Au (t)	0	1	16	74	100	28	0.33	0.07
Ni (t)	0	12,000	230,000	540,000	660,000	260,000	0.43	0.07
Cu (t)	0	17,000	370,000	1,100,000	1,300,000	480,000	0.41	0.07
Rock (Mt)	0	4	170	620	800	270	0.40	0.07

t = metric tonnes; Mt = millions of tonnes.

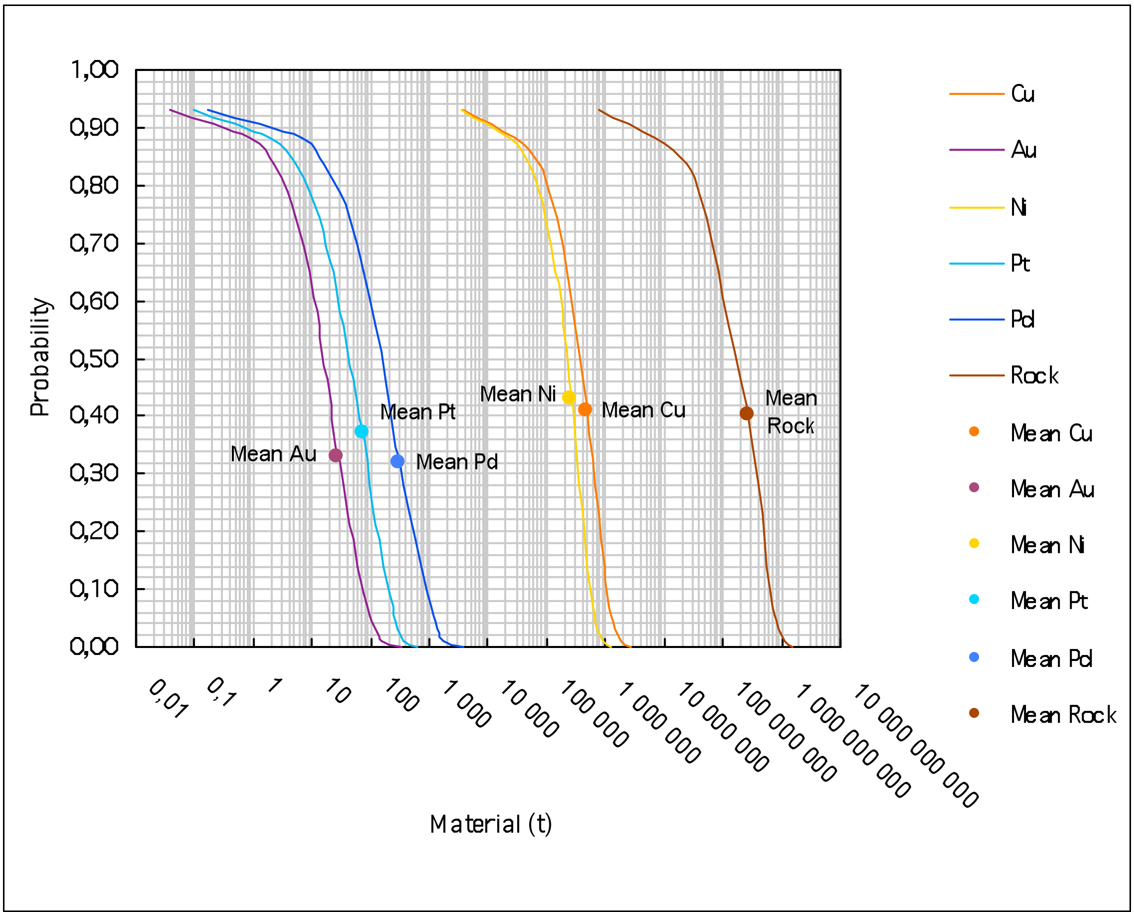

Figure 2. Cumulative frequency plot showing the results of Monte Carlo computer simulation of undiscovered resources in SyöteContactPGE.

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REEF-TYPE PGE ASSESSMENT FOR TRACT SyöteReefPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Reef-type PGE-Ni-Cu
Descriptive model: Finnish reef-type PGE-Ni-Cu (Appendix 3)
Grade-tonnage model: Finnish reef-type PGE-Ni-Cu grade model, SyöteReefPGE tonnage model (Appendix 4)

LOCATION AND RESOURCE SUMMARY

The Syöte block of the Western Intrusion of the Koillismaa Complex is in northern Finland, in the municipalities of Pudasjärvi and Taivalkoski, about 130 km NE from the city of Oulu and 130 km SE from the city of Rovaniemi. Within the 1:100 000 map sheets the tract SyöteReefPGE lies in the sheets 3532, 3541 and 3543. In the UTM sheets the block locates in the sheets S5123 and S5124. The PGE resource assessment carried out for this report is summarised in Table 1.

Table 1. Summary of selected resource assessment results for SyöteReefPGE

Date of assessment	Assessment depth (km)	Tract area (km²)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
28.08.–02.10.2008	1	158	Pt	0	Pt	840	Pt	380
			Pd	0	Pd	1,500	Pd	760
			Au	0	Au	36	Au	20
			Ni	0	Ni	230,000	Ni	160,000
			Cu	0	Cu	290,000	Cu	160,000

t = metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The permissive tract shown in Figure 1 is a surface projection of the layered series of the Syöte block. The block is E-W trending and displays repeated sections of the layered series with a dip of 20–30° to the north. The Western Intrusion of the Koillismaa Complex has been attributed to the Cr-poor type (Lahtinen et al. 1989), and therefore the whole Syöte block layered series has potential for PGE reefs. The results of a gravity survey indicate that the block continues to at least 1 km depth; drilling in the southern parts of the block has only extended to a depth of 150 m. The northern margin of the block is defined by a subvertical fault. For this reason, the permissive tract for reef-type deposits of the block roughly matches the surface projection of the block. The tract delineation is based on a geological map by Räsänen et al. (2004), diamond drilling, geophysical information (local gravity survey) and a structural model by Karinen & Salmirinne (2001). The sources of information used in the delineation of the tract are summarised in Table 4.

Known deposits

There are no well-explored reef-type PGE deposits within the Syöte permissive tract.

Prospects, mineral occurrences, and related deposit types

One poorly studied reef-type prospect, Rometölväs, is known from the very eastern end of the Syöte block (Table 2). The prospect has been studied by Isohanni (1976) and also described by Piispanen and Tarkian (1984). According to current knowledge, the Rometölväs prospect belongs to the same reef unit investigated by Isohanni (1976) in the Baabelinälkky area of the Porttivaara block.

Table 2. Significant prospects and occurrences in SyöteReefPGE.

Name	X coordinate	Y coordinate	Age (Ma)	Comments (grade and tonnage data, if available)	Reference
Rometölväs	7278 908	3527510	2.45*	0.2% Cu, 0.1% Ni, 155 ppb Au, 355 ppb Pd, 480 ppb Pt; data from drill core B7	Isohanni (1976)

*The deposit age is derived from the assumed age of the Porttivaara and Pyhitys blocks based on age data from the Koillismaa Complex (Alapieti 1982).

Exploration history

Suomen Malmi Oy found the Baabelinälkky and Rometölväs occurrences in 1966. These areas were drilled by the Koillismaa Research Project of the University of Oulu in 1973. The rest of work in the tract area has mostly been related to exploration of contact-type deposits in the marginal series. The exploration history for the Syöte intrusion is summarised in Table 3.

Table 3. Exploration history for Syöte intrusion.

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Mapping included in the regional-scale programmes listed below			
Geochemical surveys				
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	1998, 2000
Ground geophysical surveys	Gravity survey line		Univ Oulu	1971
	VLF-R, magnetic, and IP surveys		GTK	1996
	Magnetic, IP and TEM		NAN	2001
	Regional gravity survey		GTK	1999–2001, 2003, 2004
Drilling	783. 55 m in 6 drill cores of which 159.15 m at Rometölväs area in two short drill cores		Univ. Oulu	1973
	22 drill cores, total 1067.10 m.		GTK	1997
	Three drill cores, 453.50 m		NAN	2000, 2001
Other	Regional research and mapping programme in the KLIC region; mineralogical investigations	No	Univ. Oulu	1971–1976
	Regional research and exploration programme in the KLIC region	Yes	GTK	1996–2000

NAN= North Atlantic Natural Resources.
KLIC= Koillismaa Layered Igneous Complex.

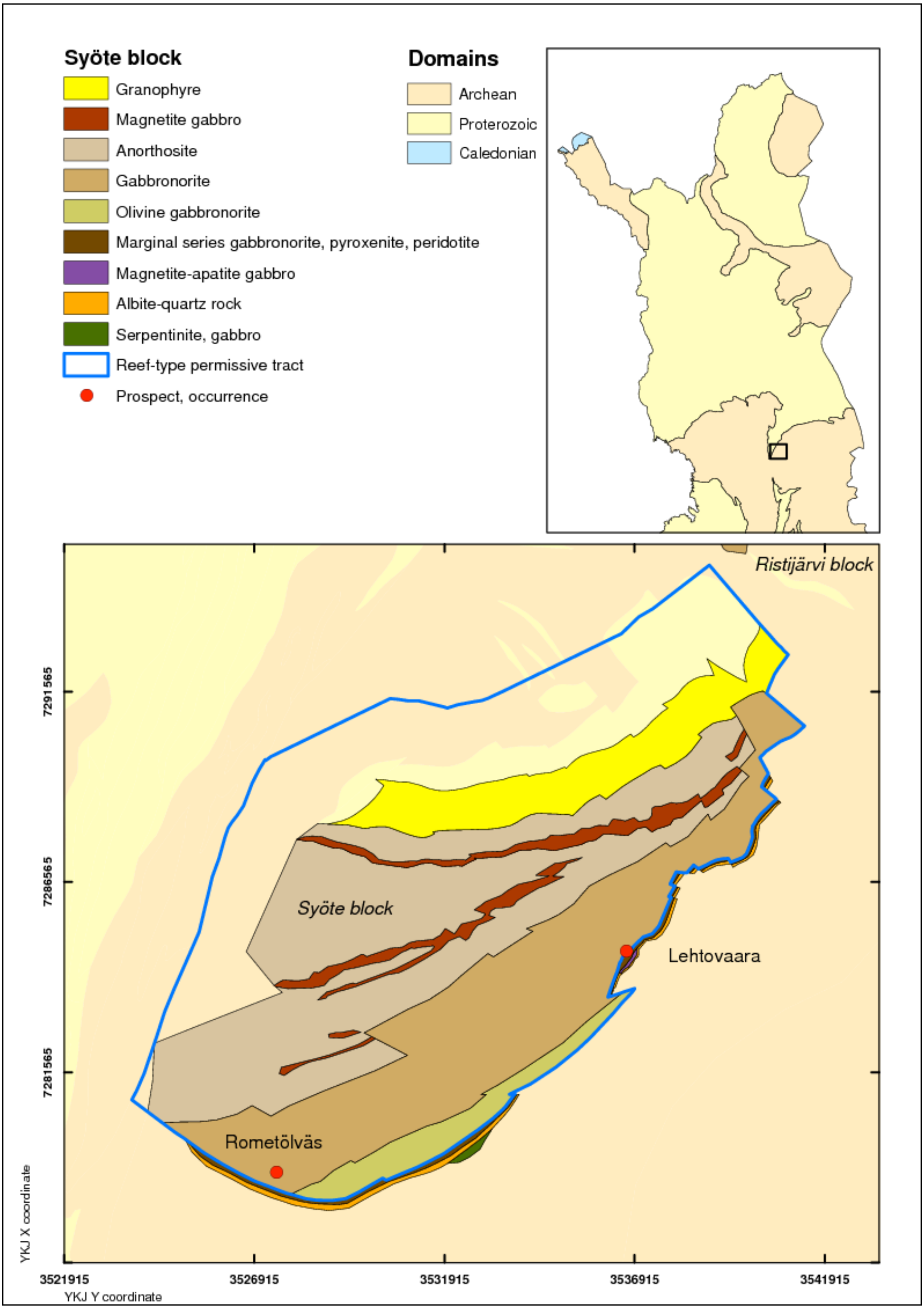

Figure 1. Location of the permissive tract SyöteReefPGE.

Sources of information

The principal sources of information used by the assessment team for the delineation of SyöteReefPGE are listed in Table 4.

Table 4. Principal sources of information used by the assessment team for SyöteReefPGE.

Theme	Type of source	Scale	Citation
Geology	Geological description of the KLIC and then known mineral occurrences	1:150 000	Piirainen et al. (1974, 1978), Juopperi (1977), Alapieti (1982)
	Geological and mineralogical description of the Syöte intrusive block		Alapieti et al. (1979)
	Geological description of the KLIC and the known mineral occurrences		Iljina (2004)
	Geological map of the KLIC region	1:200 000	Räsänen et al. (2004)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
	PhD on geology and reef-type mineralisation in the Western Koillismaa Intrusion		Karinen (2010)
Mineral occurrences	Description of mineralised localities		Isohanni (1976), Piispanen & Tarkian (1982), Iljina (2004)
Geochemistry	NA		

KLIC= Koillismaa Layered Igneous Complex.
NA = not available.

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

Geological factors that were used to estimate the number of undiscovered deposits included the geology of the intrusion, the distribution of the known occurrences, and the available geophysical and drilling data (Tables 3 and 4).

In terms of surface area, Syöte is the largest block of the Koillismaa Intrusion. This is due to low-angled dip of the block and to the extensive repetition of the igneous sequence within the block, as indicated by several layers of magnetite gabbro at Syöte. These features also make the permissive tract large and increase its potential for reef-type PGE deposits. The presence of one known reef-type occurrence suggests that the number of undiscovered contact-type deposits within the tract is, at least, one. The tract was also seen as analogous to the Porttivaara and Kuusijärvi tracts, which also contain indications of reef-type deposits. Hence, the estimators found a consensus for the number of undiscovered deposits within the SyöteReefPGE tract (Table 5).

Table 5. Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for SyöteReefPGE.

Consensus undiscovered deposit estimate					Summary statistics					Area (km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}	
1	2	2			1.6	0.46	28		1.6	158

Estimator	Estimated number of undiscovered deposits				
	N90	N50	N10	N05	N01
Estimator 1	1	2	2		
Estimator 2	1	2	2		
Estimator 3	1	2	2		
Consensus	1	2	2		

Nxx = Estimated number of deposits associated with the xxth percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were calculated by combining the undiscovered deposit estimates with the Finnish reef-type PGE grade model and the SyöteReefPGE tonnage model (Appendix 4) using the EMINERS software (Root et al. 1992, Duval 2004). Selected simulation results are reported in Table 6. Results of the Monte Carlo simulation are presented as cumulative frequency plots (Figure 2). The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralized rock.

Table 6. Results of Monte Carlo simulations of undiscovered resources in SyöteReefPGE.

Material	At least the indicated amount at the probability of					Mean	Probability of mean or greater	Probability of zero
	0.95	0.9	0.5	0.1	0.05			
Pt (t)	0	41	380	2,000	3,100	840	0.27	0.07
Pd (t)	0	91	760	3,300	5,300	1,500	0.28	0.07
Au (t)	0	2	20	87	120	36	0.32	0.07
Ni (t)	0	25,000	160,000	520,000	670,000	230,000	0.36	0.07
Cu (t)	0	11,000	160,000	710,000	1,000,000	290,000	0.33	0.07
Rock (Mt)	0	40	220	650	830	290	0.38	0.07

t = metric tonnes; Mt = millions of tonnes.

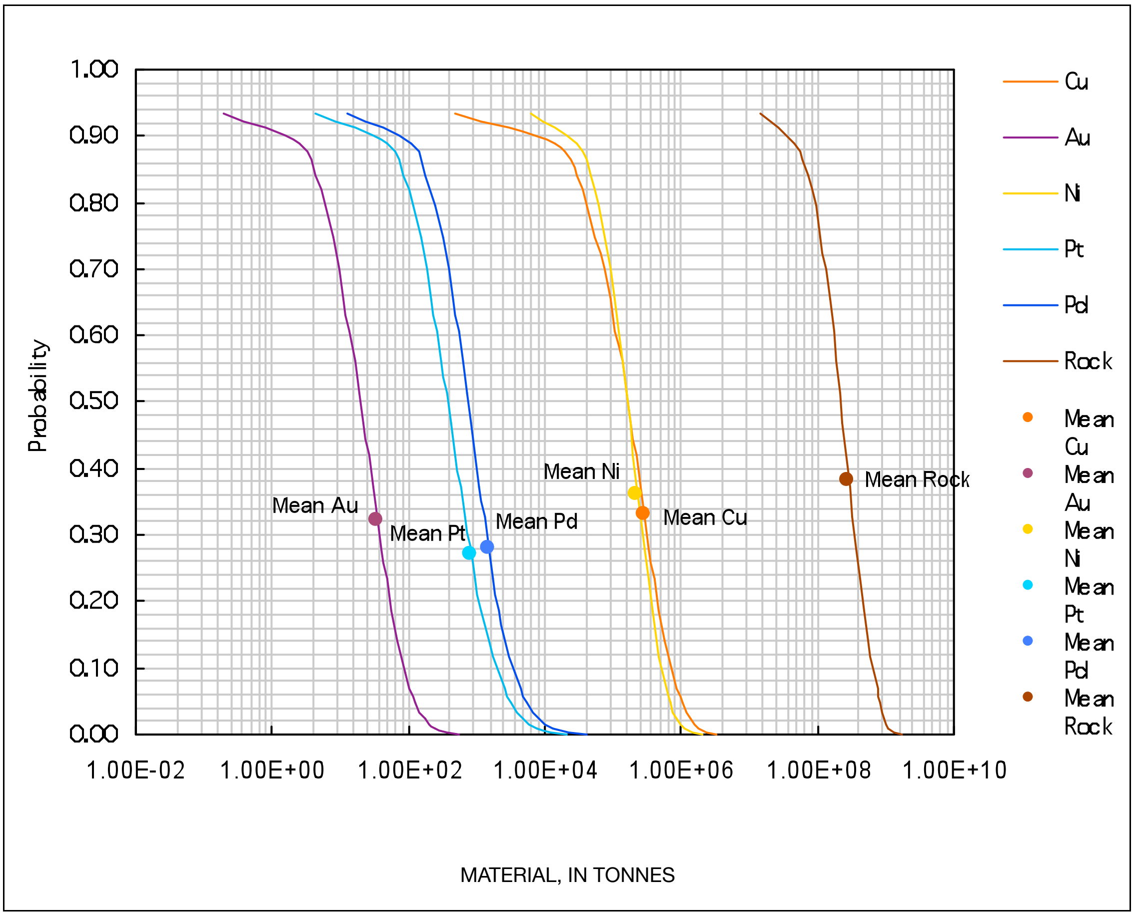

Figure 2. Cumulative frequency plot showing the results of Monte Carlo computer simulation of undiscovered resources in SyöteReefPGE.

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CONTACT-TYPE PGE ASSESSMENT FOR TRACT TilsaContactPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Contact-type Cu-Ni-PGE
Descriptive model: Fennoscandian contact-type Cu-Ni-PGE deposits (Appendix 1)
Grade and tonnage model: Fennoscandian contact-type Cu-Ni-PGE deposits (Appendix 2)

LOCATION AND RESOURCE SUMMARY

The Tilsa block of the Western Intrusion of the Koillismaa layered Igneous Complex is located in northern Finland in the municipality of Posio, 120 km southwest from the city of Rovaniemi. The 1:100 000 KKJ map sheet is 3541. The UTM map sheet containing the block is S5214. The PGE resource assessment carried out for this report is summarised in Table 1.

Table 1. Summary of selected resource assessment results for TilsaContactPGE001.

Date of assessment	Assessment depth (km)	Tract area (km^2)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
28.08.–30.09.2008	1	4.1	Pt	0	Pt	25	Pt	5
			Pd	0	Pd	110	Pd	13
			Au	0	Au	10	Au	2
			Ni	0	Ni	89,000	Ni	42,000
			Cu	0	Cu	160,000	Cu	60,000

t = metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The permissive tract delineated in Figure 1 is a surface projection of the basal contact zone of the Tilsa Block of the Koillismaa intrusion. The estimated dip of layering of the marginal series in the Tilsa Block is about 45º to the NW. The block is bounded at its northern and WSW contacts by subvertical faults, and is estimated to have a maximum thickness >1 km. On the surface, the tract delineation is based on a geological map by Räsänen et al. (2004), drilling (by GTK), geophysical information (local ground surveys) and a structural model by Karinen & Salmirinne (2001). To the NW, the permissive tract is a projection to the surface from 1 km depth, taking into account the fact that the peridotite unit and the marginal series are repeated within the block, making the tract wider than otherwise expected. The sources of information used in the delineation of the tract are summarized in Table 3.

Known deposits

No contact-type PGE deposits are known within the tract.

Prospects, mineral occurrences, and related deposit types

The marginal series rocks are mineralised, where intercepted by drilling at Tilsa. However, no obvious contact-type PGE prospects are known from the tract.

Exploration history

Exploration commenced in the Tilsa area in 1980 when Outokumpu started reconnaissance exploration in the region. Attention was drawn to Tilsa by Ni- and Cu-rich sulphide-bearing glacial erratic boulders found in 1981 (Lahtinen 1983). Despite the work in the 1980s, the Tilsa intrusive block and the first indications of contact-type mineralisation in bedrock were discovered in a project of the GTK in 1998 (Iljina 2004), during which the block was drilled. The exploration work carried out in the area, and known to us, is listed in Table 2.

Table 2. Exploration history for TilsaContactPGE001.

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Detailed bedrock mapping, outcrop sampling	Yes	GTK	1996–2000
Geochemical surveys	Not available			
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	1998
Ground geophysical surveys	Magnetic Survey		Outokumpu	1963–1965, 1981
	VLF-R and magnetic surveys		GTK	1998, 2000, 2005
	Magnetic and IP surveys		NAN	2001
Drilling	16 diamond-drill holes, total 2790.40 m	Yes	GTK	1999, 2005
Other	Regional research and mapping programme in the KLIC region.	No	Univ. Oulu	1971–1976
	Regional research and exploration programme in the KLIC region.	Yes	GTK	1996–2000

NAN = North Atlantic Natural Resources.
KLIC = Koillismaa Layered igneous Complex.

Sources of information

The principal sources of information used by the assessment team for the delineation of TilsaContact-PGE001 are listed in Tables 2 and 3.

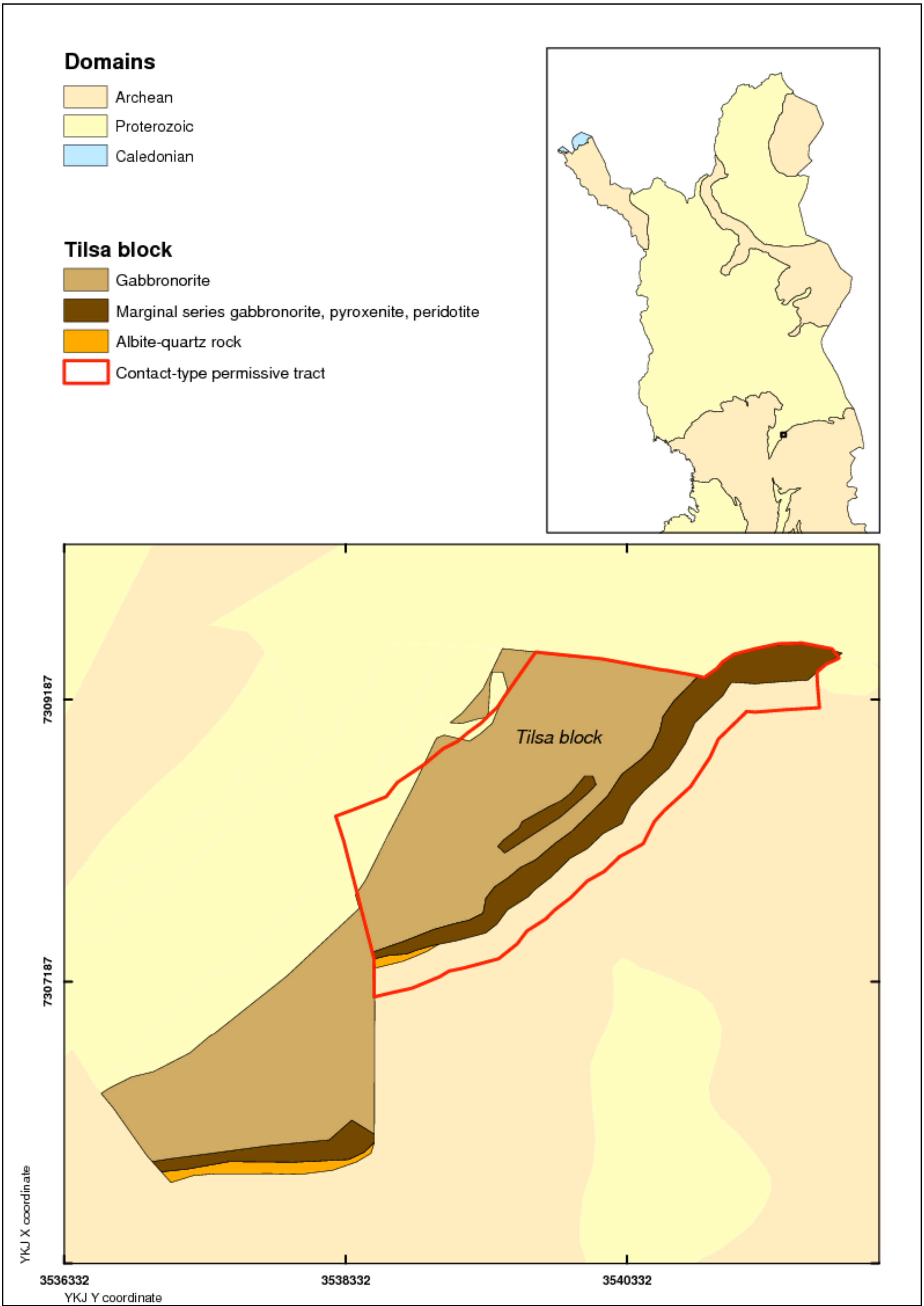

Figure 1. Location of the permissive tract TilsaContactPGE.

Table 3. Principal sources of information used by the assessment team for TilsaContactPGE001.

Theme	Type of source	Scale	Citation
Geology	Geological description of the KLIC geology and then known mineral occurrences		Alapieti (1982)
	Geological description of the KLIC geology and the known mineral occurrences		Iljina (2004)
	Geological map of the KLIC region	1:200 000	Räsänen et al. (2004)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
Mineral occurrences	General description of mineralised parts of the marginal series		Iljina (2004)
Geochemistry	NA		
Geophysics	Magnetic and VLF-R survey		Iljina (2004)
Exploration	Review of exploration in the area by Outokumpu		Lahtinen (1983)
	Detailed description of exploration activities in the area by GTK		Iljina (2004)

NA = not available.
KLIC = Kollismaa Layered Igneous Complex.

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

Geological factors that were used to estimate the number of undiscovered deposits included the geology of the intrusion, the distribution of the known deposits, and the available geophysical and drilling data (Tables 2 and 3).

The marginal series rocks are mineralised where intercepted by drilling at Tilsa. However, no obvious contact-type PGE prospects are known from the tract, although the tract is rather well known. Hence, the number of undiscovered contact-type deposits within the tract is zero or more. For the number of undiscovered deposits, the estimators did agree with higher probabilities, but disagreed for the percentile N10 for which a mean was calculated (Table 4).

Table 4. Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for TilsaContactPGE001.

Mean undiscovered deposit estimate					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
0	1	2			1.0	0.79	79	0	1.0	4.1	0.25

	Estimated number of undiscovered deposits				
Estimator	N90	N50	N10	N05	N01
Estimator 1	0	1	2		
Estimator 2	0	1	3		
Estimator 3	0	1	1		
Mean	0	1	2		

Nxx = Estimated number of deposits associated with the xx^{th} percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; Deposit density = deposit density reported as the total number of deposits per km^2. N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie, 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were estimated by combining the means of estimated numbers of undiscovered contact-type PGE deposits with the Fennoscandian contact-type PGE grade and tonnage model (Appendix 2) using the EMINERS software (Root et al. 1991, Duval 2004). Selected simulation results are reported in Table 5. Results of the Monte Carlo simulation are presented as cumulative frequency plots (Figure 2). The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralized rock.

Table 5. Results of Monte Carlo simulations of undiscovered resources in TilsaContactPGE001.

Material	At least the indicated amount at the probability of 0.95	0.90	0.50	0.10	0.05	Mean	Probability of mean or greater	Probability of zero
Pt (t)	0	0	5	85	120	25	0.25	0.31
Pd (t)	0	0	13	300	570	110	0.24	0.31
Au (t)	0	0	2	26	50	10	0.26	0.31
Ni (t)	0	0	42,000	260,000	340,000	89,000	0.36	0.31
Cu (t)	0	0	60,000	500,000	670,000	160,000	0.31	0.31
Rock (Mt)	0	0	20	360	460	91	0.25	0.31

t = metric tonnes; Mt = millions of tonnes.

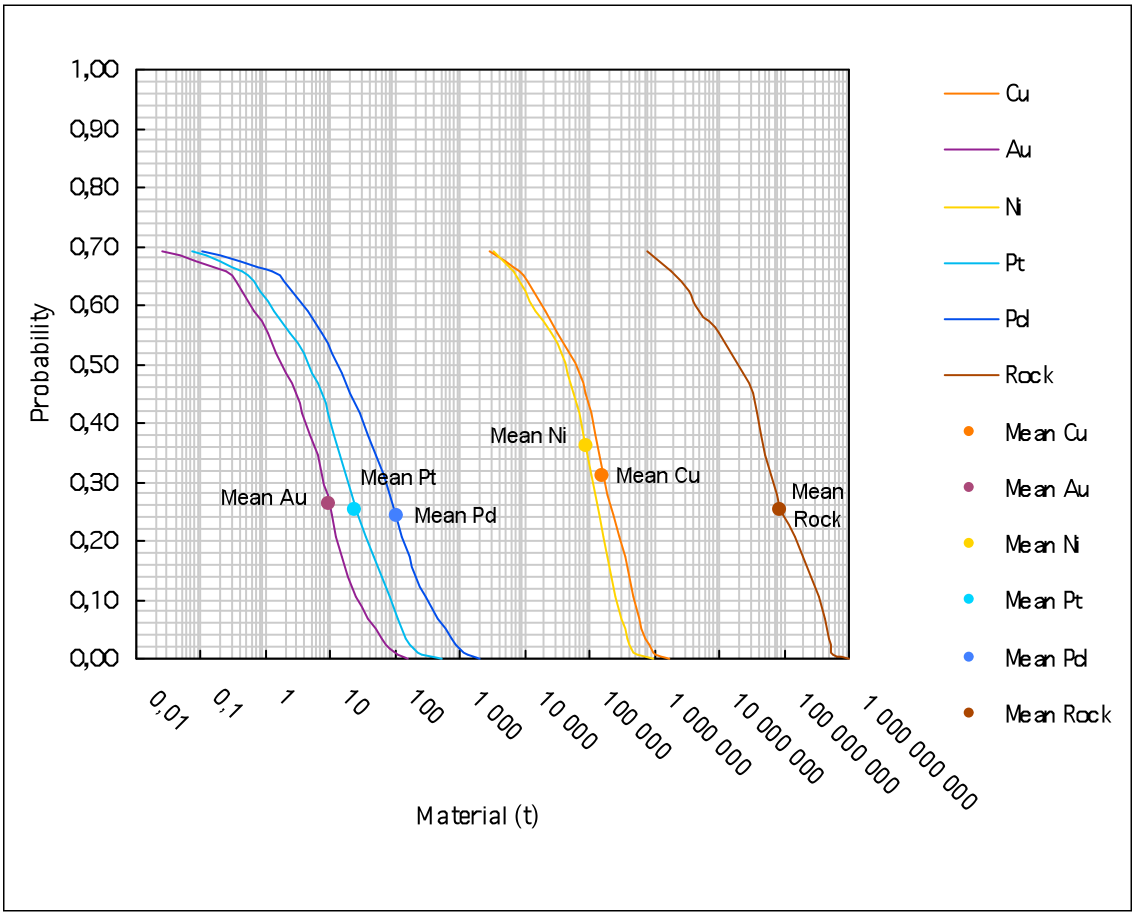

Figure 2. Cumulative frequency plot showing the results of Monte Carlo computer simulation of undiscovered resources in TilsaContactPGE001.

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REEF-TYPE PGE ASSESSMENT FOR TRACT TilsaReefPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Reef-type PGE-Ni-Cu
Descriptive model: Finnish reef-type PGE-Ni-Cu (Appendix 3)
Grade-tonnage model: Finnish reef-type PGE-Ni-Cu grade model, TilsaReefPGE tonnage model (Appendix 4)

LOCATION AND RESOURCE SUMMARY

The Tilsa block of the Western Intrusion of the Koillismaa layered Igneous Complex is located in northern Finland in the municipality of Posio, 120 km southwest from the city of Rovaniemi. The 1:100 000 KKJ map sheet is 3541. The UTM map sheet containing the block is S5214. The PGE resource assessment carried out for this report is summarised in Table 1.

Table 1. Summary of selected resource assessment results for TilsaReefPGE.

Date of assessment	Assessment depth (km)	Tract area (km²)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
30.09.2008	1	3.8	Pt	0	Pt	12	Pt	0
			Pd	0	Pd	22	Pd	0
			Au	0	Au	1	Au	0
			Ni	0	Ni	3,300	Ni	0
			Cu	0	Cu	3,900	Cu	0

t = metric tonnes.

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The estimated dip of layering in the Tilsa block is about 45° to the NW. The block is bounded in its northern and WSW contacts by subvertical faults, and is estimated to have a maximum thickness >1 km. The Western Intrusion of the Koillismaa Complex has been attributed to the Cr-poor type (Lahtinen et al. 1989), and the whole layered series of the Tilsa block therefore has potential for PGE reefs. Thus, the permissive tract delineated in Figure 1 is a surface projection of the layered series of the block. On the surface, the delineation is based on a geological map by Räsänen et al. (2004), drilling, geophysical information (local ground survey) and a structural model by Karinen & Salmirinne (2001). The sources of information used in the delineation of the tract are summarised in Table 3.

Known deposits

There are no well-explored reef-type PGE deposits within the Tilsa permissive tract.

Prospects, mineral occurrences, and related deposit types

No reef-type PGE occurrences are known within the Tilsa permissive tract.

Exploration history

Exploration commenced in the Tilsa area in 1980 when Outokumpu Oy started reconnaissance exploration in the region. Attention was drawn to Tilsa by Ni- and Cu-rich sulphide-bearing glacial erratic boulders found in 1981 (Lahtinen 1983). Despite the work in the 1980s, the Tilsa intrusive block and the first indications of contact-type mineralisation in bedrock were only discovered in 1998 (Iljina 2004), when the block was drilled. The exploration work carried out in the area, and known to us, is listed in Table 2.

Table 2. Exploration history for TilsaReefPGE.

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Detailed bedrock mapping, outcrop sampling	Yes	GTK	1996–2000
Geochemical surveys	Not available			
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	1998
Ground geophysical surveys	VLF-R and magnetic surveys		GTK	1998, 2000, 2005
	Magnetic and IP surveys		NAN	2001
Drilling	15 diamond-drill holes, total 2447.60 m	Yes	GTK	1999, 2005
Other	Regional research and mapping programme in the KLIC region.	No	Univ. Oulu	1971–1976
	Regional research and exploration programme in the KLIC region.	Yes	GTK	1996–2000

NAN = North Atlantic Natural Resources.
KLIC = Koillismaa Layered igneous Complex.

Sources of information

The principal sources of information used by the assessment team for the delineation of TilsaReefPGE are listed in Table 3.

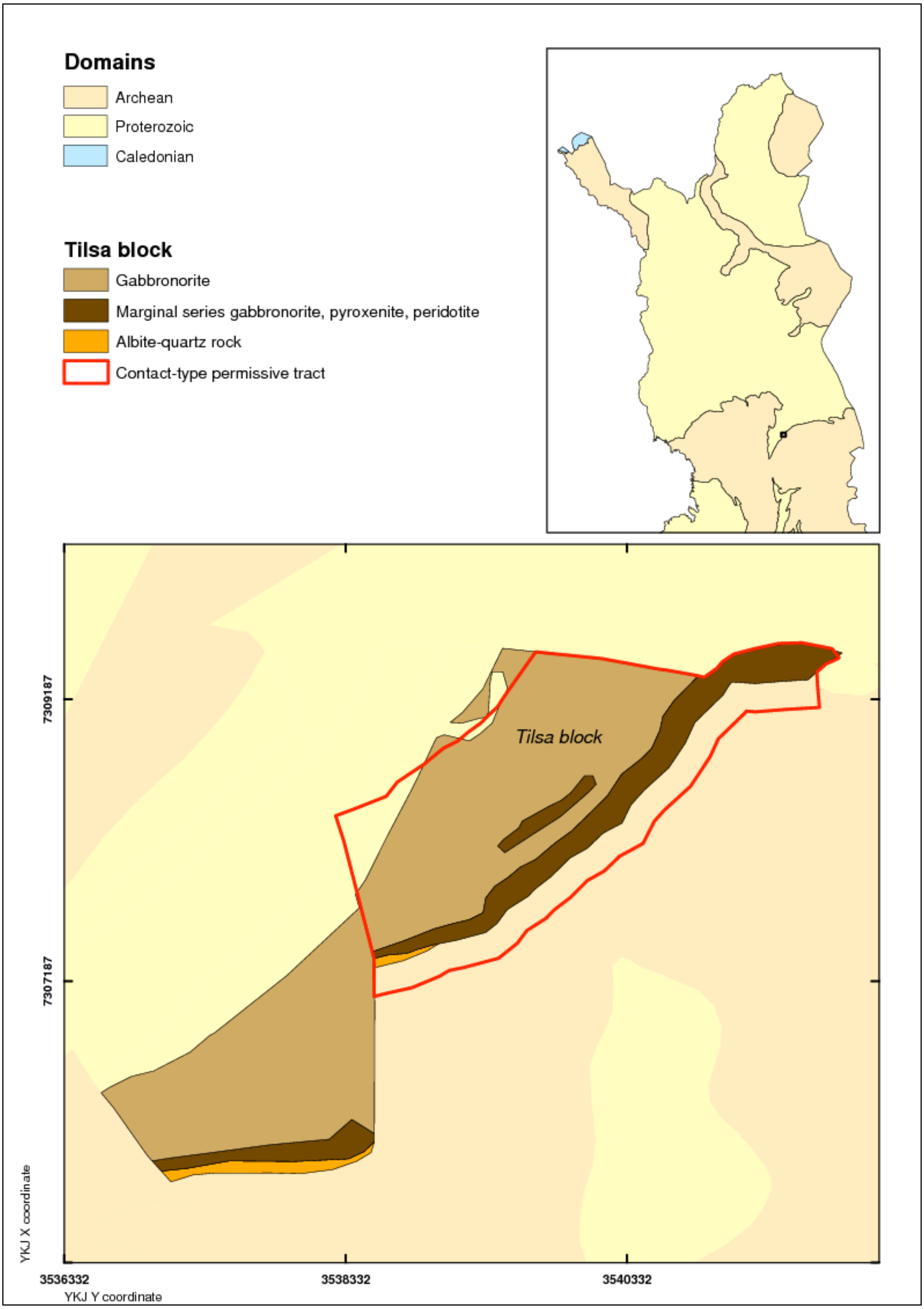

Figure 1. Location of the permissive tract TilsaReefPGE.

Table 3. Principal sources of information used by the assessment team for TilsaReefPGE.

Theme	Type of source	Scale	Citation
Geology	Geological description of the KLIC geology and then known mineral occurrences		Alapieti (1982)
	Geological description of the KLIC geology and the known mineral occurrences		Iljina (2004)
	Geological map of the KLIC region	1:200 000	Räsänen et al. (2004)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
	PhD on geology and reef-type mineralisation in the Western Koillismaa Intrusion		Karinen (2010)
Mineral occurrences	General description of mineralised parts of the marginal series		Iljina (2004)
Geochemistry	NA		
Geophysics	Magnetic and VLF-R survey		Iljina (2004)
Exploration	Review of exploration in the area by Outokumpu		Lahtinen (1983)
	Detailed description of exploration activities in the area by GTK		Iljina (2004)

NA = not available.
KLIC = Koillismaa Layered Igneous Complex.

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

Geological factors that were used to estimate the number of undiscovered deposits included the geology of the intrusion, the distribution of the known deposits, and the available geophysical and drilling data (Tables 2 and 3). No obvious reef-type PGE prospects are known from the area, although the tract is rather well known. Hence, the number of undiscovered contact-type deposits within the tract is zero or more. The estimators reached a consensus, as indicated in Table 4, that there is a small possibility for one PGE reef at Tilsa.

Table 4. Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for TilsaReefPGE.

Consensus undiscovered deposit estimate					Summary statistics					Area (km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}	
0	0	1			0.30	0.50	170		0.30	3.8

Estimator	N90	N50	N10	N05	N01
	Estimated number of undiscovered deposits				
Estimator 1	0	0	1		
Estimator 2	0	0	1		
Estimator 3	0	0	1		
Consensus	0	0	1		

Nxx = Estimated number of deposits associated with the xx^{th} percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were calculated by combining the undiscovered deposit estimates with the Finnish reef-type PGE grade model and the TilsaReefPGE tonnage model (Appendix 4) using the EMINERS software (Root et al. 1992, Duval 2004). Selected simulation results are reported in Table 5. Results of the Monte Carlo simulation are presented as cumulative frequency plots (Figure 2). The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralised rock.

Table 5. Results of Monte Carlo simulations of undiscovered resources in TilsaReefPGE.

Material	At least the indicated amount at the probability of					Mean	Probability of mean or greater	Probability of zero
	0.95	0.9	0.5	0.1	0.05			
Pt (t)	0	0	0	26	55	12	0.16	0.70
Pd (t)	0	0	0	50	100	22	0.18	0.70
Au (t)	0	0	0	1	3	1	0.19	0.70
Ni (t)	0	0	0	10,000	20,000	3,300	0.22	0.70
Cu (t)	0	0	0	12,000	23,000	3,900	0.19	0.70
Rock (Mt)	0	0	0	14	24	4	0.24	0.70

t = metric tonnes; Mt = millions of tonnes.

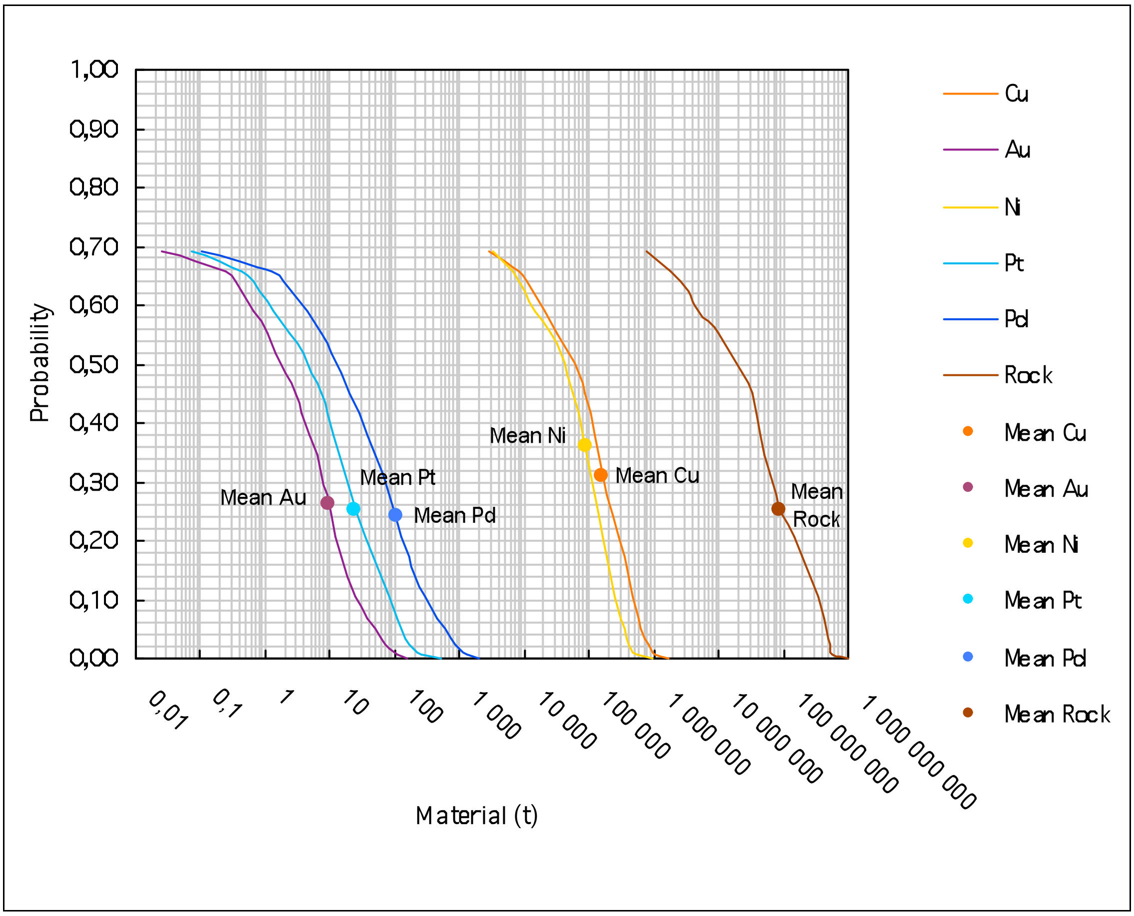

Figure 2. Cumulative frequency plot showing the results of Monte Carlo computer simulation of undiscovered resources in TilsaReefPGE.

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REEF-TYPE PGE ASSESSMENT FOR TRACT TornioReefPGE, FINLAND

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DEPOSIT TYPE ASSESSED

Deposit type: Reef-type PGE-Ni-Cu
Descriptive model: Finnish reef-type PGE-Ni-Cu (Appendix 3)
Grade-tonnage model: Finnish reef-type PGE-Ni-Cu grade model, TornioReefPGE tonnage model (Appendix 4)

LOCATION AND RESOURCE SUMMARY

The Tornio layered intrusion extends across the Finnish-Swedish border. In this report, we only consider the Finnish part of the intrusion located in northern Finland, in the municipality of Tornio, about 100 km SW from Rovaniemi and 25 km NW from Kemi (Figure 1). The 1:100 000 KKJ map sheets are 2541 and 2542. The UTM map sheet containing the Finnish part of the intrusion is S4232. The PGE resource assessment carried out for this report is summarised in Table 1.

Table 1. Summary of selected resource assessment results for TornioReefPGE

Date of assessment	Assessment depth (km)	Tract area (km^2)	Known metal resources (t)		Mean estimate of undiscovered PGE resources (t)		Median estimate of undiscovered PGE resources (t)	
01.09.2008	1	6.9	Pt	0	Pt	100	Pt	24
			Pd	0	Pd	190	Pd	51
			Au	0	Au	4	Au	1
			Ni	0	Ni	29,000	Ni	13,000
			Cu	0	Cu	36,000	Cu	8,300

t = metric tonnes.

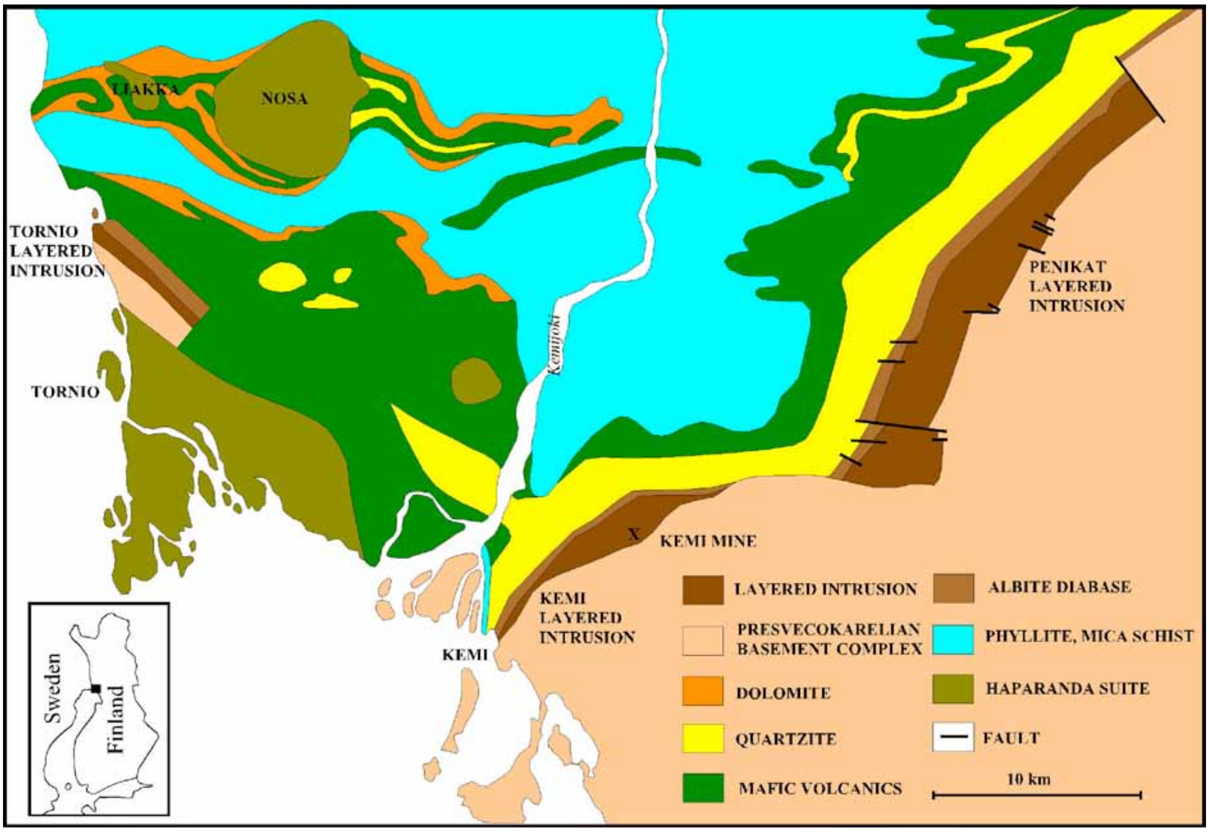

Figure 1. Location of the Tornio layered intrusion between the Peräpohja schist belt and the Archaean basement complex. Modified from Söderholm and Inkinen (1982).

DELINEATION OF THE PERMISSIVE TRACT

Geological criteria

The narrow (6 km long, 0.4–0.5 km wide) Tornio layered intrusion dips at 65°–75° to the NE, apparently into depths of more than 1 km. The extent of the intrusion to a great depth is suggested by a gravity survey performed by GTK. The upper part of the intrusion at and above the contact between the earlier Cr-rich and the later Cr-poorer magma units is used to define the permissive tract. Hence, the permissive tract matches the surface projection of this upper part of the intrusion from the surface to 1 km depth. There is only one outcrop within the intrusion, at Oravaisensaari, an island in the Tornionjoki River close to the Swedish border. The SW margin of the tract is defined by information from drilling and ground geophysical surveys (Söderholm & Inkinen 1982) – both the Finnish and Swedish parts have been drilled and surveyed. The NE margin of the tract is delineated by the projection to the surface of the hanging wall contact of the intrusion at 1 km depth. The location of the hanging wall contact is based on the Bedrock Map Database DigiKP Finland (Geological Survey of Finland 2008) and low-altitude magnetic data (Hautaniemi et al. 2005). The sources of information used in the delineation of the tract are summarised in Table 3.

Known deposits

There are no well-explored reef-type PGE deposits within the Tornio permissive tract.

Prospects, mineral occurrences, and related deposit types

No obvious reef-type PGE prospects are known from the tract.

Exploration history

Several chromitite floats were discovered in 1962–1966 that, according to the glacial transport direction, were located in the terrain between Tornio and Elijärvi, to the NW of the Kemi mine. Exploration commenced in the Tornio area in 1978 when Outokumpu Oy started to survey and drill chromite targets in the area. Drilling during 1979–1980 resulted in the discovery of the Tornio layered intrusion (Söderholm & Inkinen 1982). During 2006, Kylynlahti Copper Oy drilled a few diamond-drill holes into the uppermost part of the Tornio intrusion. The exploration history for the Tornio intrusion is summarised in Table 2.

Table 2. Exploration history for Tornio intrusion.

Theme	Type of work done	PGE analysed	Organisation	When done
Mapping	Exploration-related bedrock mapping	No	Outokumpu	1979
Airborne geophysical surveys	Low-altitude airborne magnetic, electromagnetic and radiometric survey		GTK	1982
Ground geophysical surveys	Magnetic survey covering 7 km^2		Outokumpu	1978
	Gravimetric survey covering 7 km^2		Outokumpu	1979
Drilling	12 diamond-drill holes, total about 2106 m	No	Outokumpu	1979–1980
	7 diamond-drill holes, total 185.2 m	NA	Kylylahti Copper	2006

NA = not available.

Sources of information

Principal sources of information used by the assessment team for delineation of TornioReefPGE are listed in Table 3.

Table 3. Principal sources of information used by the assessment team for TornioReefPGE.

Theme	Type of source	Scale	Citation
Geology	Brief geological description of the intrusion		Söderholm & Inkinen (1982), Alapieti & Lahtinen (1989)
	Bedrock Map Database of Finland		Geological Survey of Finland (2008)
Mineral occurrences	One publication and claim report		Söderholm & Inkinen (1982), Inkinen (1984)
Geophysics	Ground-geophysical surveys		Söderholm & Inkinen (1982), Inkinen (1984)
Exploration	General descriptions of exploration activities and results in the area		Söderholm & Inkinen (1982), Inkinen (1984)
	Mineral exploration report		Impola (2007)

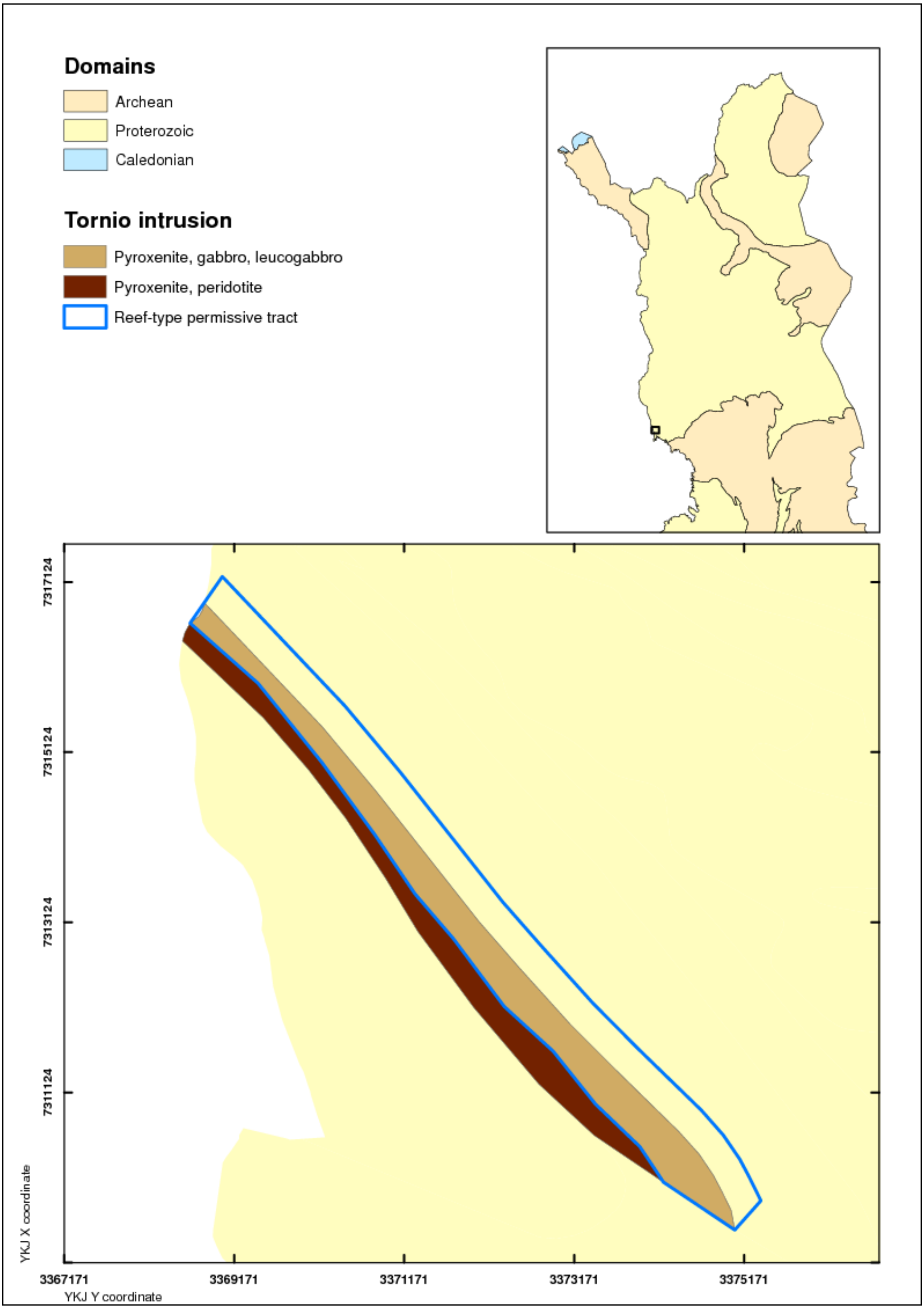

Figure 2. Location of the permissive tract TornioReefPGE. The white area to the west is Swedish territory.

ESTIMATE OF THE NUMBER OF UNDISCOVERED DEPOSITS

Rationale for the estimate

Geological factors that were used to estimate the number of undiscovered reef-type deposits included the geology of the Tornio intrusion, and the available geophysical and drilling data (Tables 2 and 3).

Not a single reef-type prospect is known within the tract. This means that the minimum number of undiscovered reef-type deposits within the tract is zero. The Tornio intrusion can be regarded as quite poorly surveyed and drilled. The geology of the intrusion is largely similar to that of the Penikat and Kemi layered intrusions, and it contains a contact zone between an earlier Cr-rich and a later Cr-poorer magma unit. On the other hand, the size of the intrusion is quite small and its narrow width suggests it might be a sill-like body. The probability that a reef-type deposit exists within the present uppermost 1 km was not considered to be very high. All three estimators assessed the N10 quantile for undiscovered deposits at one, whereas there remained disagreement on the number of undiscovered deposits (0 or 1) at higher probability levels (Table 4). Hence, the calculated mean values of undiscovered deposits at 90th, 50th and 10th percentiles were used in the Monte Carlo simulations.

Table 4. Undiscovered deposit estimates, deposit numbers, and tract area for TornioReefPGE.

Mean undiscovered deposit estimate					Summary statistics					Area (km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}	
0	1	1			0.70	0.41	58	0	0.70	6.9

Estimator	Estimated number of undiscovered deposits N90	N50	N10	N05	N01
Estimator 1	0	0	1		
Estimator 2	0	1	1		
Estimator 3	0	1	1		
Mean	0	1	1		

Nxx = Estimated number of deposits associated with the xx^{th} percentile; N_{und} = expected number of undiscovered deposits; s = standard deviation; Cv% = coefficient of variation; N_{known} = number of known deposits in the tract that are included in the grade-tonnage model; N_{total} = total of expected number of deposits plus known deposits; Area = area of permissive tract; N_{und}, s, and Cv% are calculated using a regression equation (Singer & Menzie 2005). Individual estimates are also listed.

QUANTITATIVE ASSESSMENT SIMULATION RESULTS

Undiscovered resources for the tract were calculated by combining the undiscovered deposit estimates with the Finnish reef-type PGE grade model and the TornioReefPGE tonnage model (Appendix 4) using the EMINERS software (Root et al. 1992, Duval 2004). Selected simulation results are reported in Table 5. Results of the Monte Carlo simulation are presented as cumulative frequency plots (Figure 3). The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralized rock.

Table 5. Results of Monte Carlo simulations of undiscovered resources in TornioReefPGE.

Material	At least the indicated amount at the probability of					Mean	Probability of mean or greater	Probability of zero
	0.95	0.9	0.5	0.1	0.05			
Pt (t)	0	0	24	240	440	100	0.22	0.31
Pd (t)	0	0	51	440	760	190	0.23	0.31
Au (t)	0	0	1	12	20	4	0.26	0.31
Ni (t)	0	0	13,000	75,000	120,000	29,000	0.31	0.31
Cu (t)	0	0	8,300	100,000	160,000	36,000	0.26	0.31
Rock (Mt)	0	0	20	98	150	36	0.33	0.31

t = metric tonnes; Mt = millions of tonnes.

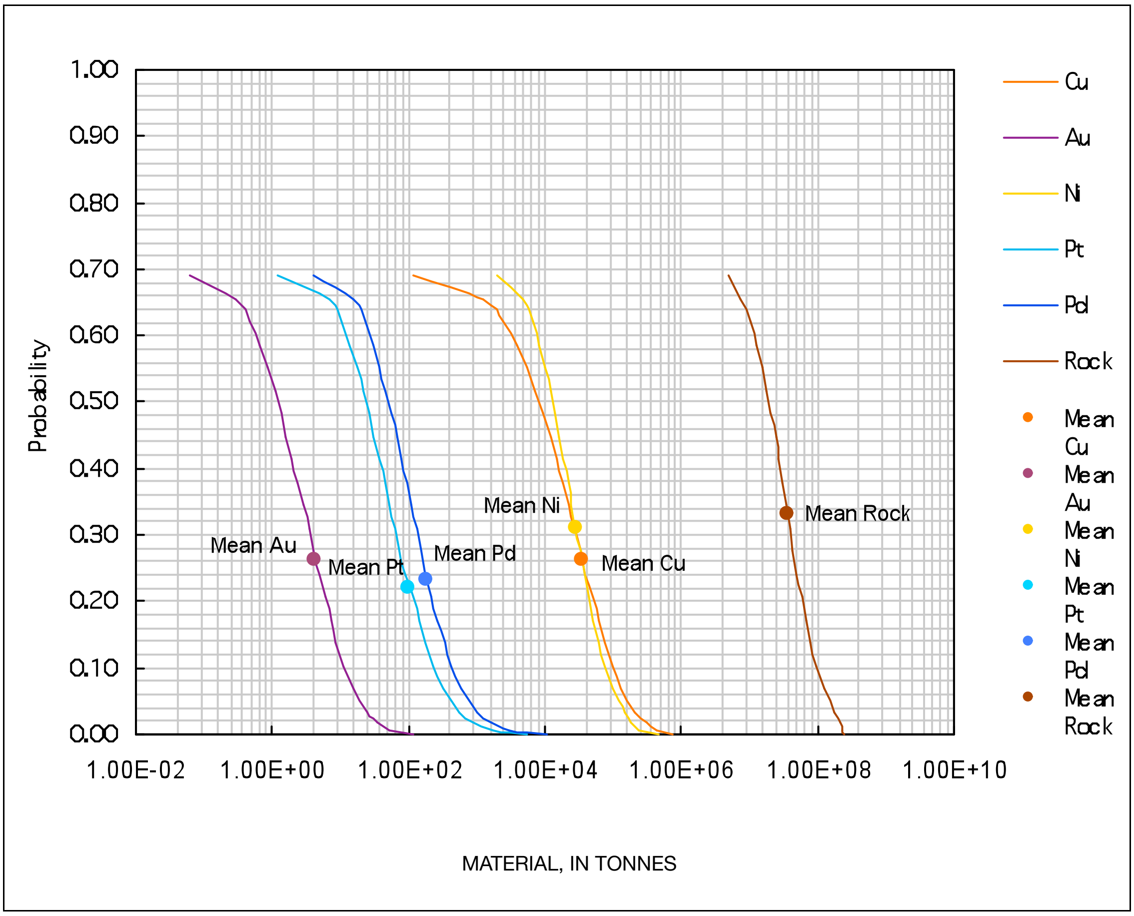

Figure 3. Cumulative frequency plot showing the results of Monte Carlo computer simulation of undiscovered resources in TornioReefPGE.

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The present work uses statistical and expert assessment methods to estimate undiscovered resources in platinum and palladium deposits hosted by mafic–ultramafic layered intrusions in the uppermost 1 km of the bedrock in Finland. It gives numerical estimates of the expected endowment of platinum, palladium, gold, nickel, and copper in undiscovered, but potentially exploitable PGE deposits in Finland.

ISBN 978-952-217-116-0 (PDF)
ISSN 0781-4240