Geological Survey of Finland
Special Paper 35

Boris Saltikoff, Kauko Puustinen and Mikko Tontti

Metallogenic zones and metallic mineral deposits in Finland

Explanation to the Metallogenic Map of Finland

Geological Survey of Finland
Espoo 2006

Saltikoff, Boris, Puustinen, Kauko & Tontti, Mikko, 2006. Metallogenic zones and metallic mineral deposits in Finland – Explanation to the Metallogenic Map of Finland. Geologian tutkimuskeskus – *Geological Survey of Finland, Special Paper 35*. 66 pages, 19 figures, 2 tables.

This paper contains explanations to the Metallogenic Map of Finland 1 : 1 000 000 (Saltikoff et al. 2002). The aim is to provide the reader with a general description of the individual metallogenic zones and with references regarding the present knowledge of the specified metallogenic zones and individual deposits and occurrences in Finland.

A metallogenic map of a region depicts the natural metallogenic zones (linear, sub-linear), provinces and fields (isometric), i.e. the areas of mineral occurrences of certain types. The map is based on knowledge about the existing mineral occurrences and favourable geological structures. The present metallogenic map of Finland is mainly empiric, and the metallogenic groups are defined as 'clusters of similar mineralisations', without precise specification of the nature of the 'similarity'. In the explanation report, the word mineralisation is used as a general term for a mineralised body. The mineralisations are divided into mineral deposits, occurrences and showings according to their volume and are classified on the map in respect to their metal content and morphological type. The metallogenic zones and provinces are classified according to the metal content of the respective mineralisations. The legend and classification of metallogenic zones and provinces and mineralisations are largely based on the principles of the Metallogenic Map of Europe of 1973, e.g. the term 'morphological type of a deposit' is used as the position of the deposit in relation to the hosting strata rather than as the geometric shape of the deposit. In the report, the metallogenic zones and provinces are individually described in terms of their location, geological setting, the most important or typical mineralisations and the most popular genetic concepts. At the end of the paper there are also descriptions of some important single deposits not belonging to any of the described metallogenic groups.

The geological base material for the Metallogenic Map comes from the Bedrock Map of Finland 1 : 1 000 000 of 1997 and the mineralisation data mainly from the Ore Deposit Database MALMIKANTA of the Geological Survey of Finland. The descriptions of the metallogenic zones and deposits in the report are accompanied by a wide list of references containing selected papers in widely used languages, English, German and in some instances French. Papers printed in national languages (Finnish or Swedish) are included only if they contain a substantial summary in English or German or if they have fundamental information. When published sources were not available, information was obtained via personal communications with informants also mentioned in the text.

Key words (GeoRef Thesaurus, AGI): metallogeny, metallogenic map, ore deposit, ore geology, mineral deposit, Finland, explanatory text.

Boris Saltikoff
Sammalkallionkuja 2 F 104
FIN - 02210 Espoo, FINLAND
E-mail: boris.saltikoff@kolumbus.fi

Mikko Tontti
Geological Survey of Finland
P.O.Box 96
FIN - 02151 Espoo, FINLAND
E-mail: mikko.tontti@gtk.fi

Kauko Puustinen
Rantakuja 8 E
FIN - 02170 Espoo, FINLAND
E-mail: kauko.puustinen@pp.inet.fi

ISBN 951-690-852-7
ISSN 0782-8535

Vammalan Kirjapaino Oy 2006

Saltikoff, Boris, Puustinen, Kauko & Tontti, Mikko, 2006. Metallogenic zones and metallic mineral deposits in Finland – Explanation to the Metallogenic Map of Finland. Geologian tutkimuskeskus – *Geological Survey of Finland, Special Paper 35*. 66 sivua, 19 kuvaa, 2 taulukkoa.

Julkaisu on Suomen metallogeenisen kartan (Metallogenic Map of Finland 1 : 1 000 000, Saltikoff et al. 2002) selitys. Sen tarkoituksena on tutustuttaa lukija Suomen metallogeenisiin vyöhykkeisiin ja alueisiin, metallimalmiesiintymiin ja -aiheisiin sekä tarjota monipuolinen ja ajankohtainen kirjallisuusviiteluettelo.

Jonkin geologisen tai maantieteellisen yksikön, tässä tapauksessa Suomen, metallogeenisessä kartassa esitetään tietyn tyyppisille malmiesiintymille otollisten metallogeenisten alueiden ja vyöhykkeiden sijainti. Kartta perustuu monipuoliseen tietoon olemassa olevista malmiesiintymistä ja niille suotuisista geologisista olosuhteista ja rakenteista. Tämä kartta on perusteiltaan empiirinen, ja metallogeeniset alueet ja vyöhykkeet on määritelty 'samankaltaisten esiintymien ryhminä' siten, että 'samakaltaisuuksien' luonnetta ei ole eksaktin täsmällisesti eritelty. Julkaisussa käytetään sanaa mineralisaatio yleisenä terminä kuvaamaan minkä tahansa kokoista malmimuodostumaa. Mineralisaatiot on jaettu malmiesiintymiin, -aiheisiin ja -viitteisiin koon mukaan, ja kartalla ne on esitetty luokiteltuina metallisisältönsä ja morfologiansa mukaisesti. Metallogeeniset ryhmät (vyöhykkeet ja alueet) on jaoteltu vastaavasti mineralisaatioiden metallisisällön mukaisesti. Kartassa on pyritty noudattamaan vuoden 1973 Euroopan Metallogeenisen kartan periaatteita, esimerkiksi termiä 'esiintymän morfologinen tyyppi' käytetään lähinnä kuvaamaan esiintymän asemaa suhteessa isäntäkivilajeihin ja –rakenteisiin eikä malmikappaleen muotoa. Julkaisussa kuvataan jokaisen metallogeenisen ryhmän sijainti, geologinen ympäristö, tärkeimmät malmiesiintymät sekä joitakin syntyteorioita. Julkaisun loppuosassa on kuvattu myös eräitä tärkeitä yksittäisiä esiintymiä, joiden ei katsota kuuluvan mihinkään kuvatuista metallogeenisistä ryhmistä.

Metallogeenisen kartan geologisena pohjana on yksinkertaistettu Suomen kallioperäkartta 1:1 000 000 vuodelta 1997 ja malmiesiintymätietojen pääasiallinen lähde on Geologian tutkimuskeskuksen malmitietokanta MALMIKANTA. Selitysjulkaisun vyöhyke- ja esiintymäkuvauksiin on liitetty laaja kirjallisuusluettelo. Sekä kartta että selitys ovat kansainvälistä lukijakuntaa ajatellen englanninkielisiä, mistä syystä kirjallisuusviitteisiin ei ole otettu yksinomaan suomen kielellä kirjoitettuja julkaisuja. Englanninkielisten julkaisujen lisäksi on muutamia saksan-, ranskan- ja ruotsinkielisiä viitteitä. Julkaistujen lähteiden puuttuessa tietoja on saatu haastattelemalla tutkijoita, jotka on myös mainittu tekstissä.

Avainsanat (GeoRef Thesaurus, AGI): metallogeny, metallogenic map, ore deposit, ore geology, mineral deposit, Finland, explanatory text.

Boris Saltikoff
Sammalkallionkuja 2 F 104
02210 ESPOO
Sähköposti: boris.saltikoff@kolumbus.fi

Mikko Tontti
Geologian tutkimuskeskus
PL 96
02151 ESPOO
Sähköposti: mikko.tontti@gtk.fi

Kauko Puustinen
Rantakuja 8 E
02170 ESPOO
Sähköposti: kauko.puustinen@pp.inet.fi

CONTENTS

Geological Survey of Finland, Special Paper 35, 2006.
Boris Saltikoff, Kauko Puustinen and Mikko Tontti
Metallogenic zones and metallic mineral deposits in Finland.

METALLOGENIC ZONES AND METALLIC MINERAL DEPOSITS IN FINLAND

Boris Saltikoff, Kauko Puustinen and Mikko Tontti

INTRODUCTION

This report contains explanations to the recent edition of the Metallogenic Map of Finland 1 : 1 000 000 (Saltikoff et al. 2002). The purpose of the report is to provide the reader with a general description of the individual metallogenic zones and with references that are as complete as possible for becoming further acquainted with the present knowledge of the specified metallogenic zones and individual metal deposits and occurrences in Finland.

In the reference list there are selected works of use to international public, i.e. publicly available papers in widely used languages (English, German and in some instances French). Papers printed in national languages (Finnish or Swedish) are included only if they contain a substantial summary in English or German. In cases where printed sources are not available, information has commonly been obtained via personal communications, and the key persons concerned are mentioned.

Scope of the map

A metallogenic map of a region depicts the natural metallogenic groups (linear or sublinear zones and isometric provinces fields), i.e. the areas of distribution of mineral occurrences of certain types. It is based on our knowledge about the existing mineral occurrences and favourable geological structures. A metallogenic map is not a prediction map for direct exploration but rather an important tool for geological decision-makings.

Ideally, a metallogenic map should be based on a comprehensive model of the development of the Earth's crust involving all processes (traditionally called 'ore forming processes') that affect the distribution and re-distribution of the chemical elements and cause accumulation of those into clusters called mineral deposits or more general mineralisations (de Launay 1913). However, we have to conclude that no such comprehensive model has been developed anywhere and the existing models of those processes (as e.g. the plate tectonic model) take into account only a part of the factors concerned. Similarly, the existing schemes of genetic classification of the mineral deposits (Smirnov 1976, Routhier & Moiseev 1983, Eckstrand 1984, Cox & Singer 1986, Laznicka 1993) still produce results contradictive to the field experience. Therefore the present metallogenic map of Finland is mainly empiric, and the metallogenic groups are defined as 'clusters of similar mineralisations', with no precise specification of the nature of the 'similarity'.

Historical review

The legend and classification of the metallogenic units used in the present metallogenic map of Finland are largely based on the principles of the Metallogenic Map of Europe, Sheet No 2 (UNESCO 1973). The se-

ries of the metallogenic maps of Europe, published by the Commission for the Geological Map of the World by IUGS, have been subject to profound international discussion since the early 1960s in respect to the classification of the deposits in size and morphological type, areal metallogenic units and the background geology. Unfortunately, very little of this discussion was properly documented. The foreword by P. Laffitte in the "Explanatory memoir of the metallogenic map of Europe and neighbouring countries 1 : 2 500 000" (UNESCO 1984) constitutes the only summary of the principles approved.

Indeed, the Metallogenic Map of Europe (UNESCO 1973) was preceeded by some other studies, e.g. in Finland by Eskola (1935) and Mikkola & Niini (1968). However, they remained less known and thus brought only a little input into the subsequent debate.

The concept used in the Metallogenic Map of Europe (UNESCO 1973) was inherited by practically all metallogenic maps published in Fennoscandia thereafter, such as the Metallogenic Map of Finland (Kahma 1973) and the Metallogenetic Map of Northern Fennoscandia (Frietsch et al. 1987), and the problems embedded in this concept were met time and again. It is for that reason they are discussed here in detail.

In the Metallogenic Map of Europe (UNESCO 1973), the mineralisations (deposits, occurrences and showings) were shown as symbols classified in terms of their morphology (presented as the shape of symbols), orientation (as direction of symbols), principal metals (as colour) and size class (as size of symbols). Genetic attributes were added as little arrows or other symbols only, because of the lack of a unanimously agreed genetic classification and of the polygenetic character of many mineralisations. Still there was a continuous fermentation in the interpretation of the genesis of particular deposits, and the resulting notations hardly satisfied the geological public.

One question giving rise to serious debate has been the size classification of the deposits. This was initially defined as the metal content of deposits, with no respect to the grade. The main problem here was the comparison of deposits of various metals. It had to be decided whether a copper deposit of 10 Mt with 4 % Cu should be considered larger or smaller than a zinc deposit of 20 Mt with 3 % Zn. The problem was solved by using an authorised table of equivalent tonnages of the various mineral commodities issued by the editors (UNESCO 1984), with a fixed boundary between the 'larges' and the 'smalls' for each mineral. It was proclaimed that this threshold value would be 1/1000 of the hitherto known world reserves for each metal. Table 1 presents the boundary values for the metallic commodities in the UNESCO list. The boundary between 'smalls' and 'showings' was set as 0.01 of the upper boundary for the 'smalls'.

Table 1. Tonnage in metal content constituting the dividing line between large and small deposits (UNESCO 1984).

Metal		Lower limit of 'large' deposits (metal tons)
Silver	Ag	500
Gold	Au	50
Cobalt	Co	10 000
Chromium	Cr	1 000 000
Copper	Cu	100 000
Iron	Fe	50 000 000
Manganese	Mn	1 000 000
Molybdenum	Mo	5 000
Niobium	Nb	20 000
Nickel	Ni	20 000
Lead	Pb	200 000
Platinum metals	PGE	10
Sulphur	S	1 000 000
Antimony	Sb	20 000
Tin	Sn	20 000
Titanium	Ti	500 000
Uranium	U	1 000
Vanadium	V	5 000
Tungsten	W	10 000
Zinc	Zn	200 000

Another problem arose about the size of the polymetallic deposits. After a discussion it was decided to define the size of a deposit as a combination of the amounts of the metals concerned. Practically speaking, the 'combined size estimate' of a deposit was calculated as a sum of the metal equivalent tonnages and the colour of the symbol assigned according to the main metal.

Legitimacy of the equivalent limit values in Table 1 has been debated since its publication, because its basis, the known world metal resources, was re-estimated every year with very contradictive results. Consequently, in many later maps, like in the Metallogenetic Map of Northern Fennoscandia (Frietsch et al. 1987), we see the boundary values are mostly similar, only differing for a few metals.

Metallogenic zones in the Metallogenic Map of Europe (UNESCO 1973) were drawn after classification by the main metals and genetic groups. In the Metallogenetic Map of Northern Fennoscandia (Frietsch et al. 1986, Frietsch et al. 1987, Frietsch 1988), metallogenic zones were traced simply as groups of similar deposits.

In addition to the above-mentioned true metallogenic maps, a few related maps of Finland and Fennoscandia deserve to be mentioned. In the Ore Deposit Map of Finland (Kahma et al. 1976), the main attention was paid to the metal content and metal proportions of the deposits. These variables were shown for each deposit drawn as a sectored circle (pie chart) of a size proportional to the total equvalent metal tonnage, with no morphological or genetic attributes. In the Map of Ore Deposits in Central Fennoscandia (Tontti et al. 1996, Lundqvist et al. 2000) mineralisation classification like that in the Northern Fennoscandian map (Frietsch et al. 1987) was applied, but no metallogenic zones were drawn. The same applies to "Map sheet no 9 (Europe)" of the Mineral Atlas of the World (Juve et al. 1997). This map was intended to be accompanied by a true metallogenic map (see Turchenko et al. 1995), but according to our knowledge that map was never printed commercially. The Metallic Mineral Deposits Map of Finland of 2000 by the present authors (Puustinen et al. 2000) mainly inherited the principles used by Kahma et al. (1976), with updated knowledge on the mineralisations and their volume. The deposits are shown as pseudo-three-dimensional spheres of a volume proportional to the tonnage and a colour according to the principal metal. The Metallic Mineral Deposits Map was actually compiled from the same material as the present Metallogenic Map, and thus functions as a useful additional tool for studying the latter. The Metallic Mineral Deposits Map was intended to serve the wider public as well, and it was accompanied with an explanatory text of popular character, entirely in Finnish (Saltikoff et al. 2000).

In the Ore Deposit Map of Finland by Kahma et al. (1976), the size parameters of deposits of various metals were calculated using the same equivalent table (Table 1) as in the Metallogenic Map of Europe (UNESCO 1973). Because of the problems involved in that classification, as discussed above, and because Table 1 did not cover all metals of interest, an alternative approach was chosen in the Metallic Mineral Deposits Map of 2000 (Puustinen et al. 2000). We stated that the 'rarity' of the various metals is fairly well reflected by their market prices. As experience shows, metal prices do indeed fluctuate, but the absolute fluctuations and especially the fluctuations in the relations between the prices of various metals are actually rather small. Consequently, the metal prices in the London Metal Exchange (LME) at a certain moment (August 1999) were chosen as a measure of their equivalent tonnages (Table 2). An estimate of the size of a deposit was calculated simply by determining the *in situ* values of all potentionally exploitable metals in the deposit, then calculating a sum of them and converting the sum to a tonnage of one metal – e.g. copper – of the same value. The principle is primitive but relatively stable.

Table 2. Equivalent tonnages for various metals on the basis of market prices from August 1999

Metal		LME price GBP/ton	Amounts of metal equal to 100 000 ton Cu
Silver	Ag	106.32	904
Gold	Au	5732.51	17
Cobalt	Co	31.90	3 013
Chromium	Cr	0.61	157 246
Copper	*Cu*	*0.96*	*100 000*
Iron	Fe	0.02	5 425 000
Manganese	Mn	0.54	178 600
Molybdenum	Mo	5.45	17 639
Niobium	Nb	1.71	56 360
Nickel	Ni	2.57	37 478
Lead	Pb	0.33	288 372
Platinum metals	PGE	7172.29	13
Sulphur	S	0.02	3 945 455
Antimony	Sb	0.80	119 890
Tin	Sn	3.37	28 506
Titanium (in ilmenite)	Ti	0.06	1 522 807
Uranium	U	13.26	7 250
Vanadium	V	14.59	6 588
Tungsten	W	2.56	37 527
Zinc	Zn	0.60	160 148

It must be stressed that the absolute values of the metals have no significance at all in these calculations. They do not reflect the gross or net value of the deposit, but simply serve as a tool for comparison of the relative size of deposits containing various metals.

The same size estimates are used in the present Metallogenic Map as the basis for size classification. On a purely empirical basis, an amount of 100 000 tonnes Cu is accepted as the basic threshold value for the 'large deposits' class, and then the threshold values for other metals are determined as tonnages approximately of the same value. These equivalent values are also shown in Table 2. The limit for the 'small deposits' class is defined as 1/100 of the former or equivalent to 1 000 tonnes Cu, and the deposits exceeding 10 000 000 tonnes Cu (in practice, only one, the Kemi Cr deposit) are classified as 'extra large' or 'world class' deposits.

PRINCIPLES APPLIED INTO THE PRESENT METALLOGENIC MAP

Definitions

In the present work, the field of study is limited with deposits and occurrences of heavy metals, in accordance with the original meaning of the term 'metallogeny' (de Launay 1913). Geologically they are easier for interpretation than the deposits of non-metallic commodities, as the intensity of the ore forming process can be implicitly described by the amount of the metals concentrated, which again is determined purely by the grade of the mineralisation (percentage of the metal concerned).

Throughout this work the word **mineralisation** is used as a general term for a mineralised body of any size; the process or the regional phenomenon is referred to as **ore forming process**. The mineralisations are divided into mineral **deposits**, **occurrences** and **showings** according to their size, as discussed in the previous chapter; the use of these terms broadly follows the common usage.

From the metallogenic point of view, a mineralisation is a natural concentration of a chemical element or some elements (and in our case, heavy metals) to such a degree that it forms an unusual segregation of metal-rich mineralogical species, ore minerals, somewhere in the Earth's crust (de Launay 1913). This definition includes no economic parameters at all. However, in practice the only comprehensive information available is the description of real exploration and mining objects, where non-geological parameters (like cut-off grade, harmful elements, unfavourable location) always are implicitly included e.g. in tonnage estimation, and we are dependent on that information in our metallogenic reasoning.

A **metallogenic zone** (if sub/linear) or **provincefield** (if isometric) is an area favourable for the presence of mineralisations of one (or more) particular type(s). Because such favourability is always controlled by some geological factors, the metallogenic zones roughly coincide with main geological structures. The control may be of varying character, and the relationship between a metallogenic zone and a geological structure varies correspondingly. For example, zones of stratiform mineralisations of the banded iron formation are absolutely restricted to certain stratigraphic units, while a "titanium-iron province" means an area hosting scattered mafic intrusions with titanium-iron mineralisation and thus is always somehow indefinite.

Base data

The geological material in the present Metallogenic Map, drawn as the base map and used for delineating metallogenic zones, comes from the Bedrock Map of Finland 1 : 1 000 000 (Korsman et al. 1997). Fig. 1 shows a reduction of that map and the system of main regional geographic-geological blocks named after Nironen et al. (2002). The magnetic and gravimetric maps of Finland (shown as Fig. 2 and 3) were involved as additional materials for understanding and interpretation of the sub-surface and deep geological structures.

For a comprehensive description of the geology of the bedrock of Finland, the reader is advised to the monograph "Precambrian Geology of Finland – Key to the Evolution of the Fennoscandian Shield" (Lehtinen et al. 2005).

In the Metallogenic Map, the legend of the bedrock geology is strongly generalised as compared with the original bedrock map. Of the stratigraphical and lithological units, only those of the highest rank are shown. A non-traditional feature pictured is the presence of two megablocks or domains: the Kola-Karelian Domain that occupies the north-eastern part of Finland and represents a craton of Archaean age partly with a Proterozoic overprint, and the Svecofennian Domain of the south-western part with a crust entirely of Lower Proterozoic age (Puustinen et al. 1995). This feature (Fig. 4) is paid special attention because of its importance from the point of metallogeny. Especially the border zone between the two domains running across Central Finland, the Raahe-Laatokka zone, has been for a long time known as a territory of high metallogenic potential (Kahma 1973, Kahma 1978, Ekdahl & Filippov 1999). A number of most important metallogenic zones (Rantasalmi Au zone, Juva-Puumala Ni-Cu province, Kotalahti Ni-Cu zone, Vihanti-Pyhäsalmi Zn-Cu-Pb zone) are grouped immediately at the flanks of the border line, and some others (e.g. Outokumpu Cu-Zn-Co zone, Laivakangas Au zone, Hitura Ni-Cu province) lie not far away from it. The geology of the

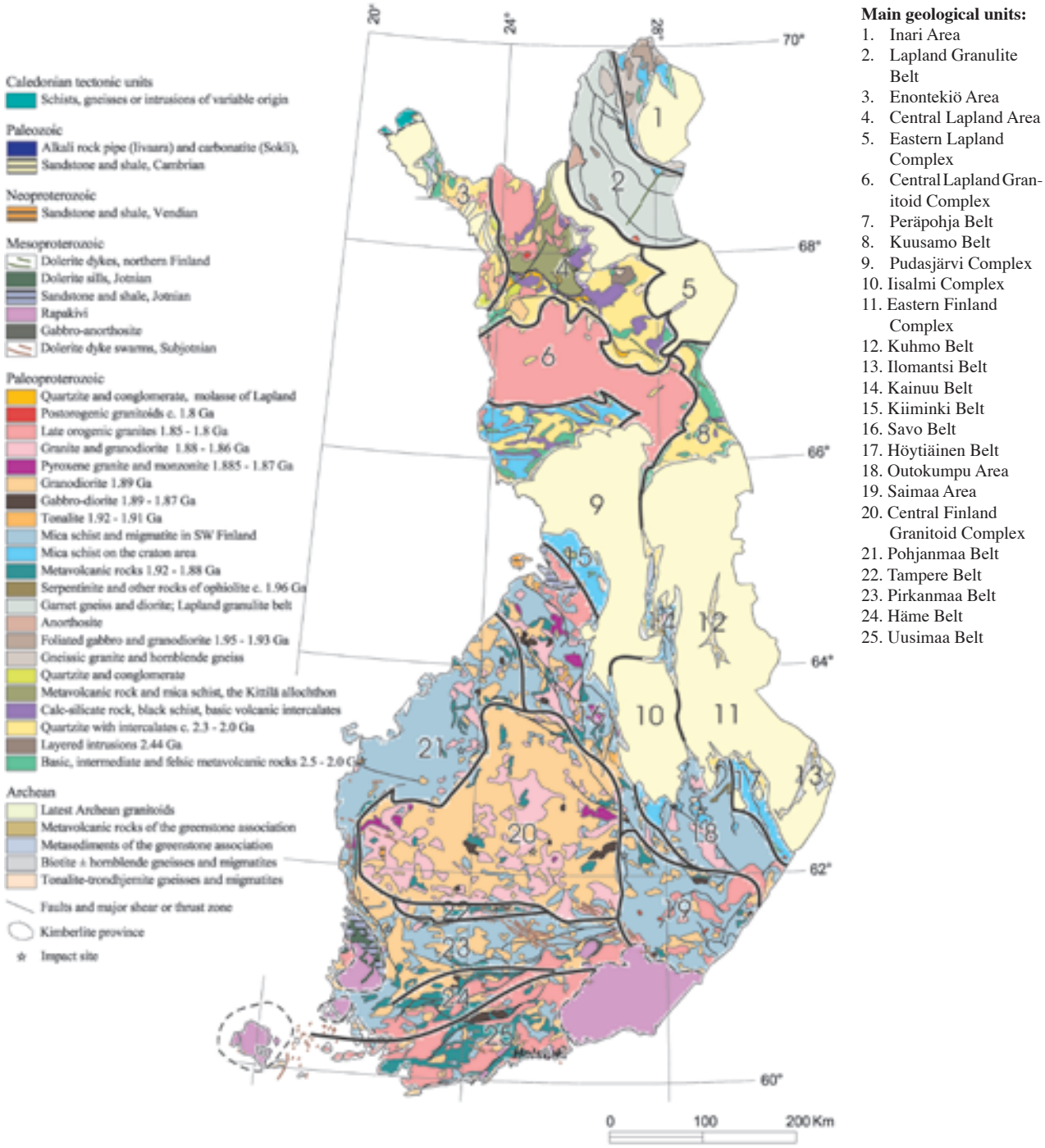

Fig. 1. The bedrock of Finland (after Korsman et al. 1995) and the territorial geological units (Nironen et al. 2002). The unit numbers are referred to throughout this paper in the description of the metallogenic zones.

Raahe-Ladoga zone is described in several papers, the most comprehensive of them being a monograph edited by Korsman (1988).

The characteristics of the mineral deposits and occurrences presented in the Metallogenic Map and referred to in the present report are collected from the reference sources listed in connection with the description of each zone, and partly from unpublished archive materials. The primary data is also stored in the national Ore Deposit Database maintained by the Geological Survey of Finland since 1970s (Gaál et al. 1977, Saltikoff & Tarvainen 1990), now available under the name MALMIKANTA (Geological Survey of Finland/GTK, web pages, under preparation). The same characteristics are used in the Metallic Mineral Deposits Map (Puustinen et al. 2000), with exception of some few latest revisions. Particularly, the figures of the size of the deposits mentioned below are the

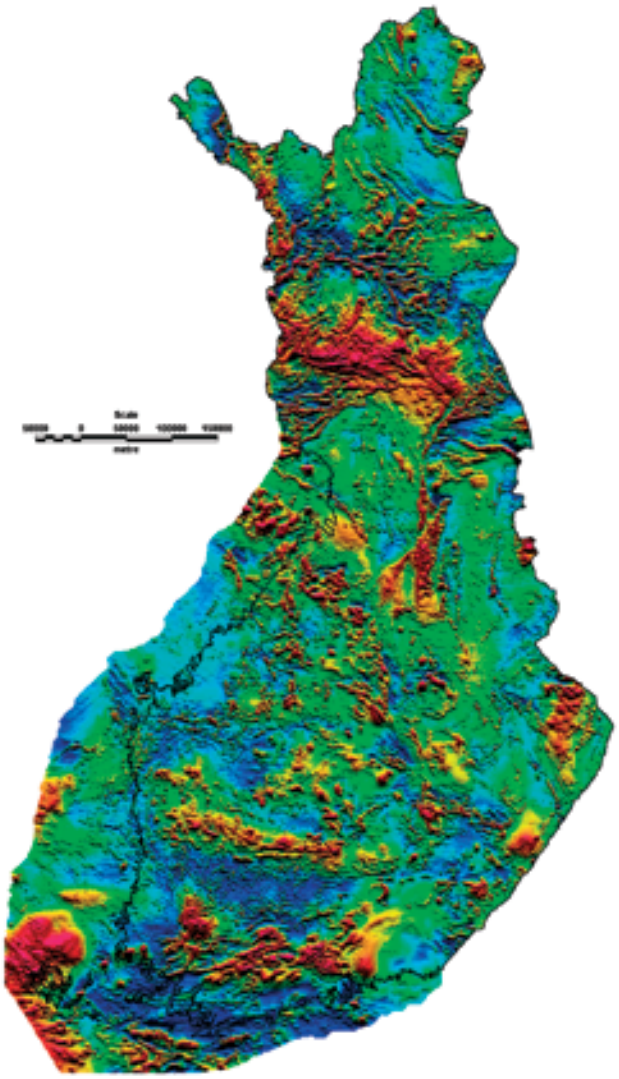

Fig. 2. Aeromagnetic map of Finland. Data from the Geological Survey of Finland (Korhonen 1980).

Fig. 3. Gravimetric map of Finland. Gravity data from the Finnish Geodetic Institute and the Geological Survey of Finland (Kääriäinen and Mäkinen 1997, Elo 1997).

most recent available estimates. If not otherwise stated, they are geological *in situ* estimates of the (Measured + Indicated) class. Production figures for the exploited deposits are taken from the report on mining history in Finland, preliminarily described by Puustinen (1997) and now updated until 2001. The mineral deposits and occurrences cited in the present report and not indicated in the Metallogenic Map can most easily be seen in the Metallic Mineral Deposits Map (Puustinen et al. 2000).

The references belonging to particular zones and mineralisations are listed in connection with the corresponding descriptions. Besides, there are a number of general papers describing or reviewing the deposits of the entire country. Of such papers, we present the above-mentioned paper by Kahma (1973) on the metallogeny of Finland; a monograph on the exploited deposits in Finland edited by Aurola (1954); the section "Finland" by Isokangas (1978) in a monograph "Mineral Deposits of Europe"; papers by Rouhunkoski (1982), Papunen (1986) and Ketola (1986) on the exploration practices in Finland, by Frietsch et al. (1979) on the ore deposits in the entire Scandinavia, and by Puustinen (1997) on the history and statistics of mining in Finland. There are also several papers dealing with metallogeny and geology of deposits and occurrences of particular metals, such as Mikkola & Rouhunkoski (1980) and Inkinen & Hiltunen (1980) on copper deposits; Nuutilainen & Paakkola (1977) on iron deposits; Puustinen (1981), Gaál & Sundblad (1990) and Eilu et al. (2003) on the deposits and metallogeny of gold; Papunen & Gorbunov (1985) and Puustinen et al. (1995) on the deposits and metallogeny of nickel; Kulonpalo &

Fig. 4. The main geoblocks (domains) in Finland. After Puustinen et al. (1995).

Marmo (1955) on molybdenum mineralisations; and IUREP (1982) on uranium deposits. Recently, on-line textual public databases describing deposits of some metals have been developed in the Geological Survey of Finland, like FINGOLD (Eilu 1999) and FINZINC (Eilu 2000).

Finally, attention should be given to reports and books on the mineral deposits and occurrences in Finland dating back as far as the 18th century. These early papers are unfortunately all written in Swedish and as such unavailable to the international public; however, a reader familiar with the language may be interested in these. The earliest one is a description of the geology and mineral deposits of southwestern Finland by Daniel Tilas (1738); then come the two books by C. O. Bremer (1824 and 1825) and then the widely known monograph called "Materialer till Finlands geognosi" by H. J. Holmberg (1858). These papers have widely been used by the later researchers as information sources on ancient mining targets, especially in the Orijärvi metallogenic zone.

Classification of the mineralisations and metallogenic zones

The mineralisations (mineral deposits and occurrences) are classified on the map in respect to their metal content (total amount of the metals and the principal metal) and morphological type. The metallogenic zones are classified according to the metal content of the respective mineralisations. No genetic parameters are shown on the map, as the genetic conceptions vary from time to time. The metallogenic models presented by various authors are mentioned in the present publication, with reference to the original sources.

The principal metals of the mineralisations are shown by the colour of the mineralisation symbols, following common practices. In a case of a multimetal mineralisation, the principal (dominating) metal is understood as the metal that yields the largest relative tonnage in the mineralisation. In the colour scheme, the only non-traditional feature is that cobalt is included in the same group with copper rather than with nickel. This reflects the fact that the cobalt-dominated ore types (e.g. Co-Au type) closely resemble the copper types, even if cobalt as a by-product submissively follows nickel. Sulphur (pyrite) ore type is discarded as an independent class; the occurrences of sterile pyrite, once anxiously explored for sulphur, are included in the iron type.

The size of a mineralisation is defined as the total amount of the metals concentrated in the mineralisation. In a metallogenic map, deposit size is a parameter of less importance. The mineralisations are simply divided into two main size classes: 1) major deposits and minor deposits plus the subgroup of "world class deposits" (extra large), and 2) the class of minute

occurrences and showings (extra small). The precise size estimates of the deposits and major occurrences in Finland are depicted in the "Metallic Mineral Deposits Map" (Puustinen et al. 2000), and the principles of their size calculation is discussed in the chapter "Historical review" of the present paper.

Morphological types

The term 'morphological type of a deposit' is used in the same sense as in the Metallogenic Map of Europe (UNESCO 1973). It is hereby understood as the position of the deposit in relation to the hosting strata rather than as the geometric shape of the deposit. Definition of the nomenclature used is as follows:

- Stratiform deposits: syngenetic supracrustal mineralisations strictly restricted to particular layers in strata, such as black schists, palaeoplacers or banded iron formations,
- Stratabound deposits: mineralisations of possibly syngenetic initial origin but eventually concentrated by epigenetic processes in particular layers of strata, such as the volcanic hosted massive sulphide deposits,
- Stocks: nebular or irregular disseminations in intrusive rock bodies other than layered intrusions, such as intrusive-hosted nickel-copper deposits; also deposits of the porphyry copper type are included here,
- Magmatic stratiform: deposits in the sheet-like layered intrusions,
- Vein deposits: mineralisations restricted to single veins, vein swarms or shear zones with more or less distinct orientation,
- Irregular replacement bodies: stockworks (vein networks with no orientation), deposits called 'metasomatic pipes',
- Replacement zones: skarn bodies, silicification bodies etc. with distinct orientation controlled by other factors than the strata,
- Pipes: pipe-like intrusions, such as carbonatite pipes,
- Placers: alluvial mineralisations in recent overburden.

In practice, very few deposits represent one pure morphological type. Thus contradictions in classification of the deposits are always possible. For instance, even the stratiform mineralisations form real deposits only along with secondary concentration processes (e.g. thickening in folding) and are close to the stratabound type; mineralised veins are always accompanied by a certain amount of ore-grade replacement zones; magmatic layering or stratification is found in many minor mafic intrusions, and the boundary between 'magmatic stratiform' and 'stock' type deposits is somewhat arbitrary. Porphyry copper deposits could be classified either in the 'stock' class (as here) or in the 'stockwork' class (as done by Juve et al. 1997).

DESCRIPTION OF THE METALLOGENIC ZONES

The individual metallogenic zones delineated in the Metallogenic Map of Finland are shown in Fig. 5. In this section, they are described in terms of their location, geological setting, the most important or typical mineralisations and the most popular genetic concepts, with reference to the original papers. At the end of the paper there are also descriptions of some important single deposits not belonging to any of the described metallogenic groups.

The Orijärvi Zn-Cu-Pb + Fe zone (1) is a zone of supracrustal Zn-Cu-Pb mineralisations hosted by skarns and Al-rich rocks (including cordierite-anthophyllite rocks), and Fe mineralisations of skarn and banded iron formation types. These deposits belong to the same type as the Zn-Cu-Pb and Fe deposits of the Bergslagen province in Central Sweden in terms of the principal metals, host rock types and also the isotopic composition of lead in galenas (M. Vaasjoki 1981; Frietsch & Papunen 1986). In fact, the entire Orijärvi zone can be regarded to as the eastern branch of the Bergslagen province. The Orijärvi zone runs in E-W direction in the southern part of the Uusimaa Belt (geological unit no. 25 in Fig. 1). This part is characterized by abundant quartz-feldspar gneisses (leptites), interpreted partly as metamorphosed felsic volcanics, beds of marbles and calc-silicate rocks (originally pure and impure limestones) and minor occurrences of banded iron formations. It has been

1 – Orijärvi (Zn-Pb-Cu + Fe);
2 – Kemiö (Ta);
3 – Palmottu (U);
4 – Pori-Vammala-Kylmäkoski (Ni-Cu);
5 – Pirkkala-Valkeakoski (Au);
6 – Eräjärvi (Ta);
7 – Haveri-Orivesi (Au-Cu-W);
8 – Peräkorpi (Ti-Fe);
9 – Telkkälä (Ni-Cu);
10 – Juva-Puumala (Ni-Cu);
11 – Rantasalmi (Au);
12 – Virtasalmi (Cu);
13 – Ilmolahti (Ni-Cu);
14 – Kotalahti (Ni-Cu);
15 – Vehmersalmi (U);
16 – Outokumpu (Cu-Co-Zn + Ni);
17 – Koli-Kaltimo (U);
18 – Kyykkä-Hokka (Cu);
19 – Hattu (Au);
20 – Huhus (Fe);
21 – Seinäjoki (Au-Sb);
22 – Oravainen (Ni-Cu);
23 – Koivusaarenneva (Ti-Fe);
24 – Emmes (Li);
25 – Vihanti-Pyhäsalmi (Zn-Cu-Pb);
26 – Laivakangas (Au);
27 – Hitura (Ni-Cu);
28 – Talvivaara (Ni-Zn-Cu);
29 – Nuottijärvi-Sotkamo (U);
30 – Otanmäki (V-Fe-Ti);
31 – Moukkori – Lokkiluoto (Au);
32 – Kauniinlampi – Arola (Ni);
33 – Tipasjärvi – Saarikylä (Fe);
34 – Pääkkö (Fe);
35 – Koillismaa (PGE + Ni-Cu + V-Fe);
36 – Oijärvi (Au);
37 – Kemi-Penikka (Cr, PGE);
38 – Suhanko (PGE);
39 – Narkaus (PGE);
40 – Tervola (Au-Cu);
41 – Rovaniemi-Ylitornio (Mo-Cu-W);
42 – Misi (Fe);
43 – Kuusamo Au (Au);
44 – Kuusamo U (U);
45 – Suonna (Fe);
46 – Jauratsi (Fe);
47 – Kylälampi (Fe);
48 – Kittilä (Au-Cu);
49 – Koitelainen (PGE+Cr+V-Fe);
50 – Porkonen-Pahtavaara (Fe-Mn);
51 – Kesänkitunturi (U);
52 – Rautuvaara (Fe, Cu, Au);
53 – Pyhäjärvi (V-Fe-Ti);
54 – Pulju (Ni);
55 – Nirroselkä (Ni);
56 – Lemmenjoki (Au);
57 – Ivalojoki (Au);
58 – Ruossakero (Ni);
59 – Vätsäri (Fe).

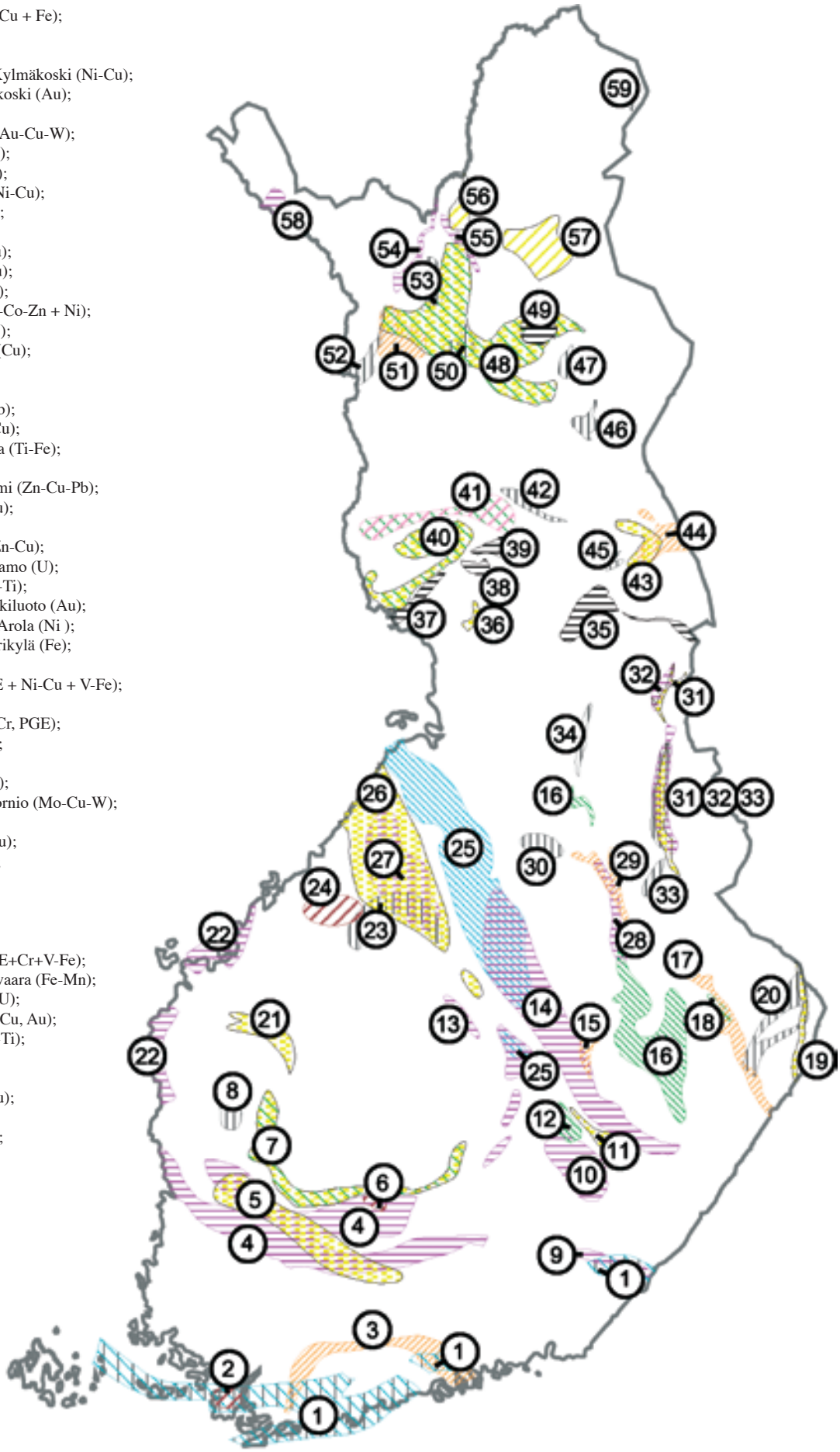

Fig. 5. The main metallogenic zones of Finland

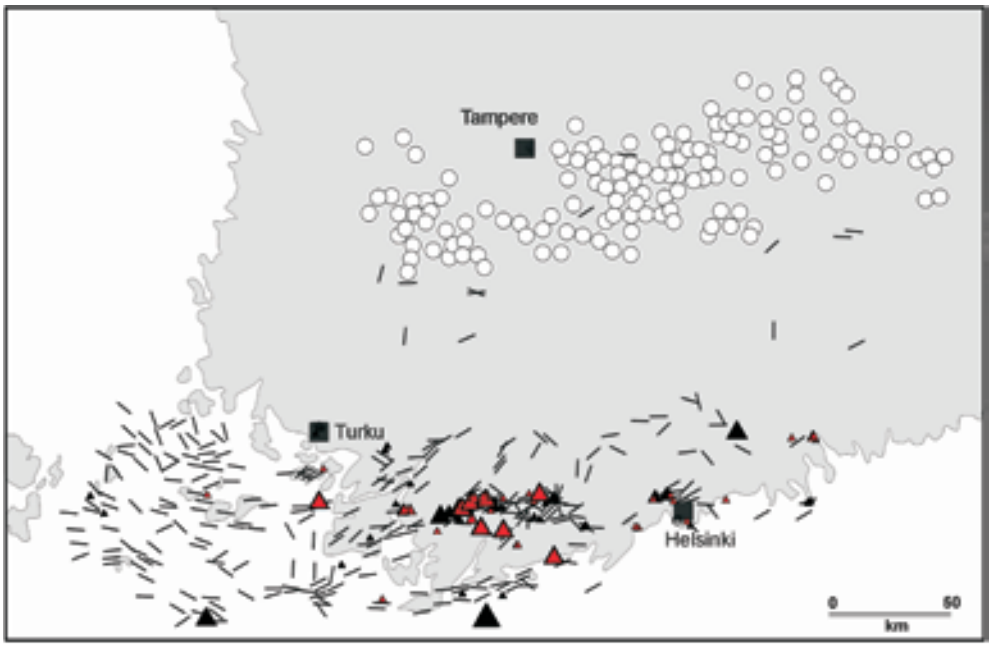

Fig. 6. The mineral deposits and occurrences of the Orijärvi zone (triangles, red – Zn-Cu-Pb type, black – Fe type) as compared to the distribution of limestone layers (dashes) in the Uusimaa Belt of southern Finland. The zone around Tampere, rich in calcareous concretions in gneisses (circles), marks a completely different milieu, the Pirkanmaa Belt. Deposit data from the materials for the Metallogenic Map, background map by courtesy of Kari A. Kinnunen (GTK).

called Leptite Belt (Eskola 1914, Lukkarinen 1986) or Svionian belt (Kinnunen & Saltikoff 1989). The ore-bearing horizons of the zone reverentially follow the marble and calc-silicate rock beds of the region (Fig. 6).

The Orijärvi zone is cut into parts by younger granitoid massifs (both Late Svecofennian granitoid masses and anorogenic rapakivi granite batoliths). The belonging of the mineralisations in the eastern parts of the zone, for example Pernaja (O. Vaasjoki 1953), Hyvärilä inside the Vyborg rapakivi batholith (Vorma 1975) and Salo-Issakka at the Russian border, to this zone has been subject to discussion, but a clear evidence thereupon was obtained by the lead isotopic composition of the deposits mentioned (M. Vaasjoki 1981 and pers. comm. 2003, Frietsch & Papunen 1986).

The southern flank of the Orijärvi zone is hidden below the sea. Probably the zone extends well to the south, and the iron deposits of banded iron formations (BIF) and/or skarn type discovered offshore in the Gulf of Finland, e.g. Jussarö, belong to this zone, too; however, this is impossible to definitely prove with the present data.

The Orijärvi zone is historically the best-known mineral province in Finland. Iron deposits in this zone have been subject to mining since 16th century (Tammekann 1926, von Knorring 1955) and copper deposits since 18th century, and the classical studies by Eskola (1914) on the regional metamorphism and metasomatism in Orijärvi was a description of the principle of the metamorphic facies. The most important recent works dealing with the geology of the zone are Latvalahti (1979), Mäkelä (1983, 1989), Colley & Westra (1987), Väisänen (1988) and Isomäki (1986). There are also noticeable works on detailed aspects, such as lithogeochemistry (Wennervirta & Papunen 1974), for the region.

The largest sulphide deposits are Orijärvi, Aijala and Metsämonttu in the central part of the zone and Attu in the west. Orijärvi (Varma 1954a, Isokangas 1978) has been exploited for almost 200 years (1757 – 1955), and yielded in total 0.92 Mt of ore at 1.32% Cu, 3.32 % Zn and 1.07 % Pb. The ore was hosted partly by cordierite-andalusite rock and partly by tremolite skarn. The main ore minerals were chalcopyrite, sphalerite and galena plus some pyrrhotite and pyrite. It is noticeable that the cordierite-hosted ore ("hard ore") regularly was copper-dominated and the skarn-hosted ore ("soft ore") zinc-dominated.

Aijala and Metsämonttu (Varma 1954b, Isokangas 1978) were discovered in 1940's. Aijala was mined in 1948 to 1960 and produced 0.84 Mt of ore at 1.59% Cu and 0.66 % Zn, Metsämonttu in 1951 to 1974, yielding 1.51 Mt at 3.34 % Zn, 0.74 % Pb, 0.28 % Cu, 25 g/t Ag and 1 g/t Au. Attu, discovered in 1750ies and test mined then, was never subjected to modern mining, despite of its significant resources, estimated

as 4.3 Mt at 1.76 % Zn and 1.05 % Pb (Pehrman 1931, Hangala 1987).

Not far away from Orijärvi there is a small deposit of a slightly other type, Iilijärvi (Mäkelä 1989). It is fairly rich in gold (1.3% Zn, 0.6% Cu, 0.6% Pb, 30 g/t Ag, 4 g/t Au). The ore in Iilijärvi is hosted by light-coloured sericite schist and contains arsenopyrite in addition to the above-mentioned sulphide ore minerals.

The largest iron deposits are located in the southernmost chain in the zone, in the archipelago of the Gulf of Finland. Jussarö (Saksela 1939, Haggerty 1964, Mikkola 1966, Laajoki 1985) was known for centuries due to the strong magnetic anomalies harmful for navigation. It was subject to exploitation in several stages between 1834 and 1967 and produced 1.65 Mt of ore at some 28 % Fe, although the real resources count not less than 5 Mt. The ore belongs to the BIF type with magnetite as practically only ore mineral.

Nyhamn was exploited in a pilot scale as an underwater mine in 1957 to 1959, and 0.08 Mt at some 20 % Fe were extracted; total estimated resources are ca. 10 Mt.

All other occurrences are very small to the present standards; in ancient times, in the 17th and 18th century, tens of mines were opened here for exploiting such minuscule objects as

- Sillböle in the Helsinki district (1744–1866; 0.035 Mt at 30 % Fe; Tammekann 1926),
- Malmberg near Orijärvi (1670–1866; 0.016 Mt at 35 % Fe; von Knorring 1955) and
- Ojamo in Lohja (1542–1838; 0.012 Mt at some 45 % Fe).

The Kemiö Ta zone (2) is a province with abundant granitic complex pegmatite bodies scattered in the mafic intrusives and supracrustal rocks of the Svecofennian complexes (Pehrman 1945, Lindroos et al. 1996). The main tantalum minerals are tantalite and tapiolite.

The pegmatites at Kemiö have long been subject to mining for non-metallic minerals, i.e. quartz and feldspar (Isokangas 1978). Recently their tantalum potential was re-evaluated and found to be of economic interest (R. Alviola, pers. comm. 2003). Thus they have to be regarded as a tantalum province, as well.

The Palmottu U zone (3) consists of a number of minor uranium disseminations in the granitic neosome of Svionian migmatites. Actually, a territory of increased radioactivity can be traced up to Turku in the west (H. Seppänen, pers. comm. 2003), but the most significant mineralisations (IUREP 1982) are limited to the marked zone. The largest of them, Palmottu (1.0 Mt at 0.11 % U; Räisänen 1989), has also been subject to extensive studies in migration of radionuclides in bedrock and groundwater (Pomiès et al. 1998, Blomqvist et al. 2000, Grundfelt 2002, Ruskeeniemi et al. 2002). The minute mineralisation at Hyrkkölä is of special interest because of its native copper content (Marcos 1996, Marcos & Ahonen 1999, Marcos et al. 1999).

At the southeastern end of the zone, several mineralisations of a different type (high-grade uraninite-quartz-haematite veins) have been encountered. They display an anomalous, sub-Phanerozoic model age (Vaasjoki 1977) and have been described as possibly belonging to the so-called unconformity type of deposits (O. Äikäs, pers. comm. 2003).

The Vammala Ni-Cu zone (4) is one of the most important nickel mining districts in Finland with the (today closed) mines of Vammala (Stormi) and Kylmäkoski and about 60 other known deposits and occurrences (Puustinen et al. 1995). These all belong to the classical Svecofennian type (Papunen & Vorma 1985, Puustinen et al. 1995) that includes practically all of the nickel deposits of economic value so far discovered in Finland.

The deposits of the Vammala zone are hosted by synorogenic mafic-ultramafic intrusions in migmatitic gneisses of the Pirkanmaa Belt (unit no. 23 in Fig. 1) that surrounds the Central Finland Granitoid Complex from the south (Peltonen 1994, 1995a, 1995b, 1995c). As such, this zone is totally analogous to the other nickel zones of the Svecofennian type like the Telkkälä, Juva-Puumala, Ilmolahti, Kotalahti, Oravainen and Hitura zones described later in the present paper. Minor differences between these zones include, e.g., the fact that most of the nickeliferous intrusions in the Vammala zone are ultramafic in composition, while the intrusions in the Kotalahti zone are predominantly mafic (noritic).

During the years, the nickel deposits and zones in Finland have been subject to a lot of studies and discussions by many authors. The most comprehensive monograph, "Nickel-copper deposits of the Baltic Shield and Scandinavian Caledonides" (Papunen & Gorbunov 1985) contains several papers on the nickel provinces in general and particularly on the Vammala zone, and on some of the most interesting individual deposits. A more recent summarising paper on the subject is a publication by the present authors on the distribution and the metallogenic types of the nickel deposits in Finland (Puustinen et al. 1995), where all the known deposits and major occurrences are listed and described in small clusters referred to by numbers (Fig. 7). These two papers are the basic references here.

Most of the authors are of the opinion that the lo-

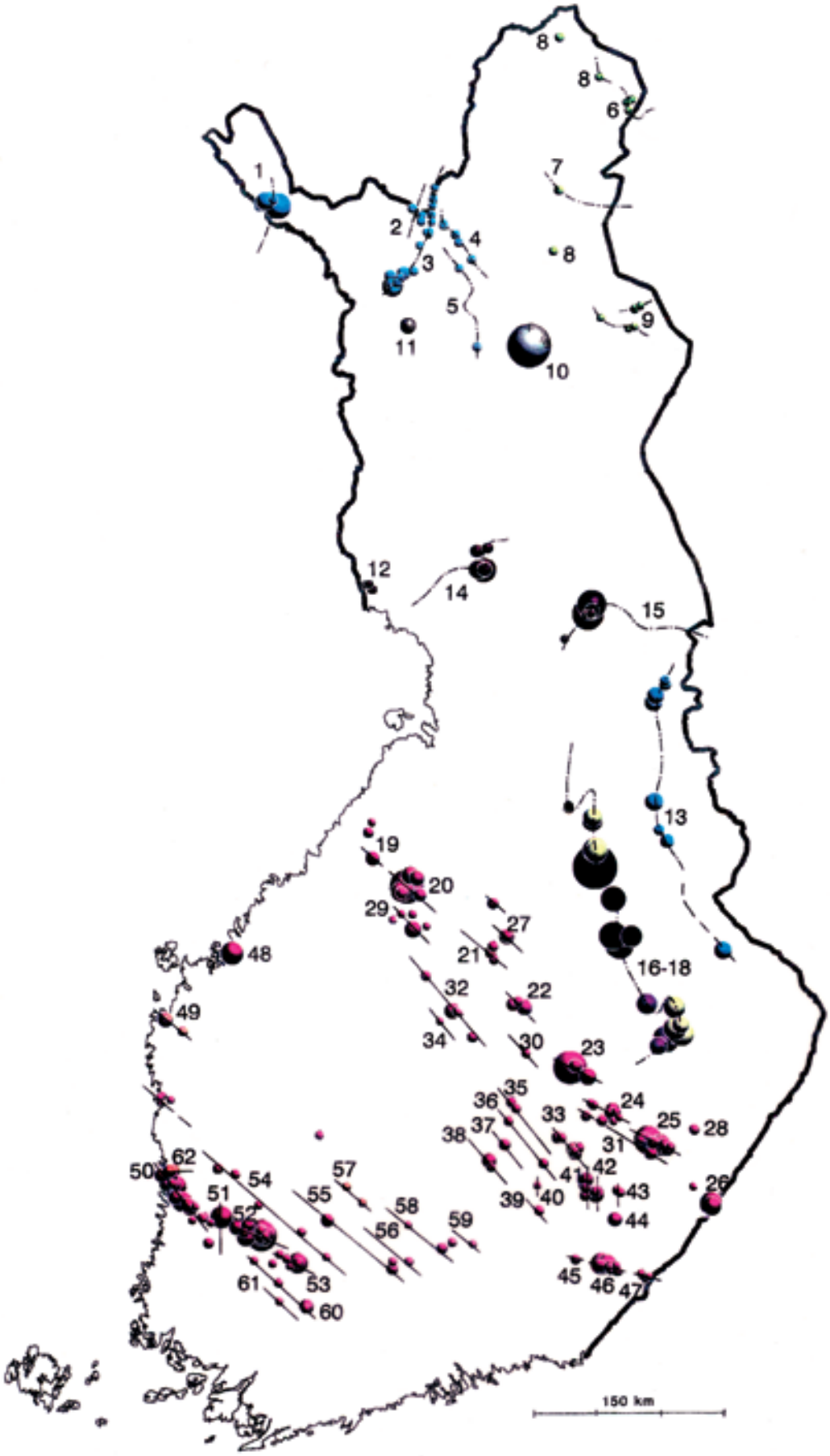

Fig. 7. Nickel deposits in Finland, grouped by size and metallogenic types (from Puustinen et al. 1995). Metallogenic types: Svecofennian – red; Outokumpu type – yellow; black schists – black; layered intrusions – violet; Archaean komatiite type – blue; others – silver-grey. Lines – linear features linked to the particular deposit clusters. Numbers refer to the deposit clusters as discussed in Puustinen et al. (1995).

cation of the Svecofennian type nickel zones and the individual deposits within them is mainly controlled by a favourable lithological environment dominated by migmatitic mica gneiss fields and trondhjemitic plutonic massifs and by favourable tectonic structures, especially fault systems. Depending on how these two factors are emphasized, the zones are depicted as linear or sub-linear units (e.g. Gaál 1985) or field-like broad belts (e.g. Papunen & Vorma 1985). Frietsch et al. (1979) brought up the idea of a single ring-like nickel belt in the migmatite belts around the Central Finland Granitoid Complex covering both the Vammala zone and all other Svecofennian nickel zones mentioned above. In the paper by Puustinen et al. (1995), the Vammala zone is referred to as a high rank entity (called "Vammala Belt") stretching from the city of Pori on the west coast (No. 50 in Fig. 7) to the Kylmäkoski deposit (No. 53 in Fig. 7), and it is divided into several lower rank clusters (called 'zones') controlled by shear lines.

According to the most recent views, the entire Pirkanmaa Belt is considered to be of a high nickel potential. Also statistical modelling of the lithological framework (Saltikoff and Koistinen 1989, Puustinen et al. 1995) and modelling of a combination of the geological, geophysical and till geochemical factors (Tiainen & Viita 1994) assign a high nickel potential to the Pirkanmaa Belt. Therefore, in the Metallogenic Map, the Vammala zone is drawn to continue east from the Kylmäkoski deposit and to include the clusters 56, 58 and 59 by Puustinen et al. (1995; see also Fig. 7). However, considering the fact that all major deposits and an overwhelming majority of minor deposits discovered hitherto are located in the stretch between Pori and Kylmäkoski, this part of the Vammala zone is delineated as the 'core' of the zone.

When drawn as broadly as in the Metallogenic Map, the Vammala zone comes near the Telkkälä zone (zone no. 9 in Fig. 5) in the east and near the Oravainen zone (no. 22, Fig. 5) in the northwest. It is not impossible that these zones may join, although there seems to be no direct evidence of it.

Of the individual deposits in the Vammala zone, the type locality, the Vammala deposit (also known as Stormi) is the largest and best studied (Häkli et al. 1979, Häkli & Vormisto 1985, Marshall & Mancini 1994, Marshall & Mancini 1995, Liipo et al. 1997). It was mined from 1974 to 1995 and produced 7.57 Mt of nickel ore with a grade of 0.68 % Ni and 0.42 % Cu. The deposit consists of sulphide dissemination in a differentiated ultramafite massif. The main orebodies occupy the bottom part of the massif in a subhorizontal way (Fig. 8).

The next most noteworthy deposit is Kylmäkoski at the southeastern end of the 'core zone' (Papunen 1974, 1977, 1980, 1985). It was the first deposit of economic value to be discovered in the zone and was mined from 1971 to 1974, producing 0.69 Mt of ore at 0.36 % Ni and 0.27 % Cu. Geologically it is very similar to Vammala, hosted by a small and shallow (less than 100 m in depth) body of ultramafic rocks. Among these a unique olivine rock with nodular and partly even orbicular texture has been detected (see e.g. Papunen 1985). The ore is mainly of the normal pentlandite-chalcopyrite-pyrrhotite dissemination type. In addition, a few massive veins containing rare

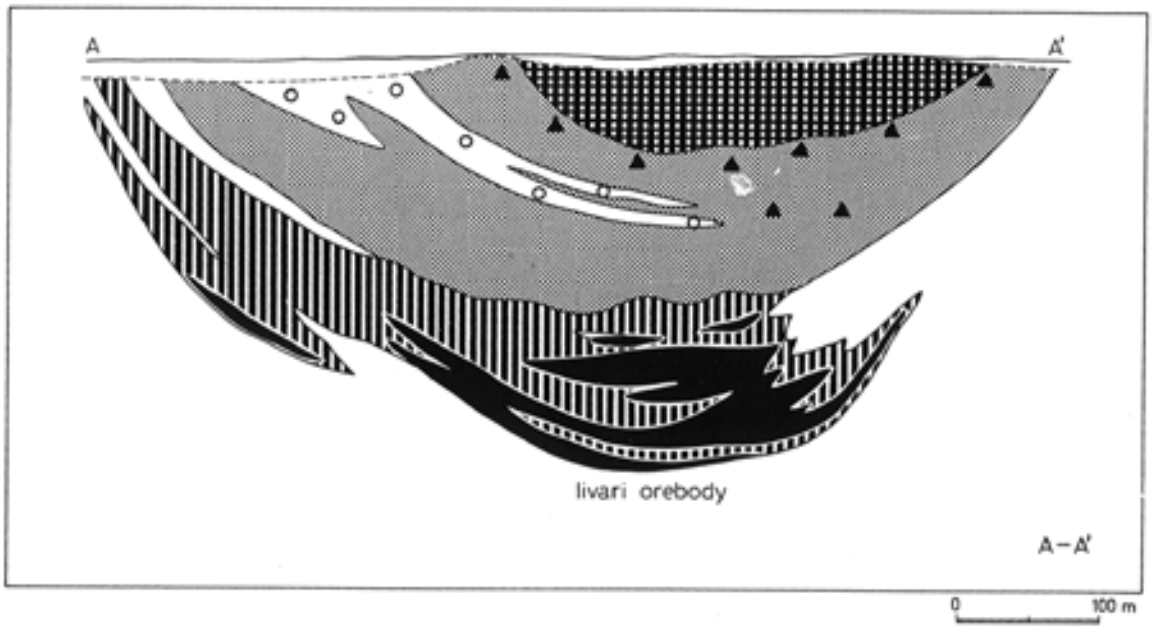

Fig. 8. Vertical section of the Vammala Ni-Cu deposit. Ore (black) in the layered intrusion composed of various ultramafic rocks (variously rastered). From Häkli & Vormisto (1985).

sulphides and arsenides, like niccolite, maucherite, gersdorffite and PGE-minerals have been encountered (Gervilla et al. 1997a, 1997b, 1998).

The minor Hyvelä deposit near the city of Pori at the northwestern edge of the 'core zone' (Stenberg & Häkli 1985) has indicated reserves of 0.8 Mt of ore at 0.53 % Ni and 0.28 % Cu. Hyvelä differs from the deposit type described above in respect to host rock, which is a slab-shaped norite body.

Of the other individually studied deposits worth mentioning in the Vammala zone is Sääksjärvi, located midway between Hyvelä and Vammala (Mancini & Papunen 2000). This deposit is unexploited, and has resources estimated at 3.5 Mt at 0.24 % Ni and 0.33 % Cu.

A very special case is the Korkeakoski deposit north of the city of Pori (Puustinen et al. 1995). This tiny deposit (0.2 Mt at 0.41 % Ni and 0.31 % Cu) is associated to a dolerite dike of the Subjotnian age (1650 Ma). Thus its relationship to the Vammala zone is perhaps spatial only.

The hitherto known mineralisations outside the core of the Vammala zone are rather small, and no comprehensive primary descriptions on them are available. Summary information on them, collected from the archived exploration reports, is published by Tiainen and Viita (1994) and Puustinen et al. (1995).

Recently the deposits of the Vammala zone have been subject to systematic studies on PGE elements (e.g. Gervilla et al. 1997b, Gervilla et al. 2004). In the course of these studies a new peculiar Re-Mo-Cu-Os mineral was found in the Ekojoki deposit (Peltonen et al. 1995).

The Pirkkala-Valkeakoski Au zone (5) consists of several minor mineralisations represented by gold-bearing quartz veins in synorogenic Svecofennian intermediate intrusives or more mafic inclusions in these, and in pelitic gneisses of the Pirkanmaa Migmatite Belt (unit no. 23, Fig. 1), an accretionary arc complex of Central and Western Finland (Gaál & Sundblad 1990, Rosenberg 1997, Eilu 1999, Eilu et al. 2003).

A few mineralisations of a similar character are located to the south of the zone under consideration. However, their relationship to the main group is uncertain, and it is possible they constitute a separate province. The largest of these, Jokisivu (Luukkonen 1994, Luukkonen et al. 1992, Luukkonen et al. 1997a), was recently proved to be of a commercially feasible size, estimated to be 1.47 Mt at 6.8 g/t Au (Dragon Mining NL 2005).

The Eräjärvi Ta zone (6) is a pegmatite province similar to the Kemiö province, although better known for its Li and Be minerals (Volborth 1951, 1954, 1960, Lahti 1981). Among the tantalum-bearing minerals, a new species, manganotantalite, was discovered here (Lahti et al. 1983).

The Haveri-Orivesi Au-Cu-W zone (7) is confined to the narrow volcanics-dominated Tampere Schist Belt (unit no. 22, Fig. 1) that lies between the Pirkanmaa Migmatite Belt and the Central Finland Granitoid Complex (Kähkönen 1987, Kähkönen 1989, Nironen 1989a, Nironen 1989b, Gaál & Sundblad 1990). The zone includes three mines:

- The Haveri Au-Cu mine, exploited from 1942 to 1960, with resources recently estimated at 1.6 Mt at 2.85 g/t Au and 0.39 % Cu (Stigzelius 1944, Lupander & Räisänen 1954, Isokangas 1978, Mäkelä 1980, Kähkönen et al. 1981, Karvinen 1997, Nironen 1994),
- The Ylöjärvi Cu-W-(Au) mine, which yielded 4.01 Mt at 0.75 % Cu, 0.04 g/t Au and 0.09 % W between 1943 and 1966 (Himmi 1954, Himmi et al. 1979, Isokangas 1978, Gaál et al. 1981) with its well-studied mineralogy (Clark 1964a, 1964b, 1964c, 1965a, 1965b, 1966; Clark & Clark 1968),
- The Kutemajärvi Au mine started in 1990 and has yielded 1.06 Mt at 9.7 g/t Au (A. Luukkonen et al. 1992, A. Luukkonen 1994, A. Luukkonen et al. 1997b, Poutiainen & Grönholm 1996, Mänttäri et al. 1997, Kojonen et al. 1999c, Laine 2002).

Some other prospects, like Ahvenlammi (Lindmark 1986, A. Luukkonen et al. 1992), Järvenpää (ibid.) and Tammijärvi (A. Luukkonen 1994, Eilu 1999) have hitherto proved uneconomic.

The mineralisations typically contain chalcopyrite as the main copper mineral, arsenopyrite, native gold and gold tellurides as gold minerals and scheelite in the tungsten bearing parts, plus a lot of minor ore minerals, a.o. cassiterite and antimony minerals. The host rocks are mostly represented by mafic metavolcanics, which typically are strongly altered by tourmalinisation (as at Ylöjärvi), silicification or sericitisation (as at Kutemajärvi).

The Peräkorpi Ti-Fe province (8) is an area in the western part of the Central Finland Granitoid Complex (unit no. 20 in Fig. 1), where several mafic to ultramafic intrusions of rather small size occur associated with Svecofennian granitoids. These intrusions carry ilmenite-magnetite mineralisations (Kärkkäinen 1999, Kärkkäinen & Appelqvist 1999, Kärkkäinen 2001) and are also notable for their rather high apatite content, which makes many of them potential sources of phosphorus as well. The resources of the Peräkorpi deposit itself are estimated at 30 Mt at 23.1 % Fe, 2.35 % Ti and 2.5 % P_2O_5.

It could also be noted that the mineralised intrusions always show distinct stratification and the mineralised bodies constitute an organic part of this. Thus they are drawn as 'magmatic-stratified' bodies despite the fact that intrusions do not fulfil the strict definition of 'layered intrusions'.

A few isolated Ti-Fe minor mineralisations are also known southwards from this province, e.g. Susimäki and Riuttamaa to the south of the Vammala nickel zone (Palmunen 1925, van Lamoen 1979), Attu-Fe (van Lamoen 1977) and Heinäsuo inside the Orijärvi zinc-copper zone (von Knorring 1955). Kulonsuonmäki near Karkkila was mined from 1817 to 1896 and produced 0.024 Mt at some 40 % Fe and 1.8 % Ti.

The Telkkälä Ni-Cu zone (9) consists of two minor nickel deposits, Telkkälä and Ahokkala (Häkli et al. 1975, Häkli 1985), and a number of small showings all hosted by minor mafic intrusions embedded in Svecofennian gneisses in the southern corner of the Saimaa area (unit no. 19, Fig. 1). In the south and west, the zone is enclosed by younger rapakivi granites of the Vyborg batholith. Its relations to the other nickel zones of eastern Finland are not clear, and there is a possibility that rather it represents a continuation of the western Pori-Vammala zone (metallogenic zone no. 4).

At Telkkälä, another orebody was detected in 1987, soon after the first exploitation period, and the initial description of the deposit is by Häkli (1985). This new discovery was predominantly an offshoot orebody in mica gneiss just below the formerly known deposit (O.-P. Isomäki, pers. comm. 2002; Fig. 9) and yielded an amount of metal even larger than the initial discovery. This event clearly shows the exploration potential of even the minor mineralisations at least in the present zone. In total, 0.61 Mt at 1.29 % Ni and 0.33 % Cu were mined in Telkkälä within two periods between 1969 and 1992.

The minute deposit of Kitula (Marmo 1955) may belong to a similar type but lies isolated and surrounded by granitoid rocks some 30 km apart from Telkkälä. Therefore it is not included in this zone. The deposit was quickly mined in 1970, yielding some 0.02 Mt ore at 0.67 % Ni and 0.24 % Cu.

The Juva-Puumala Ni-Cu province (10) is a region difficult to delineate in the central part of the Saimaa area (unit no. 19, Fig. 1) where minor tholeiitic mafic intrusions of the Svecofennian age intrude migmatitic gneisses and carry nickel-copper deposits and occurrences (Makkonen 1996, Puustinen et al. 1995). The style of mineralisation resembles that in all other Svecofennian nickel-copper provinces, and in many reports (e.g. Frietsch et al. 1979), the Juva-Puumala province is drawn as connected to the Kotalahti zone. In the present paper it is delineated as an independent province because it lies entirely to the west of the crustal-scale Kolkonjärvi shear zone, in the Svecofennian Domain, and thus belongs to a separate geoblock (Fig. 10).

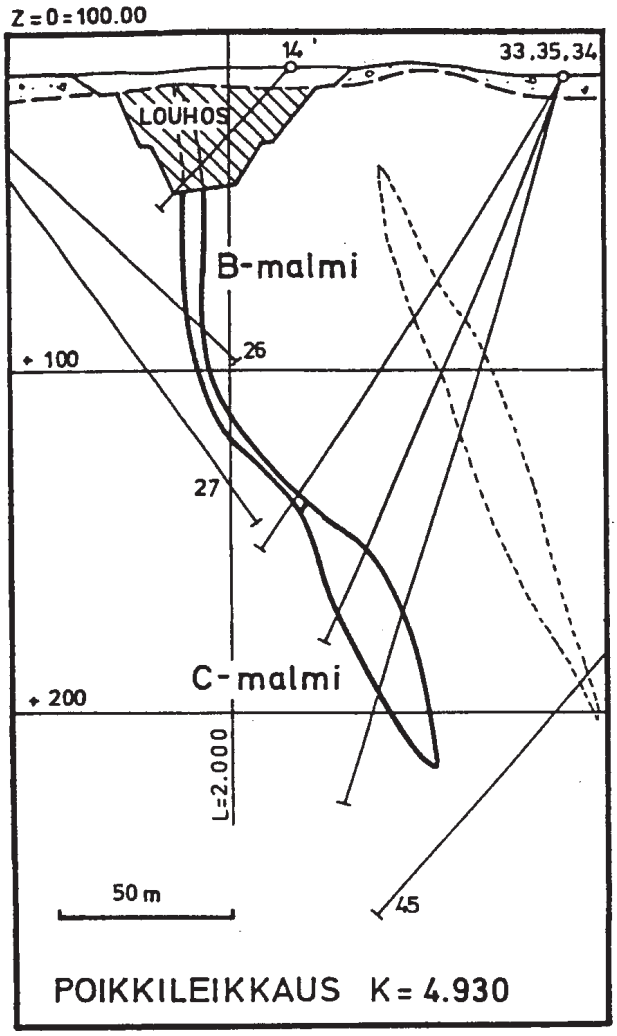

Fig. 9. Cross-section of the Telkkälä open pit ('louhos') and the deeper orebodies (called 'B-malmi' and 'C-malmi'). Unpublished materials by Outokumpu Mining Oy., by courtesy of O.-P. Isomäki

In the western parts of the Saimaa area, closer to the Central Finland Granitoid Complex, there are numerous minor remnants of analogous associations of migmatitic gneisses with mafic intrusions and nickel-copper mineralisations. They are marked on the Metallogenic Map as small unnumbered spots of the province.

The Rantasalmi Au zone (11), located in the northern part of Lake Saimaa (block no. 19), in the vicinity of the Kolkonmäki shear zone, consists mainly of the Pirilä and Osikonmäki gold deposits and some few minor occurrences. All of them are generally considered to be epigenetic.

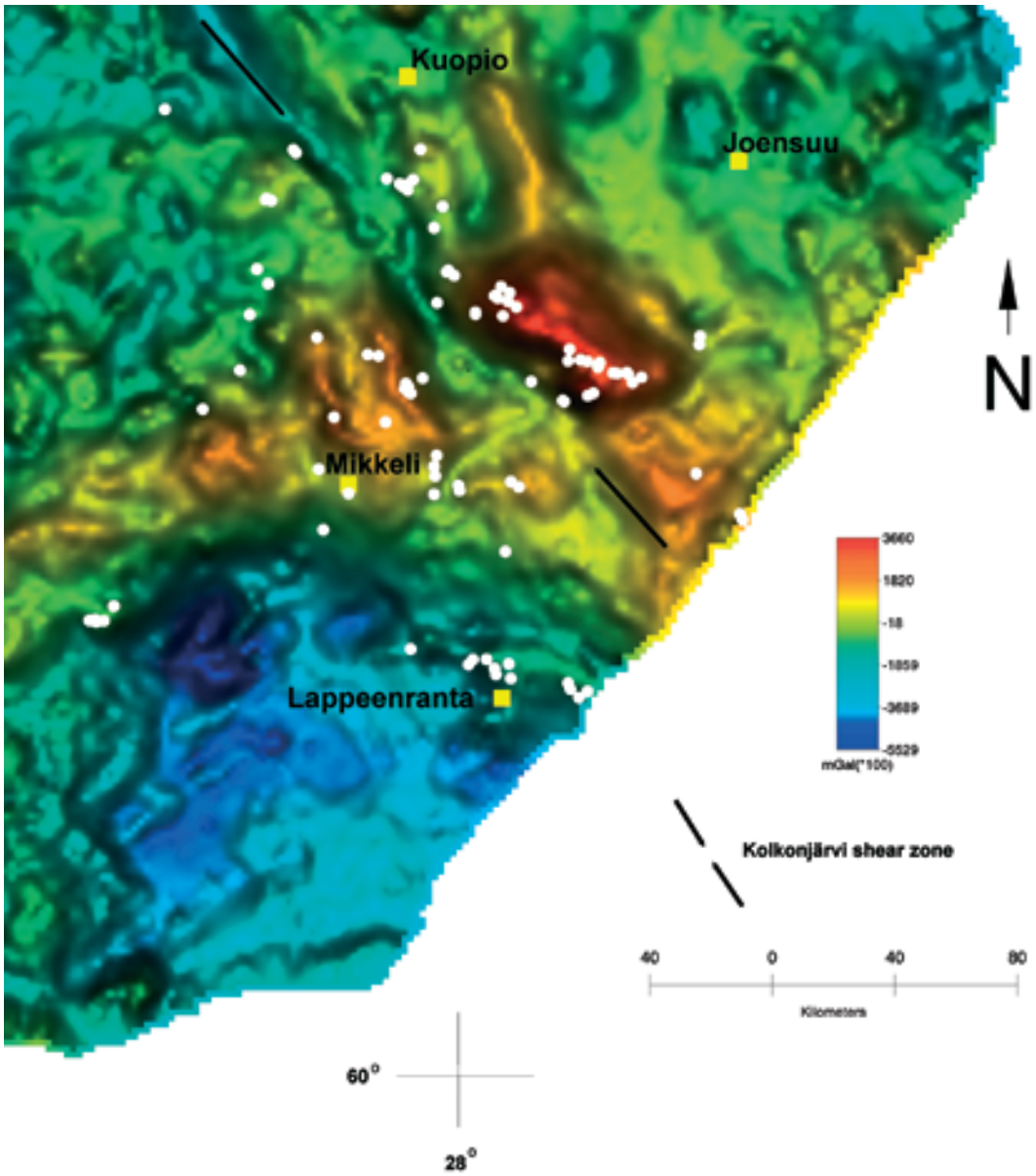

Fig. 10. Ni-Cu deposits and occurrences of south-eastern Finland plotted on a gravimetric map (from Makkonen 1996). Nickel mineralisations, indicated by white dots, form: the Telkkälä zone (immediately north and east of Lappeenranta), the Juva-Puumala province (around Mikkeli) and the Kotalahti zone (northeast from the Kolkonjärvi shear zone).

The Pirilä deposit (0.15 Mt at 8 g/t Au and 30 g/t Ag; Makkonen & Ekdahl 1988, Kontoniemi 1998) is hosted by a quartz rock body in the so-called Pirilä Belt, a complex at the contact zone between volcanic rocks and metapelites including a narrow iron formation.

The Osikonmäki deposit, comprehensively described in a monograph (Kontoniemi & Nurmi 1998) with 4 detailed articles dealing with metallogeny (see under the main heading), and in several other papers (Kontoniemi 1989, Kontoniemi & Ekdahl 1990, Kontoniemi et al. 1991, Vaasjoki & Kontoniemi 1991, Kontoniemi 1997, Kontoniemi et al. 1998), is hosted by a synorogenic tonalite pluton (1887 Ma) and exhibits a strong structural control. The geological *in situ* ore resources at Osikonmäki have been estimated to be 2.2 Mt, averaging 3.1 g/t Au and 0.77 % As.

The most common sulphide minerals at Pirilä and Osikonmäki include pyrrhotite, arsenopyrite, löllingite and chalcopyrite. Gold occurs as native gold and electrum, as inclusions and at grain boundaries of and between arsenopyrite and silicate grains. Special studies have been published on fluid inclusions geochemistry (Poutiainen 1993) and the general geochemical characteristics of these deposits (Nurmi et al. 1991a, b).

The Virtasalmi Cu zone (12) is a chain of skarn-like bodies that contain several copper mineralisations with very little of other metals (except iron). The zone be-

longs to an isolated crustal block of high metamorphic grade (Hyvärinen 1969, Pekkarinen 2002) in the very northern corner of the Saimaa area (unit no. 19 in Fig. 1). The largest of the mineralisations, the Virtasalmi (Hällinmäki) deposit was exploited between 1966 and 1984 and yielded 4.25 Mt at 0.76 % Cu. It consists of chalcopyrite-cubanite-pyrrhotite mineralisation with some magnetite lumps, hosted by dark, iron-rich andradite-hedenbergite skarn. What is amazing, is that a bed of very pure white marble with a little wollastonite and completely iron-free diopside organically belongs to the strata and is only 100 m away from the dark skarn horizon. In fact, the marble is an essential part of the complex and has been exploited in a couple of small quarries.

A volcanic origin of the rocks in the complex has been proposed (Lawrie 1987), and consequently an affinity between the Virtasalmi zone and the Vihanti zone has been suggested (Ekdahl & Philippov 1999). On the other hand, the similarity of the complex to the Orijärvi zone is also striking, e.g. in terms of the presence of magnetite skarn, wollastonite-bearing marble and even minor iron formation horizons (Pekkarinen 2002).

The Ilmolahti Ni-Cu zone (13) is a narrow strip of mica gneiss remnants in the northern part of the Central Finland Granitoid Complex that hosts a chain of six minor nickel deposits of normal Svecofennian type. These follow a single NW-SE trending fault for a distance of about 80 km. Due to the modest size of the hosting gneiss formation, this zone has been regarded as less prospective and little interest was paid to it, despite the fact that the largest of the deposits, Ilmolahti (estimated at 0.15 Mt at 0.33 % Ni and 0.25 % Cu in the explored parts) is not so far from being commercially viable. No published first hand information on the zone and deposits is available. A short description in Puustinen et al. (1995) is based on unpublished archive reports.

The Kotalahti Ni-Cu zone (14) is perhaps the best-known metallogenic zone in Finland. It was made known by Gaál (1972) and Gaál et al. (1975), who anticipated an extremely narrow and long belt running through all of central Finland roughly at the boundary between the Svecofennian and Kola-Karelian Domains, along a single deep fracture system, and including nearly all the significant nickel deposits of the Svecofennian type. It was named after the Kotalahti deposit and mine, the then largest nickel mine not only in Finland but in the entire Western Europe in the 1960s.

Over the years, concepts on the Kotalahti Nickel Belt have been studied and discussed by many authors (e.g. Gaál et al. 1978, Tontti et al. 1979, Frietsch et al. 1979, Tontti 1981, Kuosmanen et al. 1982, Gaál 1985, Papunen & Vorma 1985, Ekdahl 1993, Ekdahl & Philippov 1999). The most recent discussion and review is to be found in a monograph by the present authors on the distribution and metallogenic types of the nickel deposits in Finland (Puustinen et al. 1995).

Investigations after 1975 showed that the structure of the Kotalahti Belt is more complicated than was initially assumed: more deposits and occurrences were discovered and that made the prospective area broader, the deposit chain was confirmed not as continuous but forming separate clusters (Tontti et al. 1979, Tontti 1981), and the deposits in individual clusters were shown to have slightly various characteristics (e.g. Papunen & Vorma 1985). The boundary between the two major domains is not a straight line either (cf. Fig. 4), and the mineralisations concerned fall partly in the Svecofennian Domain and partly in the Kola-Karelian Domain. The comprehensive data on the distribution of the nickel deposits, as presented in Puustinen et al. (1995), show that the mineralisations in the belt form up at least two parallel sets of sub-linear deposit groups of lower rank (see Fig. 7).

Consequently the outlines of the nickel belt have been drawn in many different ways in different publications. Some authors joined all the nickel mineralisation zones into a broad belt covering the entire migmatite belts east of the Central Finland Granitoid Complex (e.g. Ekdahl 1993, Ekdahl & Philippov 1999), and some sketched a ring-like nickel belt covering all Svecofennian migmatite belts surrounding the Central Finland Granitoid Complex, with no preference given to the Kotalahti system (Frietsch et al. 1979). In contrast, in the above-mentioned work by Puustinen et al. (1995), the nickel-bearing territory is described in a set of small deposit clusters, without taking much of a stand on their mutual connection.

In the present Metallogenic Map, the Kotalahti zone is delineated as an elongated province of nickel-copper deposits of Svecofennian type, hosted by mafic-ultramafic intrusion bodies in an environment dominated by migmatitic mica gneisses and running on the eastern side of the Kolkonjärvi shear zone, which is indicated by a deep trough in the gravimetric map (Fig. 10). The zone includes the large deposits of Kotalahti and Laukunkangas with their neighbouring occurrences and also the Talluskanava and Ilokangas occurrence groups, thus corresponding to clusters 21 to 25 in Figure 7. This zone is separated from the Juva-Puumala province (metallogenic zone 10, Fig. 5) by the Kolkonjärvi shear zone and is located in the Savo Belt (unit no. 16 in Fig. 1), inside or at the boundary of the Kola-Karelian Domain, unlike the Juva-Puumala province, Ilmolahti zone (metallogenic

zone 13) and Hitura province (metallogenic zone 27). The two isolated deposits in Parikkala, close to the Russian border, which traditionally were referred to as the southeastern end of the originally defined Kotalahti Belt, are considered not to belong to the Kotalahti system at all. They lie in the Saimaa Area (unit no. 19, Fig. 1) in a petrographically different geoblock, separated from the Savo Belt by a large NE running fault system, as seen e.g. in the Bedrock Map of Finland (Korsman et al. 1997). It is possible they belong to the Telkkälä group (cf. Puustinen et al. 1995).

The most important deposits in the Kotalahti zone are Kotalahti and Laukunkangas. Kotalahti, the first post-war nickel mine in Finland, was discovered in 1954 and was subject to exploitation from 1958 to 1987, with a total production of 12.3 Mt of ore grading 0.66 % Ni and 0.26 % Cu. It has been studied and described by many authors in terms of geology (Haapala 1969, Isokangas 1979, Papunen & Koskinen 1985), ore mineralogy (Papunen 1970), geological and tectonic setting (Gaál 1980), geochemistry (Mäkinen 1987), and sulphur isotopes (Papunen & Mäkelä 1980). The deposit is hosted by a 'wallet-like' intrusion that ranges from gabbro to metaperidotite and is sub-conformably intruded into the supracrustal series close to a dome of Archaean basement gneiss. There are several other mafic intrusions in the region as well, but strikingly the largest of them, the Valkiajärvi gabbro intrusion, is practically barren. The Kotalahti intrusion has been dated at 1883 ± 6 Ma (Gaál 1980), and this value is accepted as a stratotype to the early Svecofennian intrusive activity. Mineralogically Kotalahti is rather simple with pyrrhotite, pentlandite and chalcopyrite as the main ore minerals and only a small amount of accessories like gersdorffite, mackinawite and argentian pentlandite restricted to an offshoot orebody. As far as the chemical composition is concerned, the most important feature is the modest PGM content (0.005 g/t Pt, less than 0.05 g/t Pd and Rh).

Around Kotalahti, there is an ore-potential area under continuous exploration with some smaller deposits and occurrences, the largest of them being Sarkalahti, Särkiniemi and Rytky (Mäkinen & Makkonen 2004). Together they form a group referred to as zone 23 in Puustinen et al. (1995).

Laukunkangas, the second largest deposit in the zone, was subject to mining between 1984 and 1994 and yielded some 6.66 Mt of ore at 0.76 % Ni and 0.22 % Cu. It belongs to a cluster of predominantly mafic (noritic) intrusive bodies with very small parts of ultramafic members (cluster 25 in Fig. 7). These intrusions also contain the minor deposits of Makkola, Hälvälä and Sulkavanniemi and some occurrences. The Hälvälä deposit was mined as a subsidiary of Laukunkangas between 1988 and 1992, and 0.25 Mt of ore was extracted at 1.41 % Ni and 0.35 % Cu. Laukunkangas is thoroughly described by Grundström (1980, 1985) and Mäkinen (1987). It is worth mentioning that at Laukunkangas the high-grade ore was contained in blind ore bodies in the lower ultramafic part of the intrusion and not in the upper, exposed parts of it.

North of Kotalahti, there are clusters of minor deposits around Ilokangas and Talluskanava (Ekdahl 1993). They are associated with serpentinite, peridotite and gabbro bodies included in narrow mica gneiss areas surrounded by granitoids. This part of the nickel zone overlaps the Vihanti-Pyhäsalmi zinc zone (metallogenic zone 25), and it is somewhat unclear whether these clusters really are a part of the Kotalahti zone (cf. Puustinen et al. 1995).

The Vehmersalmi U zone (15) includes several minute occurrences around Puutosmäki near Kuopio. Here uraninite veins have been found in layered quartz-feldspar-biotite-pyrite schists, located in the Archaean basement complex. The Puutosmäki occurrence might belong to vein-type uranium mineralisations (IUREP 1982).

The Outokumpu Cu-Co-Zn + Ni zone (16) is confined to a specific association of black schists, calc-silicate rocks, a non-clastic quartz rock and serpentinites which are all traced as a winding, discontinuous ribbon of a total length of nearly 250 km in the Outokumpu area (unit no. 16, Fig. 1) in eastern Finland. The general geological and geographical outlines of the zone are described in Haapala (1936), Väyrynen (1939), Peltola (1960), Huhma & Huhma (1970), Koistinen (1981, 1987), Park (1984, 1988, 1992), Tyni et al. (1997) (see also Fig. 11).

The metallogenic zone was named after the Outokumpu deposit, the flagship of modern mining in Finland, exploited between 1910 and 1989. This large deposit (28.5 Mt with 3.36 % Cu, 0.88 % Zn, 0.23 % Co, 22 % S, 0.12 % Ni and 0.8 g/t Au; also known as Keretti, the most recent mine unit in the deposit) was subject to intensive investigations since its discovery in 1910, and it is described in a long series of publications (e.g. Tchimichkian 1936, Mäkinen 1938, Vähätalo 1953, 1954, Disler 1953, Mikkola 1969, Mikkola & Väisänen 1972, Mäkelä 1974, Gaál et al. 1975, Koistinen 1981, Koistinen et al. 1983, Park 1984, Parkkinen 1986, Papunen 1987, Gaál & Parkkinen 1993, Laznicka 1993, Warrender et al. 1998). The proper Cu-Co deposit of Outokumpu forms a flat body of massive to densely disseminated ore in the quartz rock member of the Outokumpu Association; in addition, there is a vague zone of low-grade

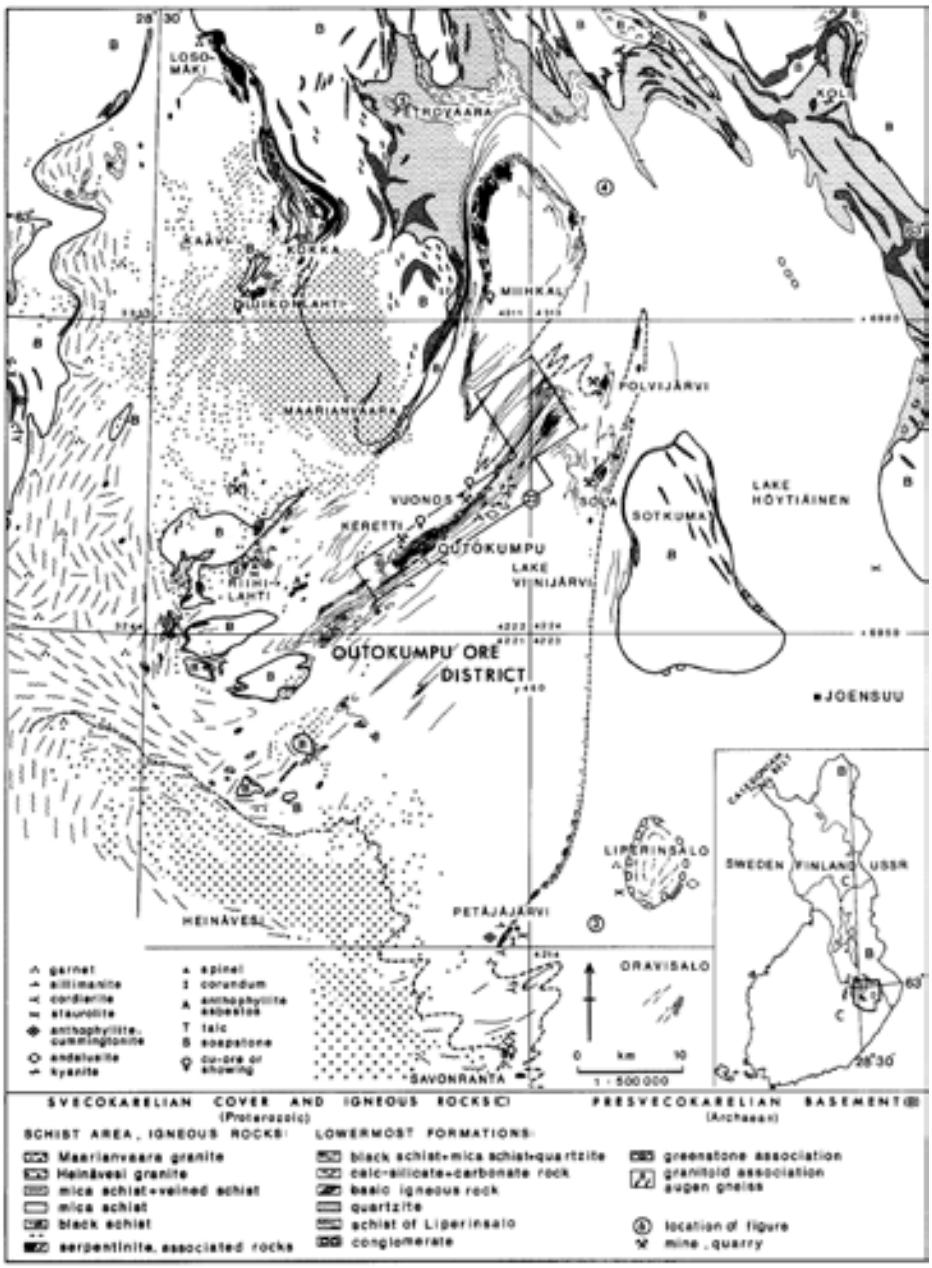

Fig. 11. Geology of the Outokumpu region. From Koistinen (1981).

Ni mineralisation in the hanging wall skarn (Fig. 12; Parkkinen & Reino 1985). The same two ore types can be found in various proportions in all the other deposits of the zone, two of which have been subject to exploitation:

- Luikonlahti, mined from 1961 to 1983 and it produced 6.9 Mt at 0.94 % Cu, 0.61 % Zn, 0.11 % Co (Koljonen 1976, Tyni *in* Tyni et al. 1997)
- The Vuonos Ni and Cu deposit (Peltola 1980, Parkkinen & Reino 1985), which was mined from 1972 to 1986 and yielded in total copper and nickel ores of 11.0 Mt at 2.14 % Cu, 1.31 % Zn, 0.14 & Co, 20.7 % S and 0.16 % Ni.

Other deposits individually described are

- Kylylahti (estimated at 5 Mt at 1.55 % Cu and 0.3 % Co; Rekola & Hattula 1995, Pekkarinen in Tyni et al. 1997) and
- Riihilahti (estimated at 0.7 Mt at 0.72 % Cu; Merkle 1982).

Genesis of the ores and the entire association have been discussed for decades, and all possible concepts have been presented, from pneumatolytic origin and metamorphic remobilisation to volcanic-exhalative, black schist derivative, etc. In recent years, two alternative models have been subject to discussion, the black schist (seafloor sedimentary) origin and the

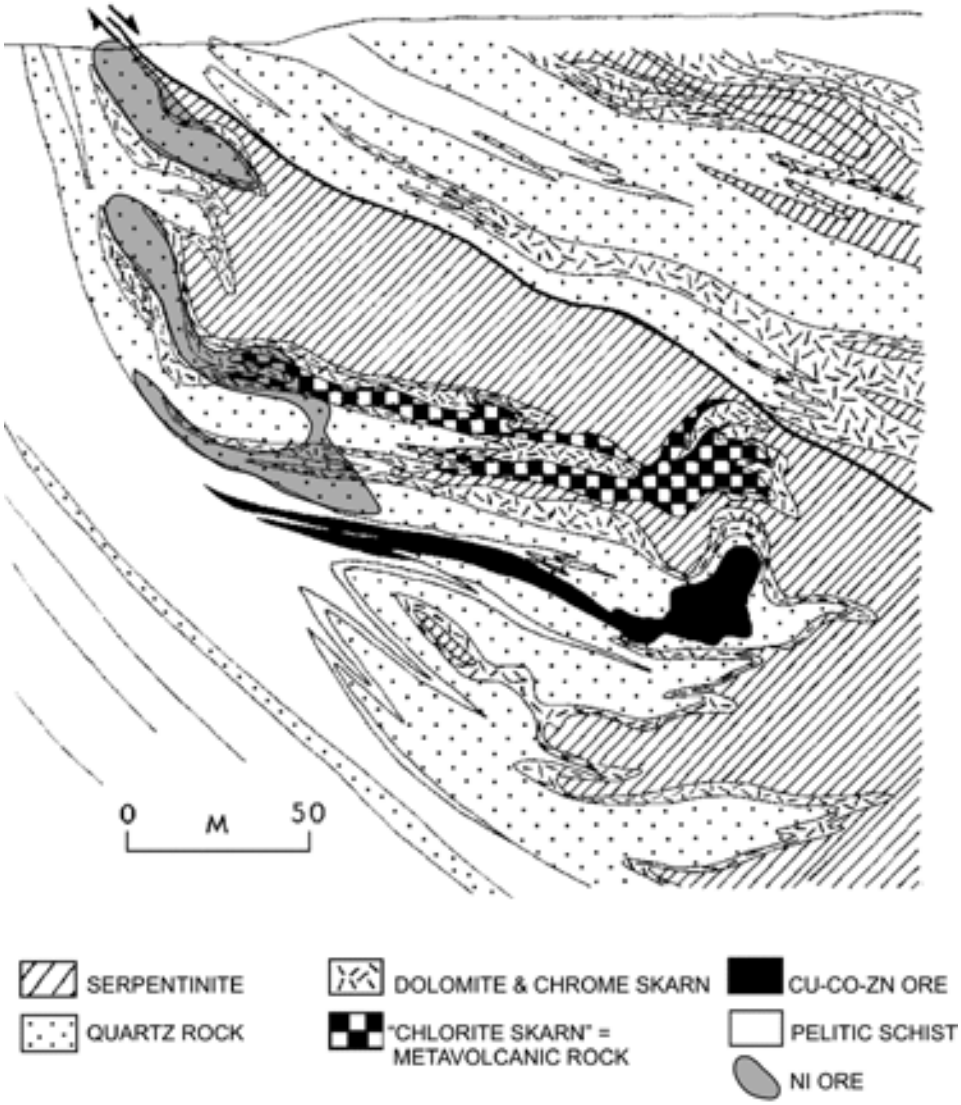

Fig. 12. Cross-section of the Outokumpu (Keretti) assemblage showing the Cu-Co-Zn deposit and the Ni mineralisation. From Laznicka (1993).

ophiolite alteration model. Genetic aspects are found in most of the papers listed above, and also in the works of Borchert (1955), Saksela (1957), Huhma (1976), Peltola (1968, 1978), Treloar et al. (1981), Rehtijärvi (1984a), Rehtijärvi & Saastamoinen (1985), Vuollo & Piirainen (1989), Loukola-Ruskeeniemi (1991, 1995b, 1999), Loukola-Ruskeeniemi et al. (1991, 1999a), Vuollo et al. (1995), Liipo (1999). Pithy reviews of the hitherto presented models are given by Papunen (1987), Laznicka (1993) and Tyni et al. (1997). Separate aspects such as geochemistry are dealt with, e.g., by Hakanen (1983).

A genetic link has been suggested between the Ni-Zn-Cu deposits of the Talvivaara zone (zone no. 28) and the Outokumpu deposit (Loukola-Ruskeeniemi et al. 1991) on the grounds of the identical character of the black schists and the geochemical characteristics in the two zones. However, direct observations show that there are two separate black schist formations present in both zones, one (para-autochtonous) carrying the Talvivaara-type deposits in Kainuu and the other (allochtonous) belonging to the Outokumpu association proper (A. Kontinen, pers. comm. 2003).

On the other hand, a distinct ophiolite formation, the Jormua mafic-ultramafic complex, has been identified in the central part of the Kainuu Belt (unit no. 14, Fig. 1; Kontinen 1987) and has been associated with the Outokumpu complex (Vuollo 1994, Liipo et al. 1995). On the pretext of this, the lithological assemblage of the Jormua complex is considered to be critical for Outokumpu-type mineralisation. Hence, the Jormua area is shown as a northern continuation of the Outokumpu zone on the Metallogenic Map.

The deposits and rocks of the Outokumpu association show many unique features in respect to their mineralogy; for example, the numerous chromium-

bearing silicate minerals and the unusual ore minerals (e.g. cobalt pentlandite and eskolaite, C_2rO_3). The first observations on these exotic minerals date back to the very beginning of the 20th century (Borgström 1901), and since that a long series of mineralogical papers has been published on the topic (Laitakari 1929, Laitakari 1930, Eskola 1933, Väyrynen 1935, Caillère & Tchimichkian 1936, Thayer 1964, Klemm 1965, Weiser 1967, Peltola et al. 1968, Springer 1968, Vorma 1970, Taylor & Finger 1971, Vuorelainen et al. 1968, Vuorelainen et al. 1972, von Knorring et al. 1986, Treloar & Putnis 1982, Treloar 1987a, Treloar 1987b, Treloar & Charnley 1987), including the discovery of several new mineral species (Kouvo & Vuorelainen 1958, Kouvo et al. 1959, Long et al. 1963, Huhma et al. 1973).

The Koli-Kaltimo U zone (17) is a chain of minor deposits and occurrences of uranium in quartz-pebble conglomerates and quartzites of the Jatulian group of the Palaeoproterozoic Höytiäinen Schist Belt (unit no. 17 in Fig. 1) of eastern Finland (Wennervirta 1960, Davidsson 1960, Piirainen 1968, IUREP 1982, Äikäs & Sarikkola 1987). Most of them, such as Ipatti, Martinmonttu and Ruunaniemi, belong to the sandstone type, but in some places, like Paukkajanvaara (Piirainen 1968, Isokangas 1978), the only exploited uranium deposit in the zone (1958-1961, 0.04 Mt at 0.14 % U), is a considerable enrichment of ore which is epigenetic and located at the contacts of a cross-cutting metadolerite.

The Koli-Kaltimo zone is accompanied by a number of uranium-thorium vein mineralisations within the territory of the Archaean basement that underlies the Jatulian arenite formation. These show the same Proterozoic age features and may represent an unconformity type uranium mineralisation (IUREP 1982, OECD 2002, O. Äikäs, pers. comm. 2003).

The Kyykkä-Hokka Cu zone (18) includes several minute mineralisations consisting of big lumps of massive sulphide minerals, chiefly chalcopyrite, bornite, chalcosite, in quartz veins which cut the Jatulian metadiabases of the Höytiäinen Belt (unit no. 17 in Fig. 1; Thoreld 1891, Aurola 1954). Despite of the impressive, fist-size lumps of ore minerals, the average copper content in these deposits is low, mainly less than 0.5 % according to modern exploration (L. Pekkarinen, pers. comm. 2003), and today they are of no commercial value. In the 19th century, at the time of handicraft industries, a few of them were subject to exploitation.

The Hattu Au zone (19) (Fig. 13) occupies the eastern branch of the Hattu Schist Belt in the Archaean Ilomantsi Greenstone Belt (unit no. 13 in Fig. 1). It is thoroughly described in 15 papers by Nurmi & Sorjonen-Ward (1993). Additional or review data about the zone can also be found in Pekkarinen (1989), Ward & Nurmi (1989), Gaál & Sundblad (1990), Ojala et al. (1990), Johanson & Kojonen (1991), Johanson et al. (1991), Kojonen et al. (1994), Rasilainen (1993, 1996), Sorjonen-Ward (1997), Stein et al. (1999), Eilu (1999), Laine (2002), and Poutiainen & Partamies (2003). Hattu was the first gold province recognized in the Archaean of the Fennoscandian Shield, and it serves as a prototype for all similar provinces in the shield.

Of the deposits and occurrences within the zone, the most important are Pampalo or also known as Ward (test mining between 1996 and 1999 with 0.13 Mt of ore at some 14 g/t Au; estimated resources at least 0.6 Mt at 7.4 g/t Au), Hosko, Korvilansuo and Rämepuro (Hattuvaara). They are epigenetic mesothermal gold disseminations and vein swarms of the Late Archaean age, with structurally controlled locations chiefly in the supracrustal rocks of the greenstone belt (Fig. 13).

The Huhus Fe zone (20) is an Archaean banded iron formation (BIF) zone, analogous to (and actually a southern continuation of) the Kostomuksha formation in Russian Karelia. Horizons of banded iron formation are common all over the Ilomantsi Greenstone Belt (Laajoki 1985, 1986, Laajoki & Lavikainen 1977, Gehör & Laajoki 1987, Laajoki & Gehör 1990), and some 10 of these have been regarded as deposits. Resources in the largest of them, the Huhus deposit, add up to a few tens of millions of tonnes of iron ore (Malminetsijä Oy, unpublished data).

In the western part of the zone, a few minor deposits of pure pyrite, such as Otravaara and Karhusaari, were discovered and even mined at the beginning of the 20th century (Saxén 1923, Hausen 1934, Aurola & Vähätalo 1939, Saksela 1951). These may represent the sulphide phase of the iron formations, but at least their final enrichment processes show distinct metasomatic features and a structural control.

The Seinäjoki Au-Sb zone (21) in the southern corner of the Pohjanmaa Schist Belt (unit no. 21, Fig. 1) was initially known for its antimony deposits, such as Törnävä (Pääkkönen 1966) and the largest one, Kalliosalo (estimated at 0.46 Mt at 0.73 % Sb and 1 g/t Au), with their native antimony and certain exotic antimony minerals (Saksela 1952, Mozgova et al. 1977, Borodaev et al. 1983, Borodaev et al. 1985, Appelqvist 1993, Mäkitie et al. 2001). However, these deposits and occurrences typically also contain significant gold (Nurmi et al. 1991a, b, Eilu 1999). The mineralisations consist of ore mineral dissemination in quartz veins and in the hosting metapelites and metagreywackes plus intermediate metavolcanic rocks. The southeastern end of the zone (e.g. the Timanttimaa occurrence,

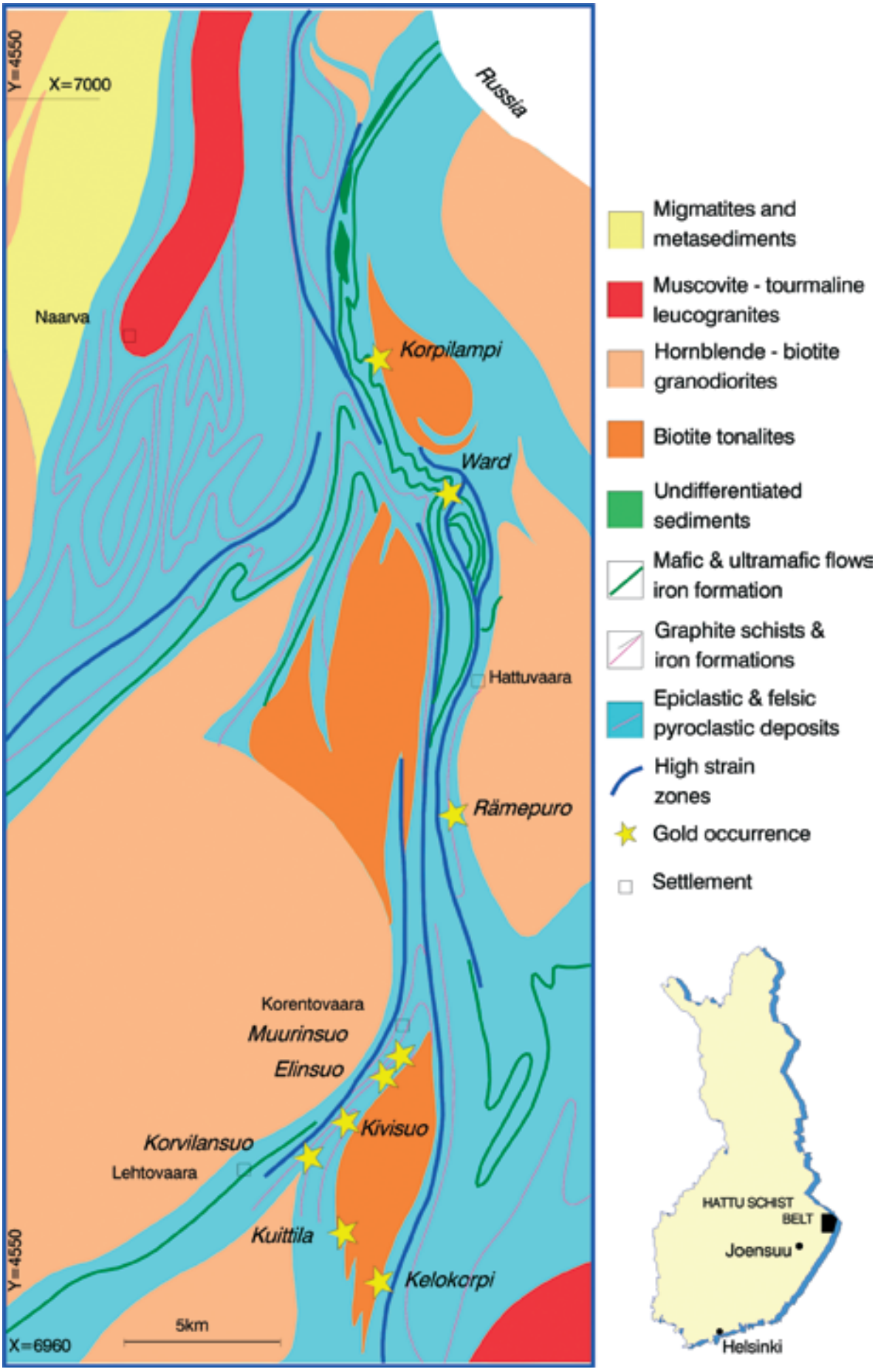

Fig. 13. General outline of the Hattu zone and the gold mineralisations. From Nurmi and Sorjonen-Ward (1993).

Eilu 1999) differs somewhat from the main zone by being of a more gold-only type.

Separate from the gold-antimony mineralisations, but distinctly belonging to the same zone, there are several occurrences of tin-bearing granite pegmatites (Alviola 1989). These constitute the largest known tin resources in Finland. Signs of minuscule tungsten (scheelite) mineralisations also occur throughout the zone.

The Oravainen Ni-Cu zone (22) is a zone of nickel-copper mineralisations in mafic or ultramafic minor intrusions in Svecofennian gneisses of the Pohjanmaa Belt (unit no. 21, Fig. 1), on the westernmost coast of Finland. The zone is distinctly underexplored, because the bedrock is overlain by thick overburden and partly by sea. Even the best-known Oravainen deposit (estimated 1.28 Mt ore at 0.95 % Ni and 0.16 % Cu; Isohanni 1985) is located about 1 km off shore. It is hosted by a pipe-like ultramafic intrusive body. Otherwise the zone is traced by findings of small showings only.

The zone reappears onshore further south, after a barren part of some 40 km. The largest nickel mineralisation detected here, Petolahti (Ervamaa 1962, Sipilä et al. 1985), is of a slightly different type, the nickel-copper ore occurring in a younger (sub-Jotnian) diabase. The Petolahti deposit was mined between 1972 and 1973, yielding 0.86 Mt ore at 0.47 % Ni and 0.38 % Cu. The zone continues further to the south, and it has been proposed that it could join the northwestern part of the Vammala (metallogenic zone 4 in Fig.5).

Koivusaarenneva Ti-Fe zone (23) is an area in the northern part of the Central Finland Granitoid Complex (unit no. 20, Fig. 1) containing a number of separate gabbroid intrusions of the Svecofennian age, rather similar to the Peräkorpi area described above (zone 8, Fig. 5). The intrusions carry ilmenite and vanadium-bearing magnetite either as dissemination or as massive bodies (Kärkkäinen 1997, Kärkkäinen et al. 1997, Kärkkäinen 1999, Kärkkäinen & Bornhorst 2003). These deposits are especially prospective as a source of titanium because of their high-quality ilmenite (Chernet & Kärkkäinen 1995). The proper Koivusaarenneva deposit is estimated to contain 44.2 Mt of ore at 4.5 % Ti, 19 % Fe and 0.15 % V.

The Emmes Li province (24) is an area containing several spodumene-rich pegmatite bodies (Alviola et al. 2001). The pegmatites mainly occur in a mica schist to mica gneiss environment with some volcanic affinities. Black schists are also not uncommon in the area.

The Vihanti-Pyhäsalmi Zn-Cu-Pb zone (25), situated on the northeastern edge of the Svecofennian Domain in the northern corner of the Savo Schist Belt (unit no. 16, Fig. 1), is by far the most important zinc producing area of modern-day Finland. Its deposits belong to the classical volcanogenic massive sulphide (VMS) type of the Palaeoproterozoic age and are confined to a single volcano-sedimentary schist association, which twines rather irregularly through the district (Isokangas 1954, Mikkola 1963, Mikkola & Väisänen 1972, Pajunen 1988, Vaasjoki & Sakko 1988, Ekdahl 1993, Laznicka 1993, Kousa et al. 1997, Loukola-Ruskeeniemi et al. 1997b, Roberts 2002, Rasilainen et al. 2003, Roberts et al. 2003a; Fig. 14). The volcanic host rocks belong to the Palaeoproterozoic Svecofennian island arc succession near the margin of the Archaean Karelian craton. Two of the deposits, Vihanti and Pyhäsalmi, belong to the largest metallic mineral deposits in Finland. They have been subject to mining for a long time, and Pyhäsalmi is still operating. Also a number of smaller deposits, situated in the central part of the zone around Pyhäsalmi, have been exploited as follows:

- Mullikkoräme (Rasilainen et al. 2003); mined between 1990 and 2000 yielding 1.20 Mt at 6.08 % Zn, 0.30 % Cu, 0.86 % Pb, 44 g/t Ag, 1 g/t Au and 17 % S,
- Ruostesuo (Roberts et al. 2003b); between 1988 and 1990 yielding 0.24 Mt at 2.63 % Zn, 0.30 % Cu, 9 g/t Ag, 0.3 g/t Au and 31 % S, and
- Kangasjärvi (Rehtijärvi 1984b, Rasilainen 1991, Roberts et al. 2004); between 1984 and 1985 yielding 0.91 Mt at 5.12 % Zn, 0.09 % Cu, 5 g/t Ag, 0.3 g/t Au and 38 % S.

The Vihanti mine is situated close to the geographical centre of Finland, in the municipality of Vihanti (Rouhunkoski 1968, Wennervirta & Rouhunkoski 1970, Rauhamäki et al. 1978, Rauhamäki et al. 1980). The first indications of the ore were pyrite-rich boulders discovered by local farmers in 1936, and the zinc orebody was located in 1946. Production started in 1954 and lasted until 1992. By that time, 27.94 Mt of ore was mined with an average grade of 5.17 % Zn, 0.46 % Cu, 0.40 % Pb, 27 g/t Ag, and 0.43 g/t Au and some 13 % S. The hosting volcano-sedimentary sequence mainly comprises rhyodacitic porphyry and calcareous rocks, with subsequent cordierite-bearing metasomatic rocks and black shales. The common host rock to the zinc ores is dolomite or skarn, although the ores are related to felsic volcanism. The whole sequence is overturned and strongly deformed in several stages. The hanging-wall contact of the ore is tectonic.

Three main generations of sulphide mineralisation

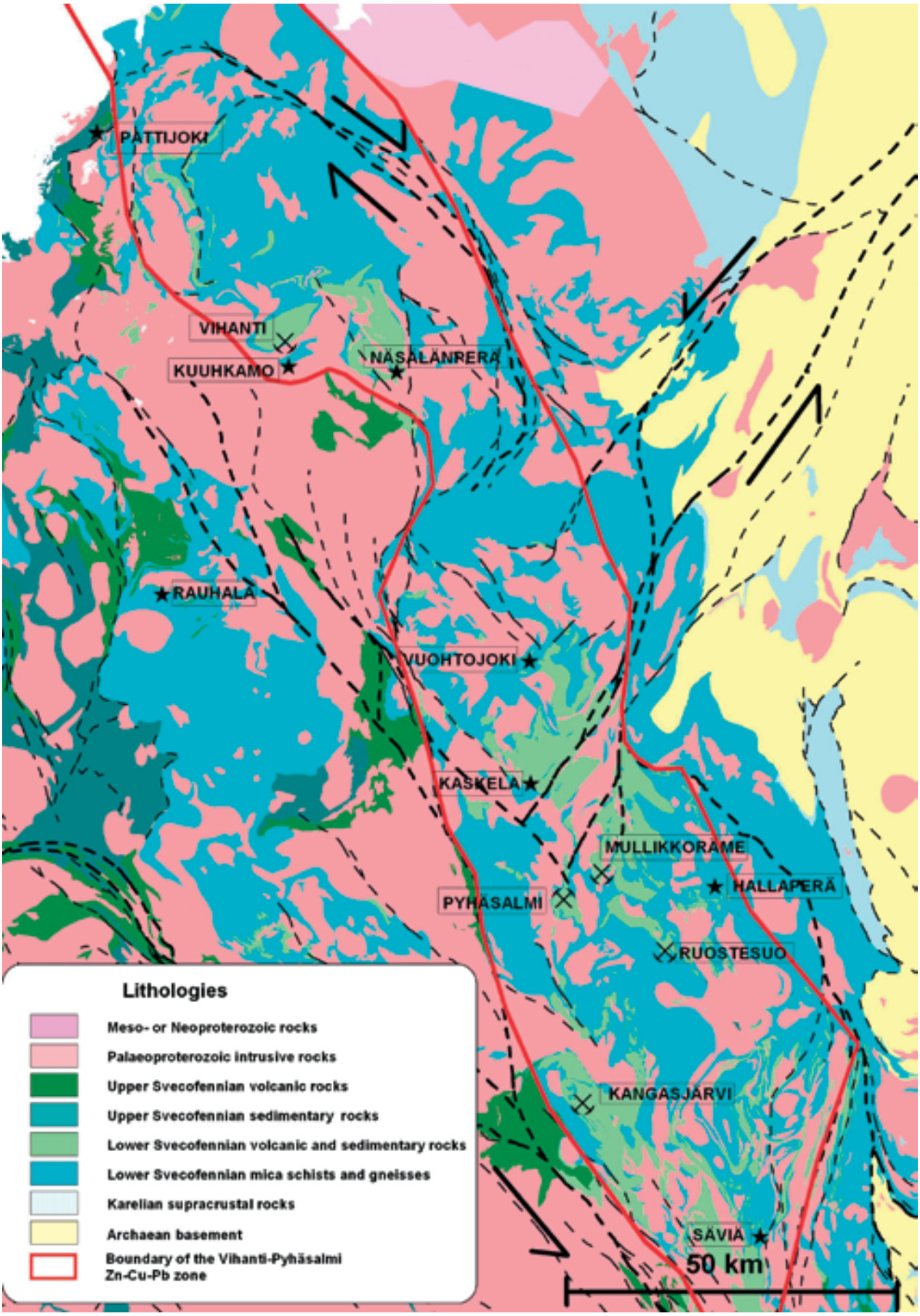

Fig. 14. Geological background, outlines of the Vihanti-Pyhäsalmi zone (red line) and the most important Zn-Cu deposits (mine symbols and stars). Note also the Rauhala deposit outside the Vihanti-Pyhäsalmi zone, described in connection with the Laivakangas Au province. Unpublished materials by the Geological Survey of Finland (GTK), by courtesy of J. Luukas, J. Kousa and J. Nikander (2005).

have been identified at Vihanti: 1) pyrite ore bodies at Hautakangas and Hautaräme with Cu- and Zn-rich parts; 2) chalcopyrite-pyrite ore bodies in skarn lenses, mined as low-grade Cu ore; 3) the youngest Pb-Ag-Sb mineralisation hosted by coarse-grained diopside skarn and also containing notable amounts of Au. A special type of mineralisation at Vihanti is a uranium-phosphorous horizon located near the stratigraphic base of the volcano-sedimentary formation (Rehtijärvi et al. 1979, Vaasjoki et al. 1980, Äikäs 1980, Äikäs 1989). The U-P mineralisation is chiefly in felsic volcanic rocks, but also skarn and dolomite may host it. Uraninite forms the main host for U and apatite for P. Its total tonnage is more than 1 Mt, but the U and P grades have – so far – been too low for exploitation.

In spite of intensive exploration only very few deposits of the Vihanti-type proper have been found in the northern part of the zone (e.g. Arkimaa et al. 1985, Kuosmanen et al. 1985, Tontti et al. 1981).

The Pyhäsalmi mine, owned by Inmet Mining Co (from 2002) is the oldest metal mine in Finland still operating and at 1450 m it is the deepest in Europe. It was discovered in 1958 and operated as an open pit from 1962 to 1976 and underground from 1967. The deposit is a Zn-Cu-barite VMS type mineralisation with hydrothermally altered host rocks that were subsequently metamorphosed, deformed, recrystallised and partially remobilised under amphibolite facies conditions. The ore is hosted by felsic pyroclastic rocks and quartz porphyries. Mafic volcanic rocks in the area are coarse-grained tuff breccias and lavas, the latter containing pillowed units. Mafic and felsic dykes are common. (Helovuori 1979, Huhtala 1979, Ekberg & Penttilä 1986, Mäki 1986, Eilu et al. 1988, Laznicka 1993, Bigham et al. 1994, Mäki & Luukas 2001, Imaña Osorio & Mäki 2003).

The composition of the Pyhäsalmi ore varies both horizontally and vertically. To a depth of about 1000 m, sphalerite is concentrated in the central part and chalcopyrite near the outer margins of the ore. At deeper levels, there is massive pyrite (low Cu, Zn) in the centre, which is enveloped by chalcopyrite ore and further outwards by Zn ore. The highest barite contents are generally encountered in the sphalerite-rich areas. The ore is a massive pyrite ore with 70 % sulphides. The sphalerite-rich ore is in some places finely banded, and thin pyrite-porphyritic bands are common. A pyrite dissemination, which in some places has a breccia structure, exists around the massive ore. Pyrrhotite has replaced pyrite at the southern end of the ore. By end of 2004, the ore tonnage mined from Pyhäsalmi has been 39.77 Mt at 2.37 Zn, 0.83 % Cu, 14 g/t Ag, 0.5 g/t Au and 36 % S; the reserves were estimated at 15.69 Mt at 1.16 % Cu, 2.72 % Zn and 39.9 % S and the resources as 17.1 Mt at 0.8 % Cu, 0.7 % Zn, 42.9 % S.

In the southernmost part of the zone the mineralisations seem to be more copper-dominated, as for example Säviä (Aho 1977). They also are more modest in size, and no commercially viable deposits have hitherto been detected, in spite of intensive exploration and sophisticated modelling of the deposits (Gaál, ed. 1988, Kuosmanen, ed. 1988).

South from the main zone there is a minor separate block where rocks of the Vihanti association and a minor deposit, Pukkisaari, were encountered (Vaasjoki 1981, R. Lahtinen 1989).

The Laivakangas Au province (26) (Gaál & Isohanni 1979, Nurmi 1984, Nurmi 1985, Nurmi & Haapala 1986, Gaál & Sundblad 1990, Nurmi et al. 1991a, Nurmi et al. 1991b, Sundblad et al. 1993, Kousa et al. 1997, Eilu 1999) is located in western Finland around the junction of the Pohjanmaa Schist Belt (unit no. 21), Savo Schist Belt (unit no. 16) and the Central Finland Granitoid Complex (unit no. 20, Fig. 1). The gold deposits, such as Laivakangas (estimated at 0.45 Mt at 3.9 g/t Au; Mäkelä et al. 1988a, Mäkelä et al. 1988b), Kiimala (Kojonen et al. 1991), Kopsa (Gaál & Isohanni 1979) and some others, are mainly epigenetic and confined to shear zones in granitoidic rocks. This brings some of them into the class of orogenic gold deposits and some close to the porphyry-copper ore type, and indeed several copper or molybdenum deposits (see e.g. Nironen & Csongrádi 1984, Piispanen 1985, Nironen & Front 1988) are spatially closely related to them and included into the same province.

Inside the gold province, there is a deposit of another type, the Rauhala Zn-Cu-Pb deposit, thoroughly described by Kojonen (1989), and by Kojonen et al. (1989). The relation of this deposit to the gold province has been discussed and the interpretation leans towards syngenetic (Kojonen et al. 1990). Its resources are estimated at 1.7 Mt of ore at 4.97 % Zn, 1.33 % Cu, 0.96 % Pb, 53 g/t Ag and 0.4 g/t Au.

The Hitura Ni-Cu province (27) is at the junction of the Pohjanmaa Schist Belt (unit no. 21, Fig. 1) and the Savo Schist Belt (unit no. 16) and is entirely overlapped by the Laivakangas Au province. It includes a tight cluster of several minor deposits of the Svecofennian type around the major Hitura deposit, plus a few minor deposits and occurrences to the NW and SW of Hitura. The Hitura province lies roughly at the continuation of the line connecting the Kotalahti and Laukunkangas Ni-Cu deposits, and it was traditionally referred to as the northernmost end of the Kotalahti Belt (e.g. Gaál 1972, Kahma 1973, Gaál et al. 1975). However, many

of the crucial characteristics of the Kotalahti Belt as defined in the papers mentioned above are not applicable to the Hitura area. The Hitura province is located deep inside the Svecofennian Domain. The deep gravimetric trough, which is interpreted as a major fault system and the leading structure for the nickeliferous mafic intrusions, is flattened here into an unstructured pattern. The deposits, especially those in the Hitura cluster proper (Isohanni et al. 1985), are associated with ultramafic bodies, and they perhaps resemble better the Oravainen deposit (see the description of the zone 22 above) than the deposits of the Kotalahti type (Papunen & Vorma 1985). Geochemically Hitura most closely resembles the Vammala deposit (Mäkinen 1987). On the other hand, no nickel mineralisations have hitherto been discovered between the Hitura province and the Oravainen province, which makes the continuous ring-like nickel belt, as proposed by Frietsch et al. (1983) and Papunen & Vorma (1985), less probable. Thus, the Hitura province is here considered to be an independent province.

The Hitura province as outlined in the Metallogenic Map includes the clusters described in Puustinen et al. (1995) as the Hitura zone (20), Perkkiö zone (19) and Muurasjärvi zone (29, Fig. 7). As such, the province is not very homogenous, but because the two latter clusters only contain quite small occurrences, we concentrate on the first group only.

As mentioned above, all of the nickel deposits in the Hitura cluster are associated with minor ultramafic intrusions. With the exception of Hitura itself, they are rather small and even the largest ones contain approximately 4 000 tonnes of nickel and 1 000 tonnes of copper each, in 0.5 – 2 Mt of ore at 0.2 – 0.74 % Ni and 0.05 – 0.14 % Cu. Of these, Makola (Huhta 1954, Haapala 1969, Isohanni et al. 1985), discovered in 1937 (Saksela & Hackzell 1938), was exploited from 1941 to 1954 and yielded 0.41 Mt at 0.74 % Ni and 0.44 % Cu.

Hitura (Papunen 1970, Papunen & Mäkelä 1980, Isohanni et al. 1985, Papunen & Penttilä 1996, Kousa et al. 1997) is not typical of its own province and, in fact, altogether unique in Finland. It is hosted by a pipe-like serpentinite massif with high magnesium content and no preserved signs of the primary premetamorphic rocks (probably dunites); the ore bodies form a nearly cylindrical entity at the outer shell of the pipe (Fig. 15); chemically Hitura is anomalous in its

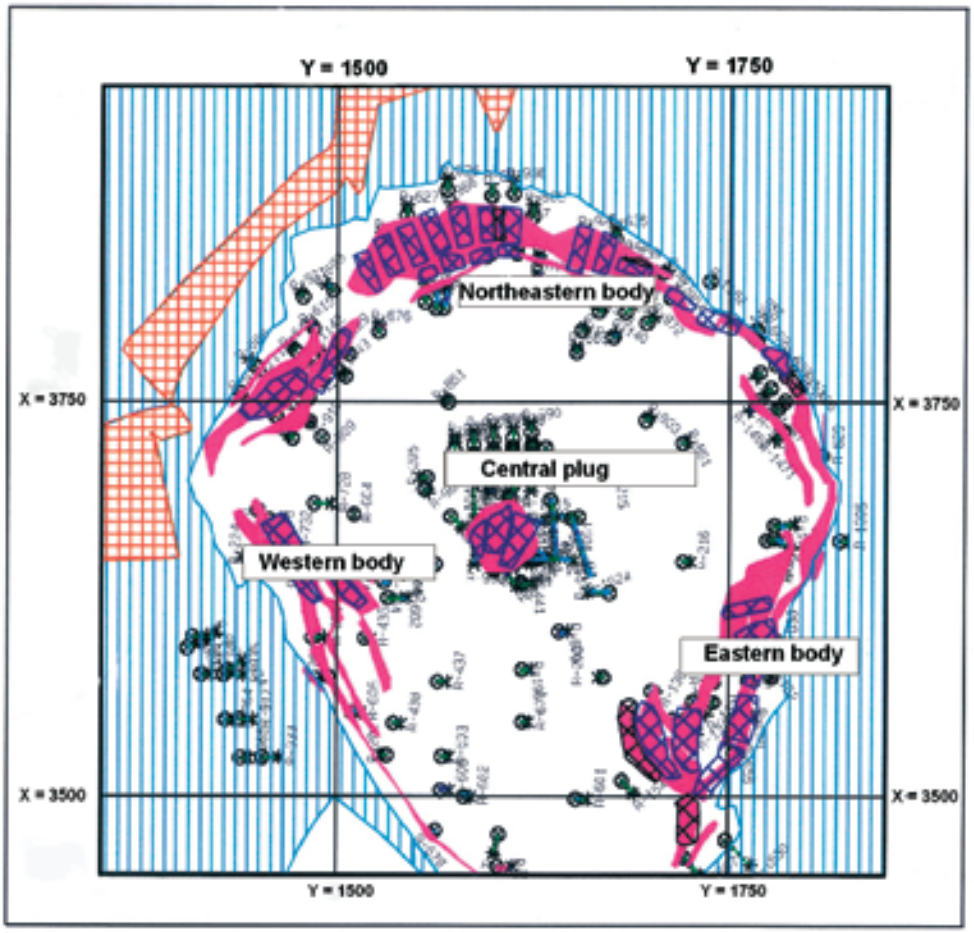

Fig. 15. Hitura nickel mine, horizontal section +350 m. According to Kojonen & Isomäki (2005). White – serpentinite, red – ore (with stopes marked with blue grid), blue vertical ruling – mica gneiss, orange grid – tonalites and granodiorites, crosses in circles – drill holes.

high, even if not constant, PGM content. This is also seen in its mineralogy (Papunen 1970, Vuorelainen et al. 1972, Häkli et al. 1976, Papunen 1977), as such rare nickel minerals as mackinawite and valleriite are abundant and a large number of PGM minerals have been detected. Just recently a new Cu-Re-Mo mineral species, tarkianite, was discovered at Hitura (Kojonen et al. 2004).

Hitura has been subject to exploitation since 1970. The unusual mineralogical conditions, particularly the abundance of oxisulphide minerals of the valleriite group, have made dressing of the ore complicated, and recently the ore has been used for production of nickel compounds rather than for metallurgical products. Until now (the end of 2004) some 13.1 Mt with 0,57 % Ni and 0,21 % Cu have been mined of the total resources, which have been estimated at 50 Mt at 0.50 % Ni and 0.16 % Cu (cf. Isomäki 2004). The amounts of PGM have been variable; the best PGM accumulation of 20 000 tonnes of ore yielded a mill feed with values as high as 0.034 g/t Pt, 0.041 g/t Pd and 0.015 g/t Rh (Isohanni et al. 1985).

The Talvivaara Ni-Zn-Cu zone (28) includes several low-grade sulphide deposits hosted by black schist, and they form a chain of 150 km within the Paleoproterozoic Kainuu Schist Belt (block no. 14; Laajoki et al. 1983, Loukola-Ruskeeniemi et al. 1997b). The most prominent of these deposits, Talvivaara (Loukola-Ruskeeniemi 1989, Loukola-Ruskeeniemi et al. 1991, Loukola-Ruskeeniemi & Heino 1993, Loukola-Ruskeeniemi 1995a, Loukola-Ruskeeniemi & Heino 1996, Loukola-Ruskeeniemi 1997) contains at least 300 Mt of sulphide-bearing rock, averaging 0.26 % Ni, 0.53 % Zn and 0.14 % Cu. Possible by-product uranium of 0.001 – 0.004 % U could also be encountered (OECD 2002). Anomalous concentrations of PGE elements have also been detected here (Pasava et al. 1997). A mineralogical curiosity at Talvivaara is the presence of alabandite (Törnroos 1982). Several attempts have been made to exploit the huge reserves of Talvivaara. Recent laboratory, bench and pilot scale experiments have shown the amenability of the black schist ore to bioleaching with high metal recoveries (Riekkola-Vanhanen 2005). After Talvivaara, the next largest deposits of this zone are Pappilanmäki, Korpimäki, Alanen and Sotinpuro, all containing a few tens of Mt mineralised rock.

Concerning the genesis of the Talvivaara type deposits, it has been suggested that originally they were metalliferous organic-rich muds deposited in anoxic conditions in a basin associated with sea floor spreading (Loukola-Ruskeeniemi 1995a). A genetic link between the Kainuu Ni-Zn-Cu deposits and the Outokumpu serpentinite-associated Cu-Co-Zn-Au-Ni ore deposit has also been anticipated (Loukola-Ruskeeniemi et al. 1991) based on lithological, mineralogical and geochemical features (cf. the description of the Outokumpu zone (16) above).

Talvivaara has also been a target of extensive environmental and geomedicinal studies (Loukola-Ruskeeniemi et al. 1998, 1999b, 2003).

The Nuottijärvi-Sotkamo U zone (29) includes uraniferous phosphorites associated with sedimentary carbonates of Paleoproterozoic sequences within the Kainuu Schist Belt (block no. 14, Äikäs 1980, Vaasjoki et al. 1980). The Nuottijärvi deposit is located in a carbonate-apatite horizon, between quartzites and graphite-bearing phyllites. An intraformational breccia characterises the deposit. The uranium resources of the Nuottijärvi deposit might be up to 1 000 t U with an average grade of 0.04 % U. (IUREP 1982, Äikäs 1989, OECD 2002).

The Otanmäki V-Fe-Ti province (30) is situated in a small triangular formation of Proterozoic rocks inside the Archaean gneisses, in the southernmost part of the Pudasjärvi complex (unit no. 9 in Fig. 1). The Otanmäki formation consists of mainly supracrustal rocks (mica schists and quartz-feldspar schists) plus some metadiabases in the middle, and an arch-like pattern of metamorphosed mafic plutonites, which surround the other lithological units of the formation (Paarma 1954, Pääkkönen 1956, Pöschl 1964, Isokangas 1978). The Fe-Ti deposits are confined to these mafic rocks. In addition, a massif of a slightly alkaline rock, originally defined as 'alkali granite' (Marmo et al. 1966), but more recently interpreted as metasomatic alkaline gneiss, intrudes the supracrustal members of the formation.

The entire formation is interpreted as a basin. The mafic rocks represent original layered intrusions that are, however, strongly metamorphosed, so the gabbroic parts are turned into amphibolites and only the anorthositic parts are recognizable as intrusivic. The mineralisations are affected by the metamorphism as well. The ore minerals are segregated into deposits and ore bodies scattered in a rather irregular way along the main mineralised horizon, which made exploitation of the Otanmäki mine complicated and a special design of magnetometric survey for locating individual ore bodies was required (cf. Paarma & Levanto 1958). On the other hand, as an advantage, the main ore minerals (magnetite and ilmenite) do not occur as lamellar 'titanomagnetite' patterns, but rather as independent grains. This feature, noticed already by Ramdohr (1956), is favourable for producing both good-quality ilmenite concentrate and high-grade magnetite product during exploitation.

Due to their high magnetite content, the deposits in

the province cause distinct magnetic anomalies and can be easily traced even by regional-scale airborne geophysical survey. The type deposit of the province and the largest one, Otanmäki, was discovered in 1938 and mined in 1953 to 1985. Its indicated ore resources add up to 36 Mt at 34 % Fe, 0.26 % V and 7.6 % Ti. The vanadium content in the magnetite is 0.62 %, and vanadium was the most valuable commodity in the ore. Also the next largest deposit, Vuorokas (7.8 Mt at 32.5 % Fe, 0.26 % V and 5.5 % Ti) was exploited from 1965 to 1985, as a subsidiary of the Otanmäki mine. Altogether 25.4 Mt of ore was produced from the two deposits, yielding 8.6 Mt Fe, 3.3 Mt TiO_2 and 0.12 Mt V_2O_5. In 1985, mining – and the entire vanadium industry in Finland – was stopped because of disturbances in the world vanadium market, and considerable ore reserves were left over. The other 4 known deposits of the province are much smaller, less than 1 Mt each.

The alkaline rock complex mentioned above also has a specific metallogenic appearance. Two minor Nb-REE mineralisations called Hautakangas and Kontioaho were encountered in pegmatitic veins connected to the complex. According to archive reports by the Rautaruukki Company, the volume of the mineralisations is modest, but they are interesting in their mineralogy. The main niobium mineral in them is fergusonite, i.e. an yttrium niobate.

The Moukkori-Lokkiluoto Au zone (31) is confined to the Kuhmo Greenstone Belt of Archaean age (unit no. 12, Fig. 1), like the next two metallogenic zones. It contains several minor deposits (e.g. Kuikkapuro) and occurrences of Archaean type, hosted mainly by mafic metavolcanics and analogous to the Hattu Au zone described above (Nurmi et al. 1991a, Nurmi et al. 1991b, Poutiainen & Luukkonen 1994, Eilu 1999, Halkoaho & Pietikäinen 1999, Papunen et al. 2001).

The Kauniinlampi-Arola Ni zone (32) comprises a series of Archaean nickel deposits and occurrences in the Kuhmo and Suomussalmi Greenstone Belts (unit no. 12, Fig. 1). The most important ones are Hietaharju and Peura-aho (Kojonen 1981, Ketola 1982, Kurki & Papunen 1985), Kauniinlampi (Halkoaho et al. 1999, Halkoaho & Pietikäinen 1999) and Arola (Puustinen et al. 1995). They are ascribed to the komatiite group (Halkoaho et al. 2000); however, many of them show features differing from the main komatiite type both in terms of metal ratios and the composition of the host rocks (cf. Kojonen 1981). A mineralogical peculiarity is the find of native nickel in Kauniinvaara, one of the minor deposits (Pakkanen & Luukkonen 1995).

The Tipasjärvi-Saarikylä Fe zone (33) (Laajoki 1985, Laajoki 1986, Laajoki & Gehör 1990) is a strata of banded iron formations within the Kuhmo Schist Belt (unit no. 12, Fig. 1) with a number of mineralisations. However, these are still smaller than those in the Huhus zone described above, and a lot of iron is included in the silicate phase (Gehör & Laajoki 1987). Like the Huhus zone, deposits of pure pyrite are known here, too, at Lake Tipasjärvi in the southernmost part of the zone (Vartiainen 1970; Taipale 1983b).

The Pääkkö Fe zone (34) includes several Superior type iron formations around Väyrylänkylä at Puolanka, in the northern part of the Kainuu Schist Belt (unit 14 in Fig. 1). The Iso-Vuorijärvi, Pääkkö, Seppola and Körölä deposits are situated in the same 10 km long or so sedimentary structure that consists of a dolomite-phyllite unit with tuffites, dolomites, black shales, phyllites, metadiabases, quatzites and iron formations. The dominant rock of the iron formations is an amphibole-rich quartz-magnetite-banded rock representing mixed oxide-silicate facies. Also quartz-siderite-banded rock of the carbonate facies and iron-rich black schists and phyllites of the sulphide facies have been encountered (Laajoki 1975a, Laajoki 1975b, Ervamaa & Laajoki 1977, Laajoki & Saikkonen 1977, Lehto & Niiniskorpi 1977, Laajoki et al. 1983). According to a whole rock Pb-Pb isochron the age of the Pääkkö iron formation is 2080 Ma (Sakko & Laajoki 1975). However, recent zircon age determinations indicate a totally Archaean provenance for the Central Puolanka Group of the Kainuu Schist Belt (Huhma et al. 2000).

In total, up to some 20 Mt of low-grade iron ore (27 % Fe, 1.2 % P, 1.9 % S) could be located in the Väyrylänkylä area. In addition to iron formations, several preglacial kaolin deposits have been located at Pihlajavaara, Pääkkö, Iso-Vuorijärvi, Honkavaara and Poskimäki (Laajoki 1975a, Laajoki 1975b). The Pääkkö Fe zone has very similar features to the large Tuomivaara iron deposit, some 60 km to the south in Sotkamo (Laajoki et al. 1983, Gehör 1994b).

The Koillismaa PGE + Ni-Cu + V-Fe zone (35) covers a complex of Palaeoproterozoic (ca. 2450 Ma) layered intrusions in northeastern Finland. The intrusive bodies of Koillismaa form the eastern half of the large discontinuous chain of platform-type layered intrusions that crosses Finland in an E-W direction at about 100 km to the south of the Polar circle (Piirainen et al. 1974, Alapieti 1982, Alapieti et al. 1990, Alapieti & Lahtinen 2002; Fig. 16). These layered intrusions were emplaced in the Archaean basement, at a level that was subsequently denuded by Palaeoproterozoic erosion, so that their hanging wall is commonly immediately covered by Proterozoic supracrustal rocks of the Jatulian series, i.e. by rocks younger than the layered intrusions themselves.

Fig. 16. The largest layered intrusions of the northern part of the Fennoscandian Shield. From Alapieti & Lahtinen (2002).

The Koillismaa intrusive complex, which lies at the junction of the Archaean Pudasjärvi complex and the Proterozoic Kuusamo Schist Belt (units no. 9 and 8, Fig. 1), consists of a group of intrusive blocks (probably, tectonically separated parts of a single intrusion) and a separate 'tail', Näränkävaara, stretching eastwards from the main group (Alapieti 1982, Alapieti & Kärki 2005).

Initially, the Koillismaa complex was explored for nickel-copper and iron-vanadium ores. Indeed, large

but low-grade Ni-Cu mineralisations were encountered at Porttivaara and Kuusijärvi in the western subgroup of the intrusive blocks (Piirainen et al. 1977, Alapieti et al. 1979a, Lahtinen 1985) and a V-rich Fe-Ti deposit was detected at Mustavaara in the Porttivaara section (Piirainen & Juopperi 1968, Juopperi 1977). The Mustavaara mine operated from 1974 to 1985 and yielded 13.4 Mt of ore at 0.2 % V. Considerable ore reserves, indicated as 38 Mt, were still left unexploited there.

The PGE potential of the Cu-Ni occurrences was soon realized (Alapieti & Piirainen 1984, Piispanen & Tarkian 1984, Lahtinen 1985). It was confirmed that they represent sulphide type Ni-Cu-PGE mineralisation in the marginal series of the layered intrusions (Lahtinen et al. 1989, Saini-Edukat et al. 1993, 1997, Iljina et al. 2001, Kojonen & Iljina 2001, GTK 2005. Reef-type enrichments in the real layered series were disclosed as well. Comprehensive reviews of the zone are given by Alapieti (1989), Alapieti et al. (1990) and by Alapieti & Lahtinen (2002).

The eastern Näränkävaara intrusion (Alapieti et al. 1979b) continues across the border into Russia. The ore potential of the intrusion is still open, as no considerable mineralisations have so far been discovered, despite many years of exploration.

The Oijärvi Au zone (36) is confined to the less known Oijärvi Greenstone Belt in the middle of the Pudasjärvi Complex (unit no. 9 in Fig. 1). The gold mineralisations of Archaean orogenic type were only discovered recently, and the only non-commercial public description available on them is in the updated versions of the FINGOLD database (cf. Eilu 1999).

The Kemi-Penikat Cr + PGE zone (37), located at the boundary between the Archaean Pudasjärvi Complex (unit no. 9) and the Proterozoic Peräpohja Belt (unit no. 7, Fig. 1), covers two western members in the 2450 Ma layered intrusions chain of northern Finland (Fig. 16). Compared to the Koillismaa zone, the Kemi-Penikat zone does not contain any sulphide accumulates of the marginal series type, but basal chromitite accumulations and chromitite reefs (cf. Lahtinen et al. 1989, Alapieti et al. 1990). Indeed, the first discovered mineralisation in this zone was the Kemi (or Elijärvi) chromium deposit, by far the largest mineral deposit in Finland with estimated reserves and resources at 162 Mt at 26 % Cr_2O_3 (Kahma et al. 1962, Kujanpää 1986, Alapieti et al. 1989a, Huhtelin 1997, Kojonen et al. 1999b). The Kemi mine, established in 1966, operates continuously and up to the present time about 30.91 Mt of ore has been extracted at an average grade of 25.7 % Cr_2O_3.

The Kemi deposit is hosted by a single oval-shaped layered intrusion of the same name (e.g. Alapieti et al. 1989a). The following intrusion to the east, belonging to this zone, the Penikat intrusion, is a long, platform-shaped massif tectonically broken into five blocks. It carries some chromium concentrations as well, but the main mineral potential lies in the intrusion's PGE content (Alapieti & Lahtinen 1986, Halkoaho et al. 1989a, Halkoaho et al. 1989b, Huhtelin et al. 1989a, Huhtelin et al. 1989b, Lahtinen et al. 1989, Halkoaho et al. 1990a, 1990b, Huhtelin 1991, Halkoaho 1993, Barkov et al. 1999, Barkov et al. 2000, Barkov et al. 2002, Alapieti & Lahtinen 2002, Kojonen et al. 2005, GTK 2005).

The PGE mineralisations in the Penikat intrusion are confined to four mineralised horizons or reefs all located inside or at the boundaries of one megacyclic unit of the layered series of the complex. They are referred to as the Sompujärvi Reef, Ala-Penikka and the Paasivaara Reef (Alapieti & Lahtinen 1986, Halkoaho et al. 1990a, Halkoaho et al. 1990b). A detailed description and review of the geology of the intrusion and mineralisations is presented by Alapieti & Lahtinen (2002) and will not be repeated here. We only wish to point that the PGE reefs continue through the intrusion but are mainly thin horizons (decimetres in thickness) with local swellings up to 20 m in depression structures called potholes, at a PGE level of less than 10 g/t. As such, the total volume of mineralisation can be estimated with some uncertainty only; figures of 2 340 tonnes Pt and 4 590 tonnes Pd have been presented for the *in situ* resources of the total field (Vermaak 1995).

At Kirakkajuppura, at the northern edge of the Penikat intrusion, a bonanza-type pocket deposit was discovered in the Sompujärvi Reef (Barkov et al. 1999, Alapieti & Lahtinen 2002). A test mine was established there in 1988 and 2 165 tonnes of ore at about 10 g/t Pt and 20 g/t Pd was extracted.

The westernmost intrusion in the chain, the Tornio intrusion, continuing to Sweden and known there as the Kukkola intrusion (Söderholm & Inkinen 1982), has received less attention after its initial discovery, as it was deemed to be of less potential. Therefore in the Metallogenic Map it is left out of the Kemi-Penikat zone.

The Suhanko PGE zone (38) and **Narkaus PGE zone (39)** are hosted by intrusions of the Portimo Layered Complex (Iljina 1994), which lies halfaway between the Penikat intrusions and the Koillismaa Complex described above. Although situated close to each other, the Suhanko and Narkaus intrusion groups differ in their shape and character of mineralisation. The Suhanko intrusions resemble the Koillismaa Complex, while the Narkaus intrusion occupies a position strictly at the boundary between the Archaean

Pudasjärvi complex and the Proterozoic sedimentary series of the Peräpohja Schist Belt (unit no. 7, Fig. 1), just like the Penikat intrusive complex, and is similarly cut into several blocks.

Five principal types of PGE mineralisations have been identified in the Portimo Complex. In the Suhanko zone, we see (1) PGE-bearing Cu-Ni sulphide disseminations, similar to those in Koillismaa; (2) massive pyrrhotite bodies; (3) a reef called Rytikangas Reef, comparable to the Ala-Penikka Reef. In the Narkaus zone, they are (2) massive pyrrhotite bodies identical to those at Suhanko; (4) a PGE reef (Siika-Kämä Reef) and (5) offset Cu-PGE mineralisations in the Archaean wall rocks (Vuorelainen et al. 1982, Hänninen et al. 1986, Huhtelin et al. 1989a, Huhtelin et al., 1989b, Iljina et al. 1989, Alapieti et al. 1989b, Iljina 1991, Lerssi et al. 1991, Iljina et al. 1992, Thalhammer et al. 1993, Andersen et al. 1999, Iljina & Hanski 2002, GTK 2005.

The resources of the largest deposits in the Suhanko zone have been estimated (Outokumpu Oy & Gold-Fields Ltd. 2002) as follows:

- Konttijärvi and Konttijärvi North: 54.0 Mt at 1.44 g/t Pd, 0.40 g/t Pt and 0.10 g/t Au;
- Ahmavaara: 99.8 Mt at 1.10 g/t Pd, 0.23 g/t Pt and 0.14 g/t Au;
- Ahmavaara East: 29.8 Mt at 0.83 g/t Pd, 0.18 g/t Pt and 0.11 g/t Au.

In total, the metal content in the Konttijärvi and Ahmavaara deposits corresponds to 9.1 Moz of (2PGE+Au). Analogously, an estimate of 5.3 Moz has been given for the ore bodies of the Siika-Kämä Reef at Narkaus (Iljina & Hanski 2002).

The Tervola Au-Cu zone (40) is in the Palaeoproterozoic Peräpohja Schist Belt (unit no. 7 in Fig. 1), which comprises a wide range of metasedimentary and -volcanic rocks with only a few intrusions aged from about 1.8 to 2.2 Ga. The Tervola zone covers a part of the Peräpohja Belt containing mafic to felsic metavolcanics, carbonate rocks, black schists and (arkose) quartzites. The regional geology is described by e.g. Perttunen (1980), Perttunen (1985), Korhonen & Säävuori (1985), Perttunen & Lappalainen (1997) and Perttunen & Vaasjoki (2001).

The Kivimaa Au-Cu deposit, discovered in 1965 (Rouhunkoski & Isokangas 1974, Niiranen & Eilu 2003), is located some 50 km southwest of Rovaniemi, in the central part of the Peräpohja Schist Belt (Nironen et al. 2002). It is a single lode comprising a major calcite-quartz vein and hosted by a tholeiitic metadolerite sill. The sill occurs apparently conformably in a sequence of mafic metavolcanic rocks. The quartz vein is E-W trending, 350 m long and 1 – 6 m wide. The continuation of the deposit is open at the depth of 60 m. The auriferous vein lies in a dip-slip fault and is enveloped by an alteration zone characterised by the mineral assemblage of calcite-chlorite-biotite-albite-pyrite. The main ore minerals are pyrite and chalcopyrite. Native gold and bismuth occur as inclusions in arsenopyrite and, possibly, as free gold. All gold appears to be in the calcite-quartz vein. The deposit was mined in 1969 yielding 18 600 tonnes of ore at 1.20 % Cu and 2.0 g/t Au.

The tiny Vinsa mineralisation, estimated at 1 000 tonnes of ore at 4 % Cu and 2.5 g/t Au, is located about 20 km west of Kivimaa. Geologically it is almost identical to Kivimaa.

The Vähäjoki iron deposit, estimated at 10 Mt of ore at 30 % Fe, is also situated in this area (Mikkola 1948, Sarala & Rossi 1998, Liipo & Laajoki 1991). It clearly belongs to the epigenetic Fe-Ox-Cu-Au type and locally contains potentially significant Au, Co and Cu (Niiranen & Eilu 2003).

The Rovaniemi-Ylitornio Mo-Cu-W zone (41), which includes several genetic types of mineralisation, is in the northern part of the Peräpohja Schist Belt (unit no. 7, Fig. 1). Here, the Paleoproterozoic Peräpohja supracrustal rocks unconformably rest on the Archaean basement complex and are bound to north by the younger Paleoproterozoic Central Lapland Granite Complex (unit no. 6, Fig. 1). The border zone is an area of polymetallic mineralisations. In the western part of the zone, in the Ylitornio area, several molybdenite occurrences are encountered. The largest of them, Kallijärvi, also called Kivilompolo (0.4 Mt, grading 0.11 % Mo), is in a migmatised granitic gneiss belt where molybdenite has been found in association with chalcopyrite in a quartz vein system (Yletyinen 1967).

The Raja-Kirakka scheelite occurrence, also in the Ylitornio area, is located in a skarn interlayer in association with an amphibolitic zone. The eastern part of the zone is characterised by a few very small Cu-, U- and Mo-occurrences in mica schist – black schist environments.

The Misi Fe zone (42) occupies a minor complex of rocks of mainly mafic composition in the extreme northeastern part of the Peräpohja Schist Belt (unit no. 7, Fig. 1), almost entirely surrounded by rocks of the Central Lapland Granite Complex (unit no. 6). The ore zone includes 13 magnetite deposits, four of which have been subject to exploitation: Kärväsvaara (1959–1967; 1.0 Mt of ore at 46 % Fe), Raajärvi (1964–1975; 5.12 Mt of ore at 46 % Fe), Leveäselkä (1969–1974; 0.3 Mt of ore at 46 % Fe; total resources ca. 1.2 Mt), and Puro (1961–1964; 0.06 Mt of ore at 53 % Fe; total

resources 0.60 Mt). The other 9 deposits detected range from 0.8 to 0.1 Mt at 30 – 55 % Fe.

The Misi iron ore zone was first described in detail in a monograph by Nuutilainen (1968). According to that publication, the most common rocks in the complex are mafic massive rocks described as gabbroids, mafic metamorphic rocks or amphibolites, further albite gabbros, albitites and subordinate metamorphic rocks of sedimentary origin (quartzites, lime/dolostones and various other schists). The mafic rocks are widely albitized, and even scapolite is not uncommon. Iron mineralisation occurs as minor ore bodies of massive magnetite or magnetite dissemination in tremolite-chlorite rock, mainly in an environment of supracrustal rocks and albitites.

The dominant ore mineral in the deposits is slightly martitized magnetite, which e.g. at Kärväsvaara constitutes about 70 % of the ore. The magnetite is rather pure, with no silicate or ilmenite inclusions. All other ore minerals, chiefly pyrite, chalcopyrite and covelline, are subordinate. This reflects the fact that the content of trace elements in the ores is rather low: 0.04 – 1.2 S %, 0.03 – 0.4 P %, 0.05 – 0.3 Ti %, 0.02 – 0.14 V % and approximately 0.03 Mn %.

According to Nuutilainen (1968), the genesis of the iron ores in the Misi area was ascribed to the spilitic mafic magmatism and the deposits were interpreted as products of crystallisation from a spilitic hydromagma at relatively low temperatures. As such, these deposits were for years regarded as a stratotype of a special magmatic iron ore type with low titanium. However, recently the geology of the entire region was reviewed by Niiranen et al. (2003, 2005a). The supracrustal complex was now correlated with the Kivalo group in the main Peräpohja Schist Belt. The widespread sodic alteration, manifesting itself as albitisation and scapolitisation, was verified to be a regional feature in the whole of Central Lapland and Kuusamo (cf. the next chapter, zone no. 43); in particular, the albite gabbros and albitites were found to be products of alteration of gabbros rather than derivates of a specific magma. The serpentinites and tremolite-chlorite rocks were found to be skarnoids developed from dolomitic marbles and the ore bodies proved to be replacement skarn bodies. The specific composition of iron ore, with its very low content of sulphur and chalcophile metals, may be ascribed to the sodium- and chlorine -rich environment.

The Misi zone is suggested to be prospective for FeOx-Cu-Au type mineralisation (Niiranen & Eilu 2003); however, no significant mineralisations of this type have been discovered as yet.

In the present Metallogenic Map, the Misi province is extended to the east to cover the minor Soinanjoki deposit. The latter, described as a magnetite deposit in amphibolite, is likely to be of the same type as those in the Misi district.

The Kuusamo Au zone (43) is one of the most important gold zones of northern Finland (Fig. 17). It is situated within the intra-cratonic, rift-related Paleoproterozoic Kuusamo Schist Belt (block no. 8 in Fig. 1) and is characterized by widespread albitized rocks that contain some thirty sulphide-bearing hydrothermal Au-Co-Cu-U occurrences (Pankka & Vanhanen 1989, Pankka & Vanhanen 1992, Pankka 1992, Vanhanen 1992, Pankka 1997, Eilu 1999, Vanhanen 2001, Eilu et al. 2005). The most prominent deposits are Kouvervaara sulphide, Apajalahti, Lemmonlampi, Säynäjävaara, Meurastuksenaho, Konttiaho, Sivakkaharju, Hangaslampi and Juomasuo. All of them share an almost similar character with pyrite and pyrrhotite as the main ore minerals and accessory cobaltite, Co-pentlandite, chalcopyrite, native gold and uraninite. Gold and cobalt are the most promising metals for exploration in the zone.

The biggest of the Kuusamo sulphide deposits, Juomasuo (estimated at 0.7 Mt with 5 g/t Au and 2 Mt with 0.2 % Co), is situated in a sericitic and silicic alteration zone. The deposit has the form of a flattened pipe. In 1992, during a test mining almost 18 000 tonnes of ore was extracted, averaging 5.9 g/t Au and 0.14 % Co.

The Konttiaho deposit comprises a set of subvertical hydrothermal breccia pipes in a fold hinge. The uranium content may locally reach up to several per cent, while gold is enriched in the matrix within uranium and sulphide minerals. The largest lode of the deposit is estimated to have a few thousand tonnes of ore.

Sivakkaharju is hosted by a quartz-sericite rock, with pyrite as the main sulphide mineral. The main commodities are represented by native gold and uraninite. The estimated ore resources are 28 000 tonnes, averaging 11.3 g/t Au, 0.03 % Co and 0.12 % Cu (Dragon Mining NL 2004).

The uranium content of the Au-Co-Cu-bearing occurrences in the zone also allows use of integrated satellite and aerogeophysical data for location of gold mineralisations (Kuosmanen et al. 1991, Arkimaa 1997).

The Kuusamo U zone (44) largely overlaps the Kuusamo Au zone. It is closely related to the latter and possibly can be regarded as a sub-type of this. Some of the small uranium occurrences could even belong rather to the Au zone, or to both. Of the noted uranium-bearing deposits, Konttiaho and Sivakkaharju also represent the sulphide type, whereas the Kouvervaara uranium occurrence is situated close but separated from the Kouvervaara sulphide Au-Co de-

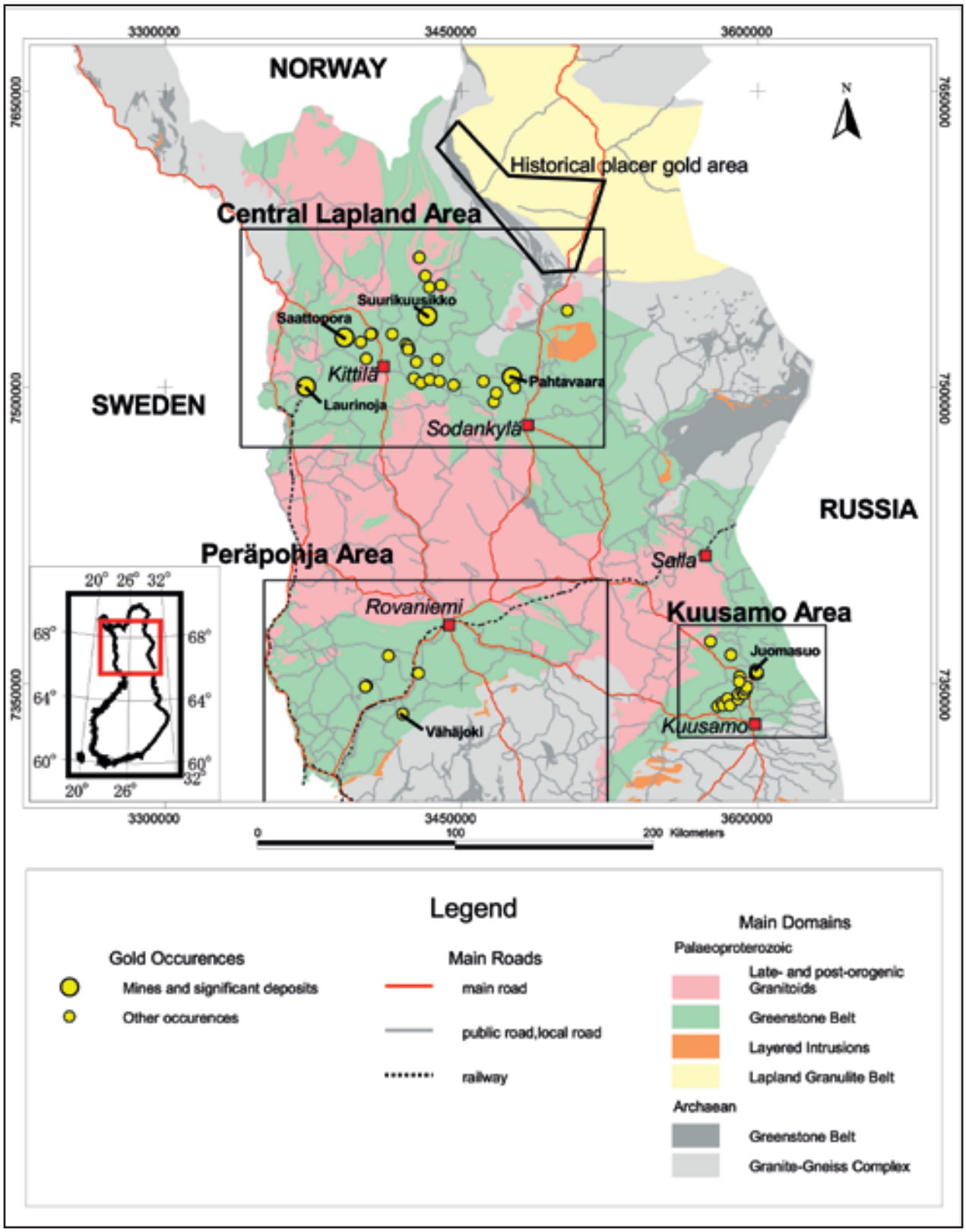

Fig. 17. The general geological map of northern Finland with the gold mineralisations. From Eilu et al. (in press). The delineated areas cover the zones in the present paper as follows: Peräpohja area - Tervola Au-Cu zone (40), Kuusamo area - Kuusamo Au zone (43), Central Lapland area - Kittilä Au-Cu zone (48), historical placer gold area - Lemmenjoki placer Au area (56) and Ivalojoki placer Au area (57).

posits, and represents an entirely different type (Pankka & Vanhanen 1989, Vanhanen 1989, Vanhanen 1992, Vanhanen 2001). Uranium has also been reported in some albite diabases. Some deposits could be located by aeroradiometric surveys (Arkimaa 1991).

The Kouvervaara sandstone-type uranium minerali-

sation is stratabound, and more than 3 km long, but only a few centimetres to some metres thick. The mineralisation is associated with the contact between sericite schist and arkose quartzite. The uranium content of the mineralisation is low, only about 200 g/t U.

The Suonna Fe zone (45) consists of the small iron deposits Karijoki, Suonna, Kirintökangas and Karipuro and belongs to the banded iron formation type in the western part of the Kuusamo Schist Belt (unit 8, Fig. 1). The iron formations occur as narrow disseminated hematite and magnetite beds in sericite schists, embedded in sericite quartzite formations (Lehto & Niiniskorpi 1977, Vanhanen 2001). In total, the zone might have about 1.5 Mt of low-grade (about 20 % Fe) iron ore.

The Jauratsi Fe zone (46) comprises banded iron formations at the southeastern part of the Central Lapland Greenstone Belt (unit no. 4, Fig. 1) at the Matalavaara, Reposelkä, Jauratsi and Rahkavaara iron deposits. The Jauratsi deposit itself is situated in an E-W aligned syncline, some 5 km long and 1 km wide. Quartzites, sericite schists, skarns and hornblende schists are found in the central parts of the syncline. To the north of the structure, the bedrock consists of mafic volcanic rocks, including komatiites at Kummitsoiva as well, whereas intermediate volcanic rocks are prevalent to the south. Hematite-magnetite-goethite-bearing iron formations are located at the northern limb of the syncline, whereas weathered goethite-bearing formations are found at the southern limb. The average chemical composition of the former is 20 % Fe, 0.02 – 0.05 % MnO, 2.4 % P_2O_5 and 0.06 % S (Lehto & Niiniskorpi 1977). The Jauratsi deposit represents oxide facies type iron formations, whereas the other iron deposits show a higher content of sulphide-bearing minerals, and thus a tendency towards sulphide facies type iron formations. In total, the Jauratsi zone might contain up to some 30 Mt of low-grade (25 – 30 % Fe) iron ore.

The Kylälampi Fe zone (47) is located some 20 km to the southeast of the large Koitelainen mafic intrusion. The zone comprises the Kylälampi and Kannusjänkä layered gabbro intrusions, situated in the eastern part of the Lapland Greenstone Belt, near the Archaean basement. Low-grade vanadiferous magnetite mineralisations (18 – 24 % Fe, 0.02 – 0.08 % V) in gabbro, granophyre and albitite have been encountered during diamond drillings. Results for U-Pb analyses on zircons from the Kylälampi gabbro show an age of 2114 Ma (Räsänen & Huhma 2001).

The Kittilä Au-Cu zone (48) forms the main metallogenic complex in the Central Lapland Greenstone Belt (unit no. 4, Fig. 1). This large greenstone belt of Palaeoproterozoic age (Frietsch et al. 1986, Frietsch et al. 1987, Frietsch 1988, Mänttäri 1995, Lehtonen et al. 1998, Hanski et al. 2001a, Vaasjoki 2001) is divided into the younger, komatiite-poor Kittilä area in the west and the older, komatiite-dominated Sodankylä area in the east, separated by a major tectonic N-S trending zone, which is marked by a chain of ophiolitic nickel-bearing serpentinites (cf. Hanski 1997). Several horizons of banded iron formations run through the entire area of the zone (e.g. the Porkonen-Pahtavaara Fe-Mn zone 50). Widespread albitization is characteristic to the entire Central Lapland Greenstone Belt and may be a crucial factor in the character of mineralisation, too.

The Kittilä metallogenic zone is analogous to the other highly ore potential Neoarchaean and Paleoproterozoic greenstone belts in Precambrian shields elsewhere in the world. The western part of the zone is characterized by base metal dominant mineralisations and the eastern part by gold dominant deposits (Fig. 18). It contains tens of hydrothermal Cu, Au and polymetallic base metal mineralisations in supracrustal sequences, with pyrrhotite/pyrite, chalcopyrite and sphalerite as the main typical sulphide minerals. On the other hand, the gold mineralisations are dominated by pyrite, chalcopyrite, arsenopyrite and native gold.

The core metalliferous gold-bearing subzone is the so-called the Sirkka Shear Zone (Keinänen & Holma 2001), which extends across the entire Lapland Greenstone Belt from Pahtavuoma in the west, through Saattopora and Sirkka to Tepsa in the east. The shear zone also has extensions to the south of Pahtavaara and to the southeast of Sodankylä.

The Pahtavuoma Cu-Zn deposit in the western corner of the zone (Korkalo 1977, Inkinen 1979, Korvuo 1997) is situated in an E-W trending volcano-sedimentary sequence. In all, the deposit comprises four stratabound copper ore bodies, six zinc ore mineralisations and three vein-type uranium occurrences. The copper mineralisations occur at the contact between schists and greenstones, hosted predominantly by graphite-bearing phyllite or micaceous schist. One of the copper deposits was mined during two periods between 1974 and 1993, and some 0.3 Mt copper ore was recovered with an average grade of 1.07 % Cu and 26 g/t Ag. The total copper ore reserves are estimated at 4.4 Mt at 1.04 % Cu and 23 g/t Ag, and zinc ore reserves of 17 Mt at 0.81 % Zn and 0.81 % Cu. Extensive mineral exploration and studies has been performed in the Pahtavuoma area during the 1960s and 1970s (c.f. Kokkola & Korkalo 1976, Mäkelä & Tammenmaa 1978, Ketola 1979, Hirvas & Mäkinen 1989, Hölttä & Karhu 2001).

The Saattopora Au-Cu deposit (Inkinen 1979, Anttonen et al. 1989, Wyllie 1989, Mänttäri 1995,

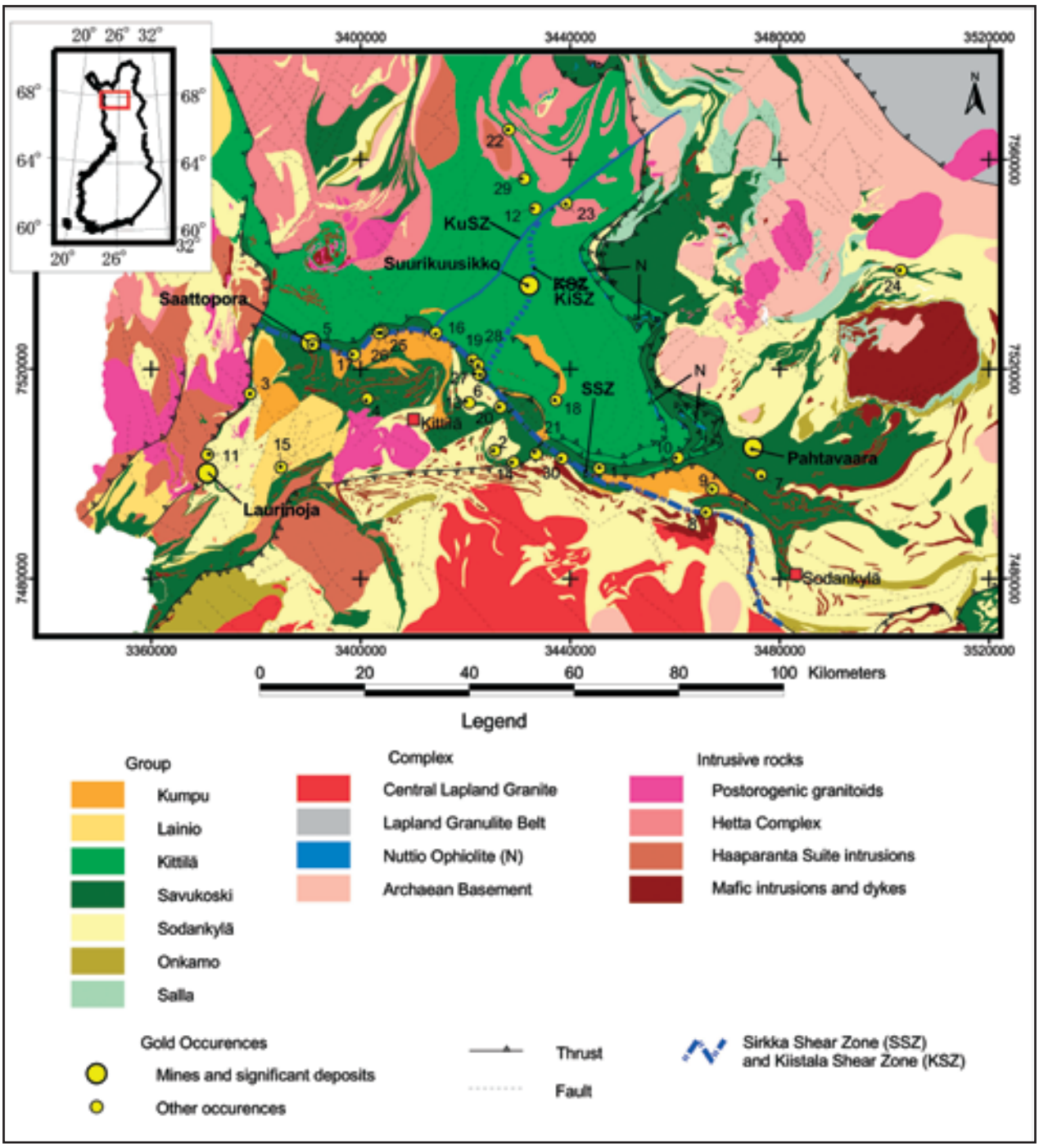

Fig. 18. General outlines of geology and the gold mineralisations of the Kittilä metallogenic zone (Saattopora to Pahtavaara) and of the Rautuvaara zone (Laurinoja, Cu-Rautuvaara) in Central Lapland. From Eilu et al. (in press).

Korvuo 1997, Eilu et al. 2005) is located in a similar environment to Pahtavuoma and is in the western part of the Sirkka Shear Zone. The ore is hosted by albitites that occur as two separate E-W trending zones. The protolith to the albitites has been an intermediate volcaniclastic rock and also felsic sediment. The highest gold grades are found in the vertical N-S trending quartz-carbonate veins. The deposit was mined from 1988 to 1995 and 2.14 Mt of gold-copper ore was recovered with an average grade of 3.25 g/t Au and 0.26 % Cu.

The Sirkka polymetallic Ni-Cu-Co-Au deposit (Inkinen 1979, Eilu et al. 2005) is one of the polymetallic nickel- and gold-bearing occurrences within the Kittilä volcano-sedimentary environment. It is associated with typical graphite-albite-biotite rocks and has a metal content of 0.32 % Ni and 0.38 % Cu. The deposit was subject to test mining from 1953 to 1956 when some

9 500 tonnes of ore was extracted. The deposit gave the name to the Sirkka Shear Zone.

The Riikonkoski Cu deposit (Puustinen 1985) is also located in the volcano-sedimentary environment, slightly to the south of the Sirkka Shear Zone. Graphite-rich black schist, sericite schist and albitite host the predominantly brecciated mineralisation. The estimated resources are 2.5 Mt with an average grade of 0.68 % Cu.

Numerous gold occurrences are located within the various hydrothermally altered albite-carbonate rocks throughout the Central Lapland Greenstone Belt. These mineralisations appear to be epigenetic and are commonly hosted by breccias and quartz vein networks. The notable occurrences along the central part of the Sirkka Shear Zone include Levijärvi, Loukinen, Soretialehto, Soretiavuoma, Hirvilavanmaa and Kutuvuoma (Härkönen & Keinänen 1989, Ward et al. 1989, Keinänen & Holma 2001, Sorjonen-Ward et al. 2001, Holma et al. 2003, Eilu et al. 2005). A monograph on the Kittilä Greenstone Belt (Ojala, ed., in press) is under preparation at the moment. It contains 13 articles dealing with the general geology, structure and prospectivity of the region and descriptions of several individual deposits.

The largest of the gold deposits is Suurikuusikko to the north of the Sirkka Shear Zone, along the so-called Kiistala Shear Zone (Härkönen & Keinänen 1989, Nurmi et al. 1991, Lehtonen et al. 1998, Hölttä & Karhu 2001, Patison & Oliver 2001, Eilu et al. 2005). It is associated with a tectonic breccia and located in the contact zone between mafic volcanic rocks and graphite-rich schists. The breccia is strongly silicified with fragments of albite rock and schists. Gold is mainly included within arsenopyrite and also within pyrite, and therefore specific methods have been tested for the recovery of gold (see Härkönen et al. 1999a, Härkönen et al. 1999b, Kojonen et al. 1999a). Using use a cut-off of 2 g/t Au and parameters from a variogarphy study show that in the central part of the Suurikuusikko deposit the measured resources are 2.5 Mt at 6.2 g/t Au, the indicated resources 9.3 Mt at 5.1 g/t Au and the inferred resources 12.5 Mt at 4.2 g/t Au (Riddarhyttan Resources AB 2005).

A significant amount of gold has also been discovered at Kuotko to the north of Suurikuusikko, in connection with the so-called Kuotko Shear Zone. Pyroclastic tholeiitic metabasalts form the major host rock and felsic dikes host the ore (Härkönen & Keinänen 1989, Eilu et al. 2005).

The Pahtavaara Au deposit in Sodankylä, in the eastern part of the Kittilä Au-Cu Zone, is situated within the extensive Sattasvaara Komatiite Complex (Korkiakoski et al. 1989, Ward et al. 1989, Korkiakoski 1992, Korkiakoski & Kilpelä 1997, Eilu et al. 2005). The metamorphosed komatiites at Pahtavaara have been converted into amphibole-chlorite rocks, biotite schists or amphibole rocks with quartz-barite veins and pods. In the biotite schists, gold is closely associated with magnetite and talc-carbonate veins. In amphibole rocks, gold is coarse-grained and dominantly occurs in a native form towards the margins of the quartz-barite veins. The deposit was mined between 1995 and 2000 and some 1.92 Mt gold ore was recovered with an average grade of some 2.14 g/t. Mining started up again in 2003 and within two years 0.43 Mt of gold ore has been extracted.

A low-grade gold mineralisation of another, paleoplacer type has been located in the conglomerates of the Kumpu Formation, at Kaarestunturi in Sodankylä and at Kumpututunturi in Kittilä. The Kumpu quartzite formation discordantly overly the greenstone sequences, thus representing the uppermost unit of the Central Lapland Greenstone Belt (Härkönen 1984, Härkönen 1986, Härkönen & Keinänen 1989).

The Koitelainen PGE+Cr+V-Fe field (49) occupies 2440 or so Ma mafic layered intrusion, which is a flat, oval brachyanticline structure, some 26 x 29 km in size and initially about 3 km in thickness, intruded through the Archaean basement (Mutanen 1997, 1996, 1989, GTK 2005) in the central part of the Central Lapland Area (block no. 4 in Fig.1, see also Fig. 16). The Archaean gneisses (Kröner et al. 1981, Mutanen & Huhma 2001) form two domes in the area. The Koitelainen intrusion shows all the standard types of igneous layering and hosts deposits of chromite, vanadium, titanium, platinum-group elements and gold. Chromitite layers mostly occur in the uppermost layers (Upper Chromitite), but also near the basement of the intrusion (Lower Chromitite). The Upper Chromitite has a varying thickness of 0.8 – 2.2 metres and extends along the strike length up to 60 km. A vanadiferous magnetite gabbro is also located in the uppermost part of the intrusion. Based on geological analogies and on a very sparse drilling density, the potential geological *in situ* resources of the Upper Chromitite of the entire intrusion might be at least several tens of million tonnes of chromium ore, averaging 21 % Cr_2O_3, 0.4 % V and 1 g/t PGE. The Os and Nd isotopic systematics of the intrusion have been studied by Hanski et al. (2001b).

The Porkonen-Pahtavaara Fe-Mn zone (50) in the western part of the Central Lapland Area (block no. 4) is a Proterozoic banded iron formation (BIF) zone. It belongs to the Central Lapland Greenstone Belt and consists of volcanic rocks with closely associated pyroclastic and chemical sediments, and associated manganiferous iron formations, notably at

the N-S trending row of hills of Porkonen, Pahtavaara, Silmänpaistama, Kuoreslaki and Haurespää. The iron and manganese of the iron formations, precipitated under oxide, carbonate or sulphide facies, derive from submarine volcanic emanations. Typically, the oxide facies is at the bottom of the sequence, with carbonate-silicate facies above it and the sulphide facies uppermost. The iron formations underwent low-grade metamorphism, as indicated by the prominence of typical iron sheet silicates in the mineral assemblages alongside magnetite and Fe-Mn-carbonates (Paakkola 1971, Gehör 1994a, Gehör 1994b).

The jaspilitic Fe and Mn deposits of the Porkonen-Pahtavaara zone have been known since 19th century (Thoreld 1866, Witt 1909, Berg 1916, Hackman 1927, Kaitaro 1949, Hytönen et al. 1966). Their jasper has also been used as a decorative stone (Kinnunen 1982).

The Kesänkitunturi U zone (51) in the western part of the Kittilä area includes two types of uranium mineralisation – the proper Kesänkitunturi type, and the uranium mineralisations encountered in connection with the Cu-Au deposits of the Kittilä zone, especially at Pahtavuoma (metallogenic zone no. 48).

The Kesänkitunturi sandstone-type deposit is located in a Paleoproterozoic orthoquartzite – sericite quartzite sequence. Here the Kumpu quartzites discordantly overlie deformed Kittilä greenstones. The geological *in situ* resources of Kesänkitunturi could be up to 950 t U, with an average grade of 0.06 % U. The only uranium-bearing mineral is uraninite (IUREP 1982). Because the deposit is situated within a natural reserve area, it cannot be exploited under any circumstances.

The Pahtavuoma uranium vein deposit consists of three ore bodies in the southern part of the greenstone-associated graphitic schists. Differing from the sulphide-bearing deposit, which is located at the contact between the schists and greenstones, the uranium ore bodies are found within separate schist horizons. Almost vertical uraninite-bearing postorogenic veins vary from some centimetres to several metres. The geological *in situ* uranium resources show 500 t U, with an average grade 0.19 % U. Similar types of veins constitute the Laavivuoma occurrence west of Pahtavuoma (Inkinen 1979, IUREP 1982, Korvuo 1997).

The Rautuvaara Fe-Cu-Au zone (52) comprises a large number of skarn-like iron deposits and occurrences including the Rautuvaara and Hannukainen mines (Mining Magazine 1982) in the western Finnish Lapland, in the westernmost branch of the Central Lapland Greenstone Belt (unit no. 4, Fig. 1), about 100 km north of the Arctic Circle (Hiltunen & Tontti 1976, Juopperi & Vornanen 1977, Mäkelä 1977, Hiltunen 1982, Lehtonen et al. 1985, Lehtonen 1988, Lehtonen et al. 1998, Väänänen & Lehtonen 2001). Genetically, most of the deposits of the zone seem to belong to the group of Fe-(Cu-Au) skarns, although recently these deposits have been included in the Fe-Ox-Cu-Au type (Eilu & Niiranen 2003, Niiranen et al. 2005b). Some of the deposits, e.g. Juvakaisenmaa, have been known, at least, since the early 17th century, as are the numerous marble deposits of the area. Besides the skarn-type deposits, there are also banded iron formations, e.g. Ristimella, and a peculiar hematite-baryte-mica schist at Taporova (Pertsev et al. 1988).

The iron deposits at Kolari, variably enriched in gold and copper, are located at the contact zone between supracrustal rocks of the Palaeoproterozoic Central Lapland Complex and a synorogenic monzonitic pluton. All ore bodies are apparently stratiform lenses hosted by the country rocks of the pluton (quartzite, quartz-feldspar schist, calcitic marble and amphibolite), and seem to have a structural control. At Hannukainen the hosting supracrustal sequence is 70 – 140 metres thick and dips at 15° to the W, while at Rautuvaara the dip is 80° SE. Alteration and gangue are characterised by diopside-hornblende exoskarns. Minor endoskarns locally hosting low-grade sulphide mineralisation are known in the (monzo)dioritic marginal unit of the pluton (Hiltunen 1982).

The principal ore mineral in the deposits is magnetite, which amounts to about 95 % of the ore minerals. The sulphur content in the ore is 1 – 5 %. It mainly occurs in pyrrhotite, although small amounts of chalcopyrite and pyrite are also present. Several ore bodies at Hannukainen (e.g. Laurinoja and Kuervitikko) and one orebody at Rautuvaara contain Au-bearing chalcopyrite and native gold in "ore-grade amounts" (0.3 – 0.7 % Cu and 0.5 – 3 g/t Au; Niiranen et al. 2005b).

The first indications of the presence of an iron deposit at Rautuvaara were obtained in 1956 in a high-altitude airborne magnetic survey. Rautuvaara was discovered in 1957 and the Hannukainen deposit, about 10 km NNE of Rautuvaara, in 1974. Rautuvaara was exploited by open pit and underground mining between 1962 and 1988, and produced 11.42 Mt of ore with a grade of 46.78 % Fe and 0.32 % Cu. Hannukainen was discovered by a low-altitude airborne magnetic survey, which indicated four orebodies. Mining has only been conducted in the Laurinoja orebody and only by open-pit methods. Production took place between 1978 and 1990, and 4.56 Mt of ore was mined with grades of some 43 % Fe, 0.88 % Cu and 0.95 g/t Au. Probable reserves at depth are several tens of Mt.

The Pyhäjärvi V-Fe-Ti zone (53) is a rather poorly

known, roughly N-S oriented, zone of amphibolite with hornblendite, mica gneiss, quartzite, gneissic granite and granite. Magnetite-ilmenite occurrences of unknown size and grade (massive veins and disseminations) occur in the sill-like amphibolites. There are no publications on the zone; the information given here is based on oral communication and internal reports of the former Otanmäki Oy, today Rautaruukki Oy.

The Pulju Ni zone (54) is one of the high nickel potential zones in Lapland. It is a distinct narrow zone about 100 km long and 1 – 2 km wide, located in the northern corner of the Central Lapland Area (unit no. 4, Fig. 1), and is associated with a prominent geophysical aeromagnetic high. The zone is almost N-S trending in its northern parts, but curves toward the southwest and branches in its southern part. It contains tens of small and low-grade nickel occurrences of komatiite type (Puustinen et al. 1995, cf. Fig. 7). The largest occurrences are Hotinvaara (1.3 Mt at 0.43 % Ni and less than 0.1 % Cu) and Iso-Siettelöjoki (0.5 Mt at 0.29 % Ni and 0.01 % Cu), with more potential occurrences around Kietsimä in the north (Puustinen et al. 1995). According to Papunen (1993, 1998), the Pulju zone is a rift-related volcano-sedimentary sequence that contains lithologies typical of komatiitic greenstone belts, and both metasomatic and magmatic sulfides have been encountered there.

The Nirroselkä Ni zone (55) trends NW-SE and can be traced for some 70 km at the northern boundary of the Central Lapland Area (unit no. 4, Fig. 1), along the marginal zone of the Lapland Granulite Belt (unit no. 2). The zone is composed of an amphibolitic sequence with ultramafic komatiitic rocks, mica schists, quartzites and iron formations. All of the small nickel occurrences detected so far have approximately the same size and nickel grade (0.01 Mt at 0.15 % Ni and 0.01 % Cu). The Nirroselkä and Pulju zones share many common features and the almost coalesce at their northern ends (Puustinen et al. 1995).

The Lemmenjoki placer Au area (56) is located in the basin of the river Lemmenjoki and its tributaries, in the western parts of the Lapland Granulite Belt (unit no. 2, Fig. 1). Although the first hints of the presence of gold in the overburden here date already from the year 1901, it was the Ranttila brothers who discovered actual gold in September 1945 (Stigzelius 1954, Johansson et al. 2002). Since then, numerous professional and amateur prospectors have made their trails there. Gold nuggets have also become objects of collection and as such, subject to studies for their genuineness (Kinnunen 1996, Kinnunen et al. 1997). Some platinum nuggets have also been found sporadically in gold panning (Vuorelainen & Törnroos 1986a, Vuorelainen & Törnroos 1986b, Törnroos & Vuorelainen 1987, Törnroos et al. 1998).

The Ivalojoki placer Au area (57) in the basin of the river Ivalojoki is the oldest gold field known in Finland (Stigzelius 1954, Saarnisto & Tamminen 1987, Saarnisto et al. 1991, Johansson et al. 2000). It was discovered during a government expedition in September 1868 (Fircks 1906, Sundell 1936). This started a gold rush in 1870. According to the official records of the Mining Board, some 470 kg gold was recovered between 1870 and 1916. However, the actual amount could be some 1 500 kg up to the present day. Professional and amateur prospectors also favour this area even today, and the issue of collecting nuggets and their genuineness and properties is of consequence (Kinnunen 1996, Kinnunen et al. 1997, Kinnunen 2003). The bedrock source for placer gold in Pleistocene till and gravel is unknown. It has been assumed that gold is derived ultimately from the local granulite bedrock, in which mildly auriferous retrogressive shear zones have been known (Ward et al. 1989).

The southernmost end of the Ivalojoki area, the Tankavaara field, is situated near the southern border of the Lapland Granulite Belt (Johansson et al. 2000). Also here, professional and amateur prospectors have favoured the area since 1934.

The Ruossakero Ni zone (58) in the Enontekiö area in northwestern Lapland (unit no. 3 in Fig. 1, Puustinen et al. 1995) is associated with an Archaean greenstone belt composed of mafic volcanic rocks and volcaniclastic sediments, surrounded by Archaean granodioritic basement gneisses. The two largest of the nickel deposits, Ruossakero (5.5 Mt at 0.53 % Ni and 0.02 % Cu) and Sarvisoaivi (0.7 Mt at 0.40 % Ni and 0.05 % Cu), are associated with serpentinized peridotite and dunite bodies of komatiitic composition. The zone extends to the south in Sweden, where two nickel occurrences of a similar type, Kurkovare and Keukiskero, have been located (Frietsch et al. 1987). Thus the total length of the zone could be some 75 km. Additionally, the large Tshohkkoaivi differentiated gabbro-peridotite body, occurring close to Ruossakero, could be related to this Ni zone.

The Vätsäri Fe zone (59) counts four small occurrences of banded iron formations (Lehto & Niiniskorpi 1977). They are connected to skarn horizons of amphibolite units surrounded by the granite gneiss basement rocks in the Inari area (unit no. 1 in Fig. 1) of northeastern Lapland. It has been suggested that the zone could be a part of the Pechenga nickel-bearing zone.

To the west of the Vätsäri zone, banded iron formations are also encountered at Supru and Koppasaari.

SIGNIFICANT DEPOSITS OUTSIDE THE DEFINED METALLOGENIC ZONES

In addition to the metallogenic zones and provinces described above, there are several mineral deposits that could not be connected to any metallogenic groups or have their relatives far away. Some of them have been even important mining targets. The most important of these single deposits (Fig. 19) are described in this chapter.

The Korsnäs Pb-REE deposit in the westernmost Finland, inside the Oravainen Ni zone is a unique mineralisation hosted by a large calcite-diopside-baryte-allanite vein that cuts the local Svecofennian gneisses (Isokangas 1978). It was mined between 1958 and 1972 and yielded some 0.87 Mt of ore averaging 3.6 % Pb. Allanite and a couple of other REE minerals (Papunen & Lindsjö 1972) made the deposit prospective for rare-earth metals, too. During a pilot production of a REE concentrate the ore proved to contain 0.83 % Ln_2O_3.

The Hammaslahti Zn-Cu deposit (Hyvärinen et al. 1977, Gaál 1977, Karppanen 1986, Loukola-Ruskeeniemi et al. 1991) is halfaway between the Outokumpu deposit and the occurrences of the Kyykkä-Hokka zone in eastern Finland, in the central part of the Höytiäinen Belt (unit 17 in Fig. 1), on the western limb of a local anticlinorium, at the boundary between the arkositic and phyllitic members of the turbidites of the belt. The deposit consists of several flat, "fish-shaped" ore bodies overlapping one another in *en échelon* manner. The ore is chalcopyrite-pyrrhotite dissemination and breccia with sphalerite prevailing in some parts of the ore bodies, hosted by local turbidites, hydrothermally altered but otherwise just identical to the other country rocks in the area. The Hammaslahti deposit was mined from 1973 to 1986 and produced 5.59 Mt of ore at 1.11 % Cu and some 1 % Zn.

The most striking feature of Hammaslahti is that it is so conventional. It was studied from the points of view of structure (Gaál 1977, Ward 1988, Loukola-Ruskeeniemi et al. 1991, 1992), geochemistry (Hyvärinen et al. 1977) and particularly the geochemistry of the adjacent black schists (Loukola-Ruskeeniemi et al. 1991), geophysics (Airo & Karell 2001) and isotope geology (Vaasjoki 1981, Huhma 1986), but no unique characteristics of the environment – like e.g. in the Outokumpu region – were found. Genetically this sediment-hosted disseminated ore deposit was compared even with massive volcanogenic sulphide deposits (Loukola-Ruskeeniemi et al. 1992). However, most authors point out that similar conditions prevail over large territories in eastern Finland and even elsewhere in the Fennoscandian Shield, and it is unclear why no other mineralisations similar to Hammaslahti have so far been discovered here.

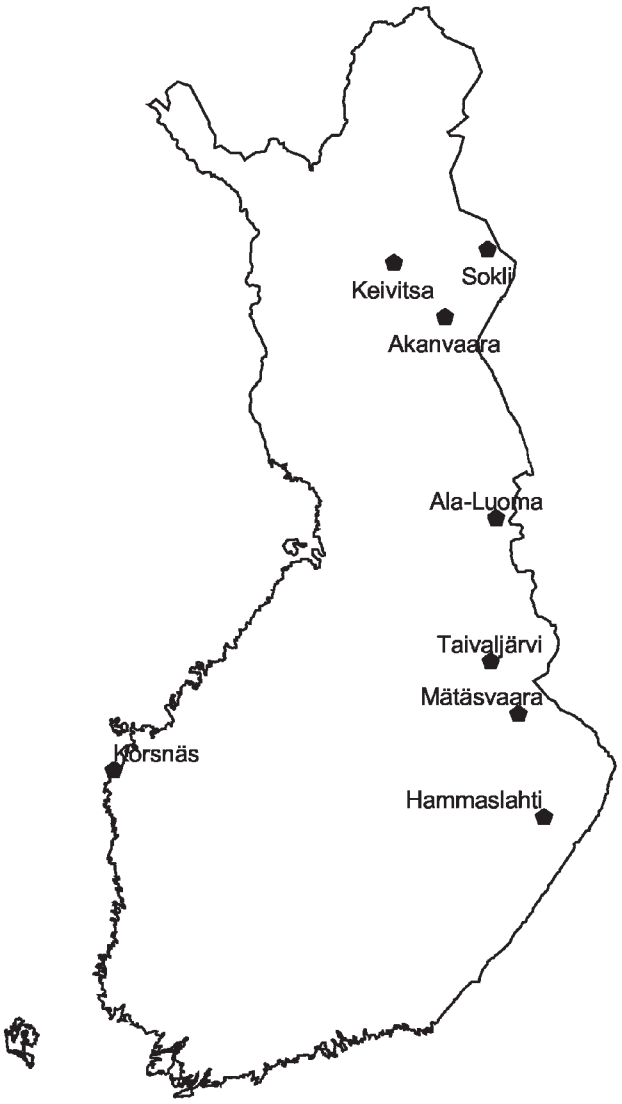

Fig. 19. The major mineral deposits not belonging to the metallogenic zones.

The Mätäsvaara Mo deposit in the Archaean terrain of eastern Finland (northeast from the Koli-Kaltimo uranium zone) is the only molybdenum deposit in Finland that has been exploited (1.15 Mt at 0.14 % Mo from 1940 to 1947. The deposit has been described by Kranck (1945), Isokangas (1978) and Mikkola (1980). It is a stockwork of quartz veins and/or silificied shear zones of Neoarchaean age (Stein et al. 1995) hosted by Archaean microcline granite and tonalite of the Eastern Finland Basement Complex (unit no. 11, Fig. 1).

A few similar molybdenum deposits have been discovered in the Archaean of eastern Finland, e.g. Jerusalemi in the easternmost corner of the country,

and Aittojärvi in the Kuhmo Greenstone Belt (unit no. 12, Fig. 1; Taipale 1983a, Kurki 1989). However, these occurrences are too scattered to be connected to any distinct metallogenic zones.

The Taivaljärvi and Ala-Luoma Ag-Zn deposits (Kopperoinen & Tuokko 1988, Papunen et al. 1989,Tuokko 1989, Diez & Engel 1989, Engel & Diez 1989) are situated in the volcanic series of the Archaean Tipasjärvi and Suomussalmi Greenstone Belts, respectively, in the Kuhmo Belt (unit no. 12, Fig. 1). They are ascribed to the Moukkori-Lokkiluoto gold zone by some authors (e.g. Esipchuk et al. 1999), but actually they are chemically different and genetically interpreted as syngenetic (volcanic-exhalative; Kopperoinen & Tuokko 1988). Together with a few minor similar occurrences they might constitute an individual metallogenic zone spatially overlapping with the Moukkori-Lokkiluoto gold zone (metallogenic zone 31 in Fig. 5).

The Keivitsa Ni-Cu-PGE-Au deposit consists of the western main Keivitsa and the nearby estern Satovaara intrusions. These mafic-ultramafic bodies are situated in the northeastern part of a faulted brachysynclinal structure (Hanski et al. 1997, Mutanen 1997, Mutanen & Huhma 2001, Gervilla et al. 2005, Lamberg et al. 2005, Mutanen 2005). Both Keivitsa and Satovaara might represent two blocks of a single intrusion, separated by a zone of northeasterly faults (Satojärvi fault zone). The Satovaara block has been displaced downwards, perhaps 2 – 3 km, in relation to Keivitsa.

The igneous layering in the lower part is roughly conformable to the base contact, but upwards the dip of the layering becomes gentler and finally almost horizontal. The intrusion is formally divided into four zones: (1) The basal marginal chill zone, (2) the ultramafic zone, (3) the gabbro zone and (4) the granophyre. The intrusion chamber was filled as a single cast. No evidence of repetitive entries of magma has been found in the Keivitsa intrusion (Mutanen 1997).

Keivitsa is one of the latest mineral discoveries in Finland, hosting a probable reserve of 120 Mt of ore within an indicated resource of 150 Mt and an inferred resource of 315 Mt. As such, it constitutes one of the major undeveloped sulphide nickel deposits (Walker 2003, Scandinavian Gold Ltd. 2005). The disseminated Ni-Cu-PGE-Au (0.25 % Ni, 0.39 % Cu, 0.6 g/t PGE+Au) mineralisation (Alapieti & Lahtinen 2002, Gervilla & Kojonen 2002, Gervilla et al. 2003) is situated in the northeastern part of the intrusive body and totals about 90 Mt. In the high-grade zone PGE appear to be concentrated in flat bodies, layers or flakes. The gently dipping flakes have Pt + Pd + Au concentrations at or above 1 g/t. This gently dipping structure is cross-cut by a tentatively 50 m wide, vertical and roughly N-S trending zone, where high grade bodies have been intersected.

The Akanvaara Cr-V-Ti-PGE deposit has an analogous geological setting and the internal structure to those of Koitelainen. It is hosted by a mafic layered intrusion, with a surface area of some 50 km^2. Structurally it is a block-faulted monocline with a general dip towards the southeast. The immediate floor consists of acid volcanic rocks, and the lowermost exposed roof rocks are felsic volcanic rocks. The intrusion hosts deposits of Cr, V, Ti, PGE and Au. At least 23 chromitite layers and numerous chromitite bands of uncertain continuity have been located. The thickness of these layers and sub-layers range from a few centimetres up to 3 metres. Chromitites with proven metallurgical properties and substantial amounts of vanadium, also contain a range of complex PGM associations (Mutanen 1996, Mutanen 1997, Alapieti & Lahtinen 2002, Gornostayev & Mutanen 2003, Mutanen 2005). U-Pb analyses of zircons from the Akanvaara gabbroic rocks give an age of 2436 Ma, while the granophyre cap has an age of 2420 Ma (Mutanen & Huhma 2001). The Os and Nd isotopic systematics of the intrusion point to an existence of coeval, crustally contaminated komatiitic volcanism (Hanski et al. 2001b).

The Sokli Fe-Nb deposit is the westernmost carbonatite complex within the igneous alkaline rock province of the Kola Peninsula (Vartiainen 1980). It was emplaced about 370 Ma ago (Kramm et al. 1993). The main mineral deposits in the complex are the regolith phosphate deposits (Vartiainen 1989), but it has also a considerable potential of iron ore. In addition, pyrochlore mineralisations have been located as fragmentally embedded in magmatic carbonatites forming discontinuous mineralised zones. The niobium mineralisations are of low grade, 0.3 – 0.5 % Nb_2O_5, the total tonnage, however, may reach up to hundreds of millions of tonnes (Lee et al. 1999, Vartiainen 2001, Wall et al. 2001).

Acknowledgements

We are grateful to all colleagues who contributed in preparing this paper and the Metallogenic Map of Finland by providing us with their original illustrations, supplying unpublished information and by discussing, advising and correcting our statements, in alphabetical order, Olli Äikäs, Tuomo Alapieti, Reijo

Alviola, Pasi Eilu, Elias Ekdahl, Markku Iljina, Osmo Inkinen, Olli-Pekka Isomäki, Niilo Kärkkäinen, Tapio Koistinen, Asko Kontinen, Jukka Kousa, Jouni Luukas, Erkki Luukkonen, Hannu Makkonen, Jarmo Nikander, Heikki Pankka, Lauri Pekkarinen, Petri Peltonen, Tapio Ruotoistenmäki, Hannu Seppänen, Jukka Väänänen, the late Matti Vaasjoki, Erkki Vanhanen, Kaj Västi and Jouni Vuollo. Special thanks go to referees Pasi Eilu and Ilmari Haapala.

REFERENCES

Aho, A. 1977. Manganoan ilmenite from the Säviä ore deposit, Pielavesi, Central Finland. Bulletin of the Geological Society of Finland 49 (1), 25–31.

Äikäs, O. 1980. Uraniferous phosphorite and apatite-bearing gneisses in the Proterozoic layers in Finland. In: Ferguson, J. ... [et al.] (editors) Uranium in the Pine Creek Geosyncline: Proceedings of the International Uranium Symposium on the Pine Creek Geosyncline, Sydney 4–8 June 1979. International Atomic Energy Agency (IAEA), Proceedings series STI/PUB/555, 675–681.

Äikäs, O. 1989. Phosphate resources in early Proterozoic supracrustal rocks, Finland, with reference to the Baltic Shield. In: Notholt, A. J. G., Sheldon, R. P. & Davidson, D. F. (editors) Phosphate deposits of the world, Vol. 2: Phosphate rock resources. Cambridge: Cambridge University Press, 429–436.

Äikäs, O. & Sarikkola, R. 1987. Uranium in lower Proterozoic conglomerates of the Koli area, eastern Finland. In: Uranium deposits in Proterozoic quartz-pebble conglomerates: Report of the working group on uranium geology organized by the International Atomic Energy Agency. Vienna: International Atomic Energy Agency (IAEA), 189–234.

Airo, M.-L. & Karell, F. 2001. Interpretation of airborne magnetic and gamma-ray spectrometric data related to the Hammaslahti Cu-Zn-Au deposit in eastern Finland. In: Autio, S. (editor) Geological Survey of Finland, Current Research 1999–2000. Geological Survey of Finland. Special Paper 31, 97–103.

Alapieti, T. T. (editor) 1989. The 5th International Platinum Symposium. Guide to the post-symposium field trip, August 4–11, 1989; Part I: The Tornio-Näränkävaara Intrusion Belt, Part II – Kuhmo-Koli-Enonkoski sites. Geological Survey of Finland, Guide 29. 263 p.

Alapieti, T. 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.

Alapieti, T. T., Filén, B. A., Lahtinen, J. J., Lavrov, M. M., Smolkin, V. F. & Voitsekhovsky, S. N. 1990. Early Proterozoic layered intrusions in the northeastern part of the Fennoscandian Shield. In: Stumpfl, E. F. & Papunen, H. (editors) Proceedings of the 5th International Platinum Symposium, Helsinki 1989. Mineralogy and Petrology 42 (1–4), 1–22.

Alapieti, T., Hugg, R. & Piirainen, T. 1979a. Structure, mineralogy and chemistry of the Syöte section in the Early Proterozoic Koillismaa layered intrusion, northeastern Finland. Geological Survey of Finland, Bulletin 299. 43 p.

Alapieti, T., Hugg, R., Piirainen, T. & Ruotsalainen, A. 1979b. The ultramafic and mafic intrusion at Näränkävaara, northeastern Finland. Tiivistelmä: Näränkävaaran ultramafinen-mafinen kerrosintruusio Koillismaalla. Geological Survey of Finland, Report of Investigation 35. 31 p.

Alapieti, T. T. & Kärki, A. J. (editors) 2005. Field trip guidebook: The early Palaeoproterozoic (2.5–2.4) Tornio-Näränkävaara layered intrusion belt and related chrome and platinum-group element mineralization, northern Finland. Geological Survey of Finland, Guide 51a. 110 p.

Alapieti, T. T., Kujanpää, J., Lahtinen, J. J. & Papunen, H. 1989a. The Kemi chromitite deposit, northern Finland. Economic Geology 84 (5), 1057–1077.

Alapieti, T. T. & Lahtinen, J. J. 1986. Stratigraphy, petrology and platinum-group element mineralization of the early Proterozoic Penikat layered intrusion, northern Finland. Economic Geology 81 (5), 1126–1136.

Alapieti, T. T. & Lahtinen, J. J. 2002. Platinum-group element mineralization in layered intrusions of northern Finland and the Kola Peninsula, Russia. In: Cabri, L. J. (editor) The geology, geochemistry, mineralogy and mineral beneficiation of platinum-group elements. CIM, Special volume 54, 507–546.

Alapieti, T. T., Lahtinen, J. J., Huhma, H., Hänninen, E., Piirainen, T. & Sivonen, S. J. 1989b. Platinum-group element-bearing Cu-Ni sulphide mineralization in the marginal series of the early Proterozoic Suhanko-Konttijärvi layered intrusion, northern Finland. In: Prendergast, M. D. & Jones, M. J. (editors) Magmatic sulphides: The Zimbabwe volume. London: The Institution of Mining and Metallurgy, 177–187.

Alapieti, T. T. & Piirainen, T. 1984. Cu-Ni-PGE mineralization in the marginal series of the Early Proterozoic Koillismaa layered igneous complex, northeast Finland. In: Buchanan, D. L. & Jones, M. J. (editors) Sulphide deposits in mafic and ultramafic rocks: Proceedings of IGCP Projects 161 and 91, 3rd Nickel Sulphide Field Conference, Perth, Western Australia, May 23–25, 1982. London: The Institution of Mining and Metallurgy, 123–131.

Alviola, R. 1989. The granitic pegmatites of the Seinäjoki and Haapaluoma groups. In: Lahti, S. I. (editor) Symposium Precambrian granitoids: Petrogenesis, geochemistry and metallogeny, August 14–17, 1989, Helsinki, Finland, Excursion C 1: Lateorogenic and synorogenic Svecofennian granitoids and associated pegmatites in southern Finland. Geological Survey of Finland, Guide 26, 41–48.

Alviola, R., Mänttäri, I., Mäkitie, H., & Vaasjoki, M. 2001. Svecofennian rare-element granitic pegmatites in the Ostrobothnia region, western Finland: their metamorphic environment and time of intrusion. In: Mäkitie, H. (editor) Svecofennian granitic pegmatites (1.86–1.79 Ga) and quartz monzonite (1.87 Ga), and their metamorphic environment in the Seinäjoki region, western Finland. Geological Survey of Finland, Special Paper 30, 9–29.

Andersen, J. C. Ø., Thalhammer, O. A. R. & Schoenberg, R. 1999. The origin of the Kilvenjärvi offset PGE deposit of the Portimo layered igneous complex, northern Finland. In: Stanley, C. J. … [et al.] (editors) Mineral deposits – Processes to processing: Proceedings of the 5th Biennial SGA Meeting and the 10th Quadrennial IAGOD Symposium, London, United Kingdom, 22–25 August 1999, Vol. 1. Rotterdam: A. A. Balkema, 697–700.

Anttonen, R., Korkalo, T. & Oravainen, H. 1989. Lapin kultaa Saattoporan kaivoksesta. Summary: Gold from Lapland – Outokumpu Oy's Saattopora mine. Vuoriteollisuus – Bergshanteringen 47, 104–108.

Appelqvist, H. 1993. Ore mineralogy in the Proterozoic Kalliosalo

gold occurrence, western Finland, with preliminary data on an unspecified mineral, Ag3Au3Sb10S10. In: Autio, S. (editor) Geological Survey of Finland, Current Research 1991–1992. Geological Survey of Finland, Special Paper 18, 37–44.

Arkimaa, H. 1991. Study of airborne gamma ray spectrometric data in prediction of uraniferous mineralizations in the Kuusamo area, northeastern Finland. In: New developments in uranium exploration, resources, production and demand: Proceedings of a Technical Committee Meeting organized by the International Atomic Energy Agency (IAEA) and the Nuclear Energy Agency (NEA) of the Organisation for Economic Co-operation and Development (OECD), Vienna, 26–29 August 1991. Vienna: International Atomic Energy Agency (IAEA), 29–33.

Arkimaa, H. 1997. The fingerprints of known gold occurrences in the Kuusamo Schist Belt as shown by airborne gamma-ray spectrometric data. In: Autio, S. (editor) Geological Survey of Finland, Current Research 1995–1996. Geological Survey of Finland, Special Paper 23, 25–28.

Arkimaa, H., Lindqvist, E. & Kuosmanen, V. 1985. Prediction of areas potential for Cu-Zn sulphide ore by means of low-altitude aerogeophysical data and statistical methods. Geoexploration 23 (3), 416.

Aurola, E. (editor) 1954. The mines and quarries of Finland. Geological Survey of Finland, Geotechnical Publications 55. 123 p.

Aurola, E. & Vähätalo, V. 1939. The pyrite deposit of Hevoskumpu in Tuupovaara. Bulletin of the Geological Society of Finland 13, 87–95; also Geological Survey of Finland, Bulletin 125, 87–95.

Barkov, A. Y., Halkoaho, T. A. A., Roberts, A. C., Criddle, A. J., Martin, R. F. & Papunen, H. 1999. New Pd-Pb and Pb-V oxides from a bonanza-type PGE-rich, nearly BMS-free deposit in the Penikat layered complex, Finland. The Canadian Mineralogist 37 (6), 1507–1524.

Barkov, A. Y., Martin, R. F., Halkoaho, T. A. A. & Criddle, A. J. 2002. Laflammeite, Pd3Pb2S2, a new platinum-group mineral species from the Penikat layered complex, Finland. The Canadian Mineralogist 40 (2), 671–678.

Barkov, A. Y., Martin, R. F., Halkoaho, T. A. A. & Poirier, G. 2000. The mechanism of charge compensation in Cu-Fe-PGE thiospinels from the Penikat layered intrusion, Finland. American Mineralogist 85 (5–6), 694–697.

Berg, G. 1916. Das Magneteisenerzvorkommen von Kittilä in Finnisch-Lappmarken. Glückauf, Berg- und Huttenmänn Zeitung 3, 45–50.

Bigham, J. M., Carlson, L. & Murad, E. 1994. Schwertmannite, a new iron oxyhydroxysulphate from Pyhäsalmi, Finland, and other localities. Mineralogical Magazine 58 (4), 641–648.

Blomqvist, R., Ruskeeniemi, T., Kaija, J., Ahonen, L., Paananen, M., Smellie, J., Grundfelt, B., Pedersen, K., Bruno, J., Pérez del Villar, L., Cera, E., Rasilainen, K., Pitkänen, P., Suksi, J., Casanova, J., Read, D. & Frape, S. 2000. The Palmottu natural analogue project, Phase II: Transport of radionuclides in a natural flow system at Palmottu, Final report. European Commission Nuclear Science and Technology, Series EUR 19611 EN. 174 p.

Borchert von, H. 1955. Kritische Anmerkungen zu zwei neuen Arbeiten über Outokumpu. Chemie der Erde XVII, 1–5.

Borgström, L. H. 1901. Mineralogiska notiser, 1–4. 1. Baryt från Pitkäranta. 2. Mineral från Kintsinniemi dolomitbrott. 3. Uwarovit från Kuusjärvi. 4. Hackmanit, ett nytt mineral i sodalitgruppen. Geoleologiska Föreningens i Stockholm Förhandlingar 23, 557–567.

Borodaev, Y. S., Bortnikov, N. S., Mozgova, N. N., Ozerova, N. A., Oivanen, P. & Yletyinen, V. 1983. Associations of ore minerals in the deposits of the Seinäjoki district and the discussion concerning the ore formation. Bulletin of the Geological Society of Finland 55 (1), 3–23.

Borodaev, Y., Mozgova, N., Ozerova, N., Slusarev, V., Oivanen, P. & Yletyinen, V. 1985. Typomorphic mineral associations of antimony deposits with native antimony in the Baltic Shield. Geologicky Zborník, Geologica Carpathica 36 (3), 305–313.

Bremer, C. O. 1824. Anvisning på malm och bergarter uti Stor-Furstendömet Finland. Första delen. Åbo. 179 p.

Bremer, C. O. 1825. Anvisning på malm och bergarter uti Stor-Furstendömet Finland. Andra delen. Åbo. 263 p.

Caillère, S. & Tchimichkian, G. 1936. Sur l'examen microscopique des minerais d'Outokumpu (Finlande). Societe Savantes de Paris, 69e Congrès, Montpellier 1936, Section des sciences, Comptes Rendus, 139–142.

Chernet, T. & Kärkkäinen, N. 1995. Geology and mineralogy of the Koivusaarenneva ilmenite deposit, Kälviä, western Finland. In: Autio, S. (editor) Geological Survey of Finland, Current Research 1993–1994. Geological Survey of Finland. Special Paper 20, 17–22.

Clark, A. H. 1964a. The composition and conditions of deposition of arsenopyrite in the Ylöjärvi deposit. Geologi 16, 114–116.

Clark, A. H. 1964b. Pyrrhotite-sphalerite relationships in the Ylöjärvi deposit, southwestern Finland. A summary. Geologi 16, 145–150.

Clark, A. H. 1964c. Studies on the mineralogy and geochemistry of the Ylöjärvi copper deposit, southwestern Finland. University of Manchester, Manuscript.

Clark, A. H. 1965a. The composition and conditions of formation of arsenopyrite and löllingite in the Ylöjärvi copper-tungsten deposit, southwestern Finland. Geological Survey of Finland, Bulletin 217. 56 p.

Clark, A. H. 1965b. The mineralogy and geochemistry of the Ylöjärvi Cu-W deposit, southwestern Finland: Bismuth-bearing apatite. Bulletin of the Geological Society of Finland 34. 195–199; also Geological Survey of Finland, Bulletin 218, 195–199.

Clark, A. H. 1966. The mineralogy and geochemistry of the Ylöjärvi Cu-W deposit, southwestern Finland: Mackinawite-pyrrhotite troilite assemblages. Bulletin of the Geological Society of Finland 38, 331–342; also Geological Survey of Finland, Bulletin 222, 331–342.

Clark, A. H., & Clark, A. M. 1968. Electron microprobe analysis of mackinawite from the Ylöjärvi deposit, Finland. Neues Jahrbuch für Mineralogie, Monatsheft 1968 (8), 259–268.

Colley, H., & Westra, L. 1987. The volcano-tectonic setting and mineralization of the early Proterozoic Kemiö-Orijärvi-Lohja Belt, southwestern Finland. In: Pharaoh, T. C. ... [et al.] (editors) Geochemistry and mineralization of Proterozoic volcanic suites. Geological Society, Special Publication 33, 95–107.

Cox, D. P. & Singer, D. A. (editors) 1986. Mineral deposit models. U.S. Geological Survey, Bulletin B 1693. 379 p.

Davidson, C. F. 1960. Uranium deposits in Finland. Mining Magazine 103, 222–223.

Diez, G. J., & Engel, W. W. 1989. A review of the Ala-Luoma Ag-Zn deposit in the Suomussalmi Greenstone Belt, eastern Finland, related to an Archean rift model. In: The 5th meeting of the European Union of Geosciences, Strasbourg, March 20–23, 1989. Terra abstracts 1 (1), 126–127.

Disler, J. 1953. Die Kupferkieslagerstätte von Outokumpu, Finnland. Geological Survey of Finland, Bulletin 161. 108 p.

Dragon Mining NL 2004. Annual Report 2003. Perth, Australia. 46 p.

Dragon Mining NL 2005. Gelogical Survey of Finland, web pages: http://www.gtk.fi/explor/; Gold.

Eckstrand, O. R. (editor) 1984. Canadian mineral deposit types – A geological synopsis. Geological Survey of Canada, Economic Geology Report 36. 86 p.

Eilu, P. 1999. FINGOLD – A public database on gold deposits in Finland. Tiivistelmä: FINGOLD – Julkinen tietokanta Suomen kultaesiintymistä. Geological Survey of Finland, Report of

Investigation 146. 224 p. Also: Geological Survey of Finland, web pages: http://www.gtk.fi/explor/; Gold.

Eilu, P. 2000. FINZINC – A public database on zinc deposits in Finland. In: Weihed, P. & Martinsson, O. (editors) 2nd annual GEODE-Fennoscandian shield field workshop on Palaeoproterozoic and Archaean greenstone belts and VMS districts in the Fennoscandian Shield, 28 August to 1 September, 2000, Gällivare-Kiruna, Sweden: Abstract volume & field trip guidebook. Luleå University of Technology, Research Report 2000:6, 11–15. Also: Geological Survey of Finland, web pages: http://www.gtk.fi/explor/; Zinc.

Eilu, P., Papunen, H. & Reino, J. 1988. Pyhäsalmen malmin kullasta. Summary: Distribution of gold in the Pyhäsalmi ore deposit. Vuoriteollisuus – Bergshanteringen 46 (1), 20–24.

Eilu, P. & Niiranen, T. 2003. Onko Suomessa rautaoksidi-kuparikulta -assosiaation (FeOx-Cu-Au, IOCG) esiintymiä? Summary: Are there IOCG deposits in Finland? Geologi 55 (1), 4–11.

Eilu, P., Sorjonen-Ward, P., Nurmi, P. & Niiranen, T. 2003. A review of gold mineralization styles in Finland. In: Sundblad, K. & Cook, N. J. (editors) A group of papers devoted to the metallogeny of gold in the Fennoscandian Shield. Economic Geology 98 (7), 1329–1353.

Eilu, P., Pankka, H., Keinänen, V., Kortelainen, V., Niiranen, T. & Pulkkinen, E. 2005. Characteristics of gold mineralisation in the greenstone belts of northern Finland. Geological Survey of Finland, Special Paper (in press).

Ekberg, M. & Penttilä, V.-J. 1986. The Pyhäsalmi Cu-Zn-pyrite deposit. In: Gaál, G. (editor) Proterozoic mineral deposits in Central Finland. 7th IAGOD Symposium and Nordkalott Project Meeting (Luleå, 1986), Excursion Guide no 5. Geological Survey of Sweden (SGU), Ser. Ca 63, 20–25.

Ekdahl, E. 1993. Early Proterozoic Karelian and Svecofennian formations and the evolution of the Raahe-Ladoga Ore Zone, based on the Pielavesi area, Central Finland. Geological Survey of Finland, Bulletin 373. 137 p.

Ekdahl, E. & Philippov, N. (editors) 1999. Raahe-Ladoga Zone structure-lithology, metamorphism and metallogeny: A Finnish-Russian co-operation project 1996–1999, Map 3 – Metallogeny of the Raahe-Ladoga Zone 1:1 000 000. Espoo: Geological Survey of Finland.

Elo, S., 1997. Interpretations of the Gravity Anomaly Map of Finland. In: Pesonen, L. J. (editor) The lithosphere of Finland – A geophysical perspective. Geophysica, 33–19, 51–80.

Engel, W. W. & Diez, G.-J. 1989. A modified stratigraphy and tectono-magmatic model for the Suomussalmi Greenstone Belt, eastern Finland, based on the re-mapping of the Ala-Luoma area. Bulletin of the Geological Society of Finland 61 (2), 143–160.

Ervamaa, P. 1962. The Petolahti diabase and associated nickel-copper pyrrhotite ore, Finland. Geological Survey of Finland, Bulletin 199. 80 p.

Ervamaa, P. & Laajoki, K. 1977. Puolangan Väyrylänkylän prekambristen rautamuodostumien geologiasta. Abstract: On the geology of the Precambrian iron formations in Väyrylänkylä, Puolanka. Geological Survey of Finland, Report of Investigation 27. 66 p.

Esipchuk, K. Y., Kopperoinen, T., Monakhov, V. & Tuokko, I. 1999. Gold in greenstone structures of Ukraine and Finland. In: Cook, N. J. & Sundblad, K. (editors) Gold '99 Trondheim – Precambrian gold in the Fennoscandian and Ukrainian Shields and related areas. The Nordic mineral resources symposium, Trondheim, Norway, May 4–6, 1999, Abstract volume. Trondheim: Norges Geologiske Undersøkelse (NGU), 66–67.

Eskola, P. 1914. On the Petrology of the Orijärvi Region in southwestern Finland. Geological Survey of Finland, Bulletin 40. 277 p.

Eskola, P. 1933. On the Chrome Minerals of Outokumpu. Geological Survey of Finland, Bulletin 103, 26–44.

Eskola, P. 1935. Malminetsinnästä ja malmityypeistä. Summary: On ore prospecting and ore types. Terra 47, 129–146.

Fircks, C. 1906. On the occurrence of gold in Finnish Lapland. Geological Survey of Finland, Bulletin 17. 35 p.

Frietsch, R. 1988. Precambrian metallogeny of Finland, Norway and Sweden. In: Zachrisson, E. (editor) Proceedings of the 7th Quadrennial IAGOD Symposium, Luleå, Sweden, August 18–22, 1986. Stuttgart: E. Schweizerbart'sche Verlagsbuchhandlung, 11–22.

Frietsch, R., Lindahl, I., Puustinen, K., Sundberg, A. & Zachrisson E. 1987. Metallogenetic map, northern Fennoscandia 1 : 1 000 000. Helsinki: Geological Surveys of Finland, Norway and Sweden.

Frietsch, R., Lindahl, I., Puustinen, K., Tontti, M. & Zachrisson, E. 1986. Metallogenetic map of northern Fennoscandia. Terra cognita 6, p. 566.

Frietsch, R. & Papunen, H. 1986. Metallogenesis of the Bergslagen province and southwestern Finland. In: Lundström, I. & Papunen, H. (editors) Mineral deposits of southwestern Finland and the Bergslagen province, Sweden. 7th IAGOD Symposium and Nordkalott Project Meeting (Luleå, 1986), Excursion guide no 3. Geological Survey of Sweden (SGU), Ser. Ca 61, 11–16.

Frietsch, R., Papunen, H. & Vokes, F. M. 1979. The ore deposits in Finland, Norway, and Sweden – A review. Economic Geology 74 (5), 975–1001.

Gaál, G. 1972. Tectonic control of some Ni-Cu deposits in Finland. In: Gill, J. E. (editor) International Geological Congress, 24th session, Montreal 1972, Section 4 – Mineral deposits, 215–224.

Gaál, G. 1977. Structural features of Precambrian, stratabound sulphide-ore deposits in Finland. Geologiska Föreningens i Stockholm Förhandlingar 99 (2:569), 118–126.

Gaál, G. 1980. Geological setting and intrusion tectonics of the Kotalahti nickel-copper deposit, Finland. Bulletin of the Geological Society of Finland 52 (1), 101–128.

Gaál, G. 1985. Nickel metallogeny related to tectonics. In: Papunen, H. & Gorbunov, G. I. (editors) Nickel-copper deposits of the Baltic Shield and Scandinavian Caledonides. Geological Survey of Finland, Bulletin 333, 143–155.

Gaál, G. (editor) 1988. Exploration target selection by integration of geodata using statistical and image processing techniques – An example from Central Finland. Geological Survey of Finland, Report of Investigation 80. 156 p.

Gaál, G., Front, K. & Aro, K. 1981. Geochemical exploration of a Precambrian batholith, source of a Cu-W mineralization of the tourmaline breccia type in southern Finland. Journal of Geochemical Exploration 15 (1–3), 683–698.

Gaál, G. & Isohanni, M. 1979. Characteristics of igneous intrusions and various wall rocks in some Precambrian porphyry copper-molybdenum deposits in Pohjanmaa, Finland. Economic Geology 74 (5), 1198–1210.

Gaál, G., Koistinen, E., Lehtonen, M. & Tontti, M. 1978. Deposit modeling of a nickel Belt in Finland. Journal of the International Association for Mathematical Geology 10 (5), 543–554.

Gaál, G., Koistinen, T. & Mattila, E. 1975. Tectonics and stratigraphy in the vicinity of Outokumpu including a structural analysis of the Outokumpu ore deposit, the Province of North Karelia, eastern Finland: Geological Survey of Finland, Bulletin 271. 67 p.

Gaál, G. & Parkkinen, J. 1993. Early Proterozoic ophiolite-hosted copper-zinc-cobalt deposits of the Outokumpu type. In: Kirkham, R. V. … [et al.] (editors) Mineral deposit modeling. Geological Association of Canada, Special Paper 40, 335–341.

Gaál, G. & Sundblad, K. 1990. Metallogeny of gold in the Fennoscandian Shield. Mineralium Deposita 25, 104–114.

Gaál, G., Tontti, M., Autio, H. & Lehtonen, M. 1977. Establishing

a national ore data file in Finland. Journal of the International Association for Mathematical Geology 9 (3), 319–325.

Gehör, S. 1994a. The Palaeoproterozoic iron-formations in Central Lapland and Kainuu, Finland, with special reference to their depositional environment and metamorphism. Res Terrae, Ser. A 9. 186 p.

Gehör, S. 1994b. REE distribution in the phosphorite bands within the Paleoproterozoic Tuomivaara and Pahtavaara iron-formations, central and northern Finland. In: Nironen, M. & Kähkönen, Y. (editors) Geochemistry of Proterozoic supracrustal rocks in Finland. IGCP Project 179 Stratigraphic methods as applied to the Proterozoic record and IGCP Project 217 Proterozoic geochemistry. Geological Survey of Finland. Special Paper 19, 71–83.

Gehör, S. & Laajoki, K. 1987. The mineralogy and regional metamorphism of the Precambrian iron-formations in Finland. In: Uitterdijk Appel, P. W. & LaBerge, G. L. (editors) Precambrian iron-formations. Athens: Theophrastus, 393–419.

Gervilla, F., Cabri, L. J., Kojonen, K., Oberthür, T., Weiser, T. W., Johanson, B., Sie, S. H., Campbell, J. L., Teesdale, W. J. & Laflamme, J. H. G. 2004. Platinum-group element distribution in some ore deposits – Results of EPMA and micro-PIXE analyses. Microchimica Acta 147 (3), 167–173.

Gervilla, F. & Kojonen, K. 2002. The platinum-group minerals in the upper section of the Keivitsansarvi Ni-Cu-PGE deposit, northern Finland. The Canadian Mineralogist 40 (2), 377–394.

Gervilla, F., Kojonen, K. & Merkle, R.K.W. 2005. Platinum-group minerals in the Proterozoic Keivitsa mafic-ultramafic intrusion, Sodankylä, northern Finland. In: Törmänen, T. O. & Alapieti, T. T. (editors) The 10th International Platinum Symposium: Platinum-group elements – From genesis to beneficiation and environmental impact, August 8–11, 2005, Oulu, Finland, Extended abstracts. Espoo: Geological Survey of Finland, 345–348.

Gervilla, F., Kojonen, K., Parkkinen, J. & Välimaa, J. 2003. Platinum-group element mineralogy, geochemistry and 3-D modeling of the Keivitsa Ni-Cu-PGE sulfide deposit, northern Finland. In: Eliopoulos, D. G. ... [et al.] (editors) Mineral exploration and sustainable development: Proceedings of the 7th Biennial SGA Meeting, Athens, Greece, 24–28 August 2003, Vol. 1. Rotterdam: Millpress, 583–586.

Gervilla, F., Papunen, H. & Kojonen, K. 1997a. Mineralogy of Pt-, Pd- and Au-bearing arsenide ores of the Kylmäkoski Ni-Cu deposit, Vammala nickel Belt, southwestern Finland. In: Papunen, H. (editor) Mineral deposits: Research and exploration – where do they meet? Proceedings of the 4th Biennial SGA Meeting, Turku/Finland/11–13 August 1997. Rotterdam: A. A. Balkema, 419–422.

Gervilla, F., Papunen, H., Kojonen, K. & Johanson, B. 1997b. Results of trace platinum group element analyses of arsenides and sulfarsenides from some Finnish PGE-bearing mafic-ultramafic intrusions. In: Papunen, H. (editor) Mineral deposits: Research and exploration – where do they meet? Proceedings of the 4th Biennial SGA Meeting, Turku/Finland/11–13 August 1997. Rotterdam: A. A. Balkema, 423–426.

Gervilla, F., Papunen, H., Kojonen, K. & Johanson, B. 1998. Platinum-, palladium- and gold-rich arsenide ores from the Kylmäkoski Ni-Cu deposit (Vammala Nickel Belt, southwestern Finland). Mineralogy and Petrology 64 (1–4), 163–185.

Gornostayev, S. & Mutanen, T. 2003. The platinum-group minerals in chromitites of the Akanvaara deposit, northern Finland, and in their processing products. In: Applied mineralogy – Papers presented at Applied mineralogy '03, Helsinki, Finland, March 17–18, 2003. Minerals Engineering 16 (11 Supplement), 1307–1312.

Grundfelt, B. 2002. Important lessons for PA: A first summing up from Palmottu. In: Maravic, H. von & Alexander, W. R. (editors), The 8th EC Natural Analogue Working Group Meeting: Proceedings of an international workshop held in Strasbourg, France, March 23–25, 1999. Luxembourg: Office for Official Publications of the European Communities, 351–356.

Grundström, L. 1980. The Laukunkangas nickel-copper occurrence in southeastern Finland. Bulletin of the Geological Society of Finland 52 (1), 23–53.

Grundström, L. 1985. The Laukunkangas nickel-copper deposit. In: Papunen, H. & Gorbunov, G. I. (editors) Nickel-copper deposits of the Baltic Shield and Scandinavian Caledonides. Geological Survey of Finland, Bulletin 333, 240–256.

GTK 1995. Geological Survey of Finland, web pages: http://www.gtk.fi/explor/; Geology.

GTK 2005. Geological Survey of Finland, web pages: http://www.gtk.fi/explor/; Gold, PGE, Zinc.

Haapala, P. 1936. On serpentine rocks in Northern Karelia. Geological Survey of Finland, Bulletin 114. 83 p.

Haapala, P. 1969. Fennoscandian nickel deposits. Economic Geology, Monograph 4, 262–275.

Hackman, V. 1927. Studien über den Gesteinsaufbau der Kittilä-Lappmark. Geological Survey of Finland, Bulletin 79. 105 p.

Haggerty, S. E. 1964. The geology of Jussarö mine, Finland. Thesis of the Royal School of Mines, London.

Hakanen, P. 1983. Cobalt as an exploration tool in the Outokumpu zone, Finland. Journal of Geochemical Exploration 19 (1–3), 611–614.

Häkli, T. A. 1985. The Telkkälä nickel deposit. In: Papunen, H. & Gorbunov, G. I. (editors) Nickel-copper deposits of the Baltic Shield and Scandinavian Caledonides. Geological Survey of Finland, Bulletin 333, 257–263.

Häkli, T. A., Hänninen, E., Vuorelainen, Y. & Papunen, H. 1976. Platinum-group minerals in the Hitura nickel deposit, Finland. Economic Geology 71 (7), 1206–1213.

Häkli, T. A., Huhma, M., Viluksela, E. & Vuorelainen, Y. 1975. A minor Ni-Cu-deposit at Telkkälä, SE-Finland. Bulletin of the Geological Society of Finland 47 (1–2), 55–70.

Häkli, T. A. & Vormisto, K. 1985. The Vammala nickel deposit. In: Papunen, H. & Gorbunov, G. I. (editors) Nickel-copper deposits of the Baltic Shield and Scandinavian Caledonides. Geological Survey of Finland, Bulletin 333, 273–286.

Häkli, T. A., Vormisto, K. & Hänninen, E. 1979. Vammala, a nickel deposit in layered ultramafite, southwestern Finland. Economic Geology 74 (5), 1166–1182.

Halkoaho, T. 1993. The Sompujärvi and Ala-Penikka PGE reefs in the Penikat layered intrusion, northern Finland: Implications for PGE reef-forming processes. Acta Universitatis Ouluensis, Series A, Scientiae Rerum Naturalium 249. 122 p.

Halkoaho, T. A. A., Alapieti, T. T. & Lahtinen, J. J. 1989a. The Ala-Penikka PGE mineralizations in the Penikat layered intrusion, northern Finland. In: Alapieti, T. (editor) The 5th International Platinum Symposium: Guide to the post-symposium field trip, August 4–11, 1989. Geological Survey of Finland, Guide 29, 93–122.

Halkoaho, T. A. A., Alapieti, T. T. & Lahtinen, J. J. 1989b. The Sompujärvi PGE mineralization in the Penikat layered intrusion, northern Finland. In: Alapieti, T. (editor) The 5th International Platinum Symposium: Guide to the post-symposium field trip, August 4–11, 1989. Geological Survey of Finland, Guide 29, 71–92.

Halkoaho, T. A. A., Alapieti, T. T. & Lahtinen, J. J. 1990a. The Sompujärvi PGE reef in the Penikat layered intrusion, northern Finland. In: Stumpfl, E. F. & Papunen, H. (editors) Proceedings of the 5th International Platinum Symposium, Helsinki 1989. Mineralogy and Petrology 42 (1–4), 39–55.

Halkoaho, T. A. A., Alapieti, T. T., Lahtinen, J. J. & Lerssi, J. M. 1990b. The Ala-Penikka PGE reefs in the Penikat layered intrusion, northern Finland. In: Stumpfl, E. F. & Papunen, H. (editors) Proceedings of the 5th International Platinum Sym-

posium, Helsinki 1989. Mineralogy and Petrology 42 (1–4), 23–38.

Halkoaho, T., Liimatainen, J., Papunen, H. & Välimaa, J. 2000. Exceptionally Cr-rich basalts in the komatiitic volcanic association of the Archaean Kuhmo Greenstone Belt, eastern Finland. Mineralogy and Petrology 70 (1–2), 105–120.

Halkoaho, T., Luukkonen, E., Niskanen, M. & Pietikäinen, K. 1999. Mobilized Ni-mineralization of the Kauniinlampi komatiite cumulate complex in the Archaean Suomussalmi Greenstone Belt, Finland. In: Precambrian rift formation, magmatism, metallogeny – Correlation of geological complexes in Fennoscandia: Proceedings of the international conference, Petrozavodsk 1999. Petrozavodsk: Karelian Research Centre, RAS, 174–175.

Halkoaho, T., & Pietikäinen, K. 1999. Ni and Au prospects of the Kuhmo and Suomussalmi Greenstone Belts. In: Papunen, H. & Eilu, P. (editors) Geodynamic evolution and metallogeny of the Central Lapland, Kuhmo and Suomussalmi Greenstone Belts, Finland: Joint field excursion and workshop of the GEODE subprojects, Archaean greenstone belts and ore deposits, Palaeoproterozoic greenstone belts and ore deposits, 11–16 September 1999. University of Turku, Department of Geology and Mineralogy, Publications 42, 60–63.

Hangala, L. S. 1987. The early Proterozoic Zn-Pb-Cu massive sulfide deposit at Attu, southwestern Finland. Geological Survey of Finland, Bulletin 341. 61 p.

Hänninen, E., Törnroos, R. & Lahti, S. I. 1986. Stillwaterite and associated platinum group minerals from the Siikakämä layered mafic intrusion, northern Finland. Lithos 19 (2), 87–93.

Hanski, E. S. 1997. The Nuttio serpentinite Belt, Central Lapland: An example of Paleoproterozoic ophiolitic mantle rocks in Finland. In: Messiga, B. & Tribuzio, R. (editors) IOS International Ophiolite Symposium: From rifting to drifting in present-day and fossil ocean basins, Pavia (Italy), September 18–23, 1995. Ofioliti 22 (1), 35–46.

Hanski, E. J., Huhma, H., Suominen, I. M. & Walker, R. J. 1997. Geochemical and isotopic (Os, Nd) study of the early Proterozoic Keivitsa intrusion and its Cu-Ni deposit, northern Finland. In: Papunen, H. (editor) Mineral deposits: Research and exploration – where do they meet? Proceedings of the 4th Biennial SGA Meeting, Turku/Finland/11–13 August 1997. Rotterdam: A. A. Balkema, 435–438.

Hanski, E., Huhma, H., Rastas, P. & Kamenetsky, V.S. 2001a. The Paleoproterozoic komatiite-picrite association of Finnish Lapland. Journal of Petrology 42, 855–876.

Hanski, E., Walker, R.J., Huhma, H. & Suominen, I. 2001b. The Os and Nd isotopic systematics of c. 2.44 Ga Akanvaara and Koitelainen mafic layered intrusions in northern Finland. Precambrian Research 109, 73–102.

Härkönen, I. 1984. The gold-bearing conglomerates of Kaarestunturi in central Finnish Lapland. In: Foster, R. P. (editor) Gold 82 – The geology, geochemistry and genesis of gold deposits. Geological Society of Zimbabwe, Special Publication 1. Rotterdam: A.A. Balkema, 239–247.

Härkönen, I. 1986. Gold in the Proterozoic conglomerates of Finnish Lapland. Terra Cognita 6, p. 538.

Härkönen, I. & Keinänen, V. 1989. Exploration of structurally controlled gold deposits in the Central Lapland Greenstone Belt. In: Autio, S. (editor) Geological Survey of Finland, Current Research 1988. Geological Survey of Finland, Special Paper 10, 79–82.

Härkönen, I., Kojonen, K. K. & Johanson, B. 1999a. The early Proterozoic Suurikuusikko refractory gold deposit, Kittilä, western Finnish Lapland. In: Stanley, C. J. … [et al.] (editors) Mineral Deposits – Processes to Processing: Proceedings of the 5th Biennial SGA Meeting and the 10th Quadrennial IAGOD Symposium, London, United Kingdom, 22–25 August 1999, Vol. 1. Rotterdam: A. A. Balkema, 159–162.

Härkönen, I., Kojonen, K. & Johanson, B. 1999b. The Proterozoic Suurikuusikko refractory gold deposit in Kittilä, Western Finnish Lapland. In: Cook, N. J. & Sundblad, K. (editors) Precambrian Gold in the Fennoscandian and Ukrainian Shields and Related Areas. Gold '99 Trondheim, Norway, May 4–6, 1999. Trondheim: Geological Survey of Norway (NGU), 89–91.

Hausen, H. 1934. Zur Genesis der karelischen "metasomatischen" Kieserzlagerstätten. Geologiska Föreningens i Stockholm Förhandlingar 56, 359–360.

Helovuori, O. 1979. Geology of the Pyhäsalmi ore deposit, Finland. Economic Geology 74 (5), 1084–1101.

Himmi, R. 1954. The copper deposit of Paronen. In: Aurola, E. (editor) The mines and quarries of Finland. Geological Survey of Finland, Geotechnical Publications 55, 15–16.

Himmi, R., Huhma, M. & Häkli, T. A. 1979. Mineralogy and metal distribution in the copper-tungsten deposit at Ylöjärvi, Southwest Finland. Economic Geology 74 (5), 1183–1197.

Hiltunen, A. 1982. The Precambrian geology and skarn iron ores of the Rautuvaara area, northern Finland. Geological Survey of Finland, Bulletin 318. 133 p.

Hiltunen, A. & Tontti, M. 1976. The stratigraphy and tectonics of the Rautuvaara iron ore district, northern Finland. Bulletin of the Geological Society of Finland 48 (1–2), 95–109.

Hirvas, H. & Mäkinen, K. 1989. Tracing of uranium-rich boulders at Pahtavuoma, northern Finland. In: DiLabio, R. N. W. & Coker, W. B. (editors) Drift Prospecting. Geological Survey of Canada, Paper 89–20, 7–12.

Holma, M. J., Keinänen, V. J., Ojala, V. J. & Eilu, P. 2003. The Levijärvi – Loukinen Au-Ni-Cu occurrence: A Palaeoproterozoic polymetallic orogenic gold mineralisation in the Sirkka Line tectonic structure, northern Finland. In: Eliopoulos, D. G. ... [et al.] (editors) Mineral exploration and sustainable development: Proceedings of the 7th Biennial SGA Meeting, Athens, Greece, August 24–28, 2003, Vol. 2. Rotterdam: Millpress, 1073–1076.

Holmberg, H. J. 1858. Materialier till Finlands geognosi. Finska Vetenskapssocieteten, Bidrag till Finlands naturkännedom, etnografi och statistik 4. 254 p.

Hölttä, P. & Karhu, J. 2001. Oxygen and carbon isotope compositions of carbonates in the alteration zones of orogenic gold deposits in central Finnish Lapland. Geological Survey of Finland, Special Paper 31, 25–29.

Huhma, A. 1976. New aspects to the geology of the Outokumpu region. Bulletin of the Geological Society of Finland 48 (1–2), 5–24.

Huhma, A. & Huhma, M. 1970. Contribution to the geology and geochemistry of the Outokumpu region. Bulletin of the Geological Society of Finland 42, 57–88.

Huhma, H. 1986. Sm-Nd, U-Pb and Pb-Pb isotopic evidence for the origin of the Early Proterozoic Svecokarelian crust in Finland. Geological Survey of Finland, Bulletin 337. 48 p.

Huhma, H., Kontinen, A. & Laajoki, K. 2000. The age of the metavolcanic-sedimentary units of the Central Puolanka Group, Kainuu Schist Belt, Finland. In: Eide, E. (editor) 24. The Nordic Geological Winter Meeting, Trondheim, January 6–9, 2000. Geonytt (1), 87–88.

Huhma, M., Vuorelainen, Y., Häkli, T. A. & Papunen, H. 1973. Haapalaite, a new nickel-iron sulphide of the valleriite type from eastern Finland. Bulletin of the Geological Society of Finland 45 (2), 103–106.

Huhta, J. V. 1954. The nickel-copper ore deposit of Makola. Geological Survey of Finland, Geotechnical Publications 55, 25–28.

Huhtala, T. 1979. The geology and zinc-copper deposits of the Pyhäsalmi-Pielavesi district, Finland. Economic Geology 74 (5), 1069–1083.

Huhtelin, T. 1997. The Kemi chrome mine and the Sompujärvi PGE occurrence in the Penikat layered intrusion, northern

Finland. In: Korkiakoski, E. & Sorjonen-Ward, P. (editors) Research and exploration – where do they meet? 4th Biennial SGA Meeting, August 11–13, 1997, Turku, Finland. Excursion Guide B1 – Ore deposits of Lapland in northern Finland and Sweden. Geological Survey of Finland, Guide 43, 11–15.

Huhtelin, T. A. 1991. Platinum-group element mineralization in the upper part of the Penikat layered intrusion, northern Finland. Geologiska Föreningens i Stockholm Förhandlingar 113 (1), 51–53.

Huhtelin, T. A., Alapieti, T. T. & Lahtinen, J. J. 1989. The Paasivaara PGE mineralization in the Penikat layered intrusion, northern Finland. In: Alapieti, T. (editor) The 5th International Platinum Symposium – Guide to the post-symposium field trip, August 4–11, 1989. Geological Survey of Finland, Guide 29, 123–144.

Huhtelin, T. A., Alapieti, T. T. & Lahtinen, J. J. 1990. The Paasivaara PGE reef in the Penikat layered intrusion, northern Finland. In: Stumpfl, E. F., Papunen, H. (editors) Proceedings of the 5th International Platinum Symposium, Helsinki 1989. Mineralogy and Petrology 42 (1–4), 57–70.

Huhtelin, T. A., Lahtinen, J. J., Alapieti, T. T., Korvuo, E. & Sotka, P. 1989. The Narkaus intrusion and related PGE and sulphide mineralizations. In: Alapieti, T. (editor) The 5th International Platinum Symposium – Guide to the post-symposium field trip, August 4–11, 1989. Geological Survey of Finland, Guide 29, 145–161.

Hytönen, K., Nuutilainen, J., Ojanperä, P. & Vornanen, E. 1966. Manganoan siderite from Kittilä, western Lapland. Geologi 18, 98–99.

Hyvärinen, L. 1969. On the geology of the copper ore field in the Virtasalmi area, eastern Finland. Geological Survey of Finland, Bulletin 240. 82 p.

Hyvärinen, L., Kinnunen, K. & Mäkelä, M. 1977. The geochemistry, fluid inclusions, sulfur isotopes and origin of the Hammaslahti copper ore deposit, Finland. Geological Survey of Finland, Bulletin 293. 23 p.

Iljina, M. J. 1991. Platinum-group element mineralization in the southern part of the Portimo layered igneous complex, northern Finland. Geologiska Föreningens i Stockholm Förhandlingar 113 (1), 53–55.

Iljina, M. 1994. The Portimo layered igneous complex – with emphasis on diverse sulphide and platinum-group element deposits. Acta Universitatis Ouluensis, Series A, Scientiae Rerum Naturalium 258. 158 p.

Iljina, M. J., Alapieti, T. T., Lahtinen, J. J. & Lerssi, J. M. 1989. The Suhanko-Konttijärvi intrusion and related sulphide and PGE mineralizations. In: Alapieti, T. (editor) The 5th International Platinum Symposium, Guide to the post-symposium field trip, August 4–11, 1989. Geological Survey of Finland, Guide 29, 163–187.

Iljina, M. J., Alapieti, T. T. & McElduff, B. M. 1992. Platinum-group element mineralization in the Suhanko-Konttijärvi intrusion, Finland. In: Barnes, S. J. (editor) Proceedings of the 6th International Platinum Symposium, Part 1. Australian Journal of Earth Sciences 39 (3), 303–313.

Iljina, M. & Hanski, E. 2002. Multimillion-ounce PGE deposits of the Portimo Layered Igneous Complex, Finland. In: Boudreau, A. (editor) 9th International Platinum Symposium, July 21–25, 2002, Billings, Montana, USA, Extended abstracts. Billings, MT: Duke University, 193–196.

Iljina, M. J., Karinen, T. T. & Räsänen, J. E. 2001. The Koillismaa Layered Igneous Complex: general geology, structural development and related sulphide and platinum-group element mineralization. In: Piestrzynski, A. ... [et al.] (editors) Mineral deposits at the beginning of the 21st century: Proceedings of the Joint 6th Biennial SGA-SEG Meeting, Kraków, Poland, August 26–29, 2001. Lisse: A. A. Balkema, 649–652.

Imaña Osorio, M. & Mäki, T. 2003. Preserved primary textures of the Pyhäsalmi Zn-Cu VMS deposit, Finland: Evidences of subsea-floor replacement and Svecofennian post-depositional sulfide mobilization. In: Eliopoulos, D. G. ... [et al.] (editors) Mineral exploration and sustainable development: Proceedings of the 7th Biennial SGA Meeting, Athens, Greece, 24–28 August 2003, Vol. 2. Rotterdam: Millpress, 1077–1078.

Inkinen, O. 1979. Copper, zinc, and uranium occurrences at Pahtavuoma in the Kittilä Greenstone Complex, northern Finland. Economic Geology 74, 1153–1165.

Inkinen, O. & Hiltunen, A. 1980. Copper deposits in northern Finland. In: Jankovic, S. & Sillitoe, R. H. (editors) European copper deposits: Proceedings of an international symposium held at Bor, Yugoslavia, 18–22 September 1979. Belgrade: Belgrade University, Faculty of Mining and Geology, 188–190.

Isohanni, M. 1985. The Oravainen nickel occurrence in western Finland. In: Papunen, H. & Gorbunov, G. I. (editors) Nickel-copper deposits of the Baltic Shield and Scandinavian Caledonides. Geological Survey of Finland, Bulletin 333, 189–210.

Isohanni, M., Ohenoja, V. & Papunen, H. 1985. Geology and nickel-copper ores of the Nivala area. In: Papunen, H. & Gorbunov, G. I. (editors) Nickel-copper deposits of the Baltic Shield and Scandinavian Caledonides. Geological Survey of Finland, Bulletin 333, 211–228.

Isokangas, P. K. 1954. The Vihanti zinc deposit. Geological Survey of Finland, Geotechnical Publications 55, 29–32.

Isokangas, P. 1978. Finland. In: Bowie, S. H. U., Kvalheim, A. & Haslam, H. W. (editors) Mineral deposits of Europe, Volume 1 – Northwest Europe. London: The Institution of Mining and Metallurgy & The Mineralogical Society, 39–92.

Isomäki, O.-P. 1986. The sulphide ore deposits in the Orijärvi-Aijala field. In: Gaál, G. (editor), 17th Nordic Geologists' Meeting, Helsinki, 1986: Excursion guide, Excursion C 3 – Metallogeny and ore deposits of South Finland. Geological Survey of Finland, Guide 16, 46–56.

Isomäki, O.-P. 2004. Nivalan Hituran nikkelikaivoksen malminnosto ylitti 12 miljoonaa tonnia – Esiintymän löytämisestä 40 vuotta. Summary: In 40 years after the discovery over 12 million tonnes of nickel ore has been hoisted from Hitura mine, western Finland. Geologi 56 (3), 76–79.

IUREP (International Uranium Resources Evaluation Project) 1982. Orientation phase mission – Summary report: Finland. Paris: Organisation for Economic Co-operation and Development (OECD), Nuclear Energy Agency (NEA). 24 p.

Johanson, B. & Kojonen, K. 1991. Ore mineralogy of gold occurrences in the late Archean Ilomantsi Greenstone Belt, eastern Finland. In: Ladeira, E. A. (editor) Brazil Gold '91 – The economics, geology, geochemistry and genesis of gold deposits: Proceedings of the symposium Brazil Gold '91, Belo Horizonte, MG, 13–17 May 1991. Rotterdam: A. A. Balkema, 183–186.

Johanson, B., Törnroos, R. & Kojonen, K. 1991. Thallian silver telluride from the Korvilansuo gold prospect in the Archaean Hattu Schist Belt, Ilomantsi, eastern Finland. In: Autio, S. (editor) Geological Survey of Finland, Current Research 1989–1990. Geological Survey of Finland, Special Paper 12, 91–96.

Johansson, P., Huhta, P., Nenonen, J. & Hirvasniemi, H. 2000. Kultakaira: Geologinen retkeilykartta – Geological outdoor map, Ivalojoki-Saariselkä 1:50 000. Rovaniemi: Geological Survey of Finland. 1 map and guidebook. 44 p.

Johansson, P. Nenonen, J., Hirvasniemi, H., Valkama, J., Bister, T., Tranberg, J. & Manninen, Tuomo 2002. Lemmenjoki: Geologinen retkeilykartta – Geological outdoor map 1:50 000. Rovaniemi: Geological Survey of Finland. 1 map and guidebook. 47 p.

Juopperi, A. 1977. The magnetite gabbro and related Mustavaara vanadium ore deposits in the Porttivaara layered intrusion, northeastern Finland. Geological Survey of Finland, Bulletin 288. 68 p.

Juopperi, A. & Vornanen, E. 1977. The Rautuvaara mine of Rautaruukki Oy. In: Prospecting in areas of glaciated terrain, August 1977, Finland: Excursion Guide. London: The Institution of Mining and Metallurgy, 21–24.

Juve, G. (editor and compiler), Emberger, A. & Størseth, L. R. (compilers) 1997. The mineral atlas of the world, Map sheet no 9, Europe and neighbouring countries, Scale 1 : 10 000 000 – Atlas mineral du monde, Feuille no 9, Europe et des pays limitrophes, Echelle 1 : 10 000 000. Trondheim: Norges Geologiske Undersøkelse (NGU) and Paris: Commission de la Carte Géologique de Monde (CCGM).

Kääriäinen, J. & Mäkinen, J., 1997. The 1979–1996 gravity survey and the results of the gravity survey of Finland 1945–1996. Publications of the Finnish Geodetic Institute 125. 24 p.

Kähkönen, Y. 1987. Geochemistry and tectonomagmatic affinities of the metavolcanic rocks of the early Proterozoic Tampere Schist Belt, southern Finland. Precambrian Research 35, 295–311.

Kähkönen, Y. 1989. Geochemistry and petrology of the metavolcanic rocks of the early Proterozoic Tampere Schist Belt, southern Finland. Geological Survey of Finland, Bulletin 345. 107 p.

Kähkönen, Y., Mäkelä, K. & Rosenberg, R. J. 1981. Rare earth elements in Proterozoic metabasalts and associated volcanogenic sulphide ore from Haveri, southwestern Finland. Bulletin of the Geological Society of Finland 53 (1), 11–16.

Kahma, A. 1973. The metallogenic map of Finland 1:2 000 000. Geological Survey of Finland, Bulletin 265, with a map appendix.

Kahma, A. 1978. The main sulphide ore belt of Finland between Lake Ladoga and the Bothnian Bay. Bulletin of the Geological Society of Finland 50 (1–2), 39–43.

Kahma, A., Saltikoff, B. & Lindberg, E. 1976. Suomen malmiesiintymät – Finlands malmförekomster – Ore deposits of Finland 1:1 000 000. Espoo: Geological Survey of Finland.

Kahma, A., Siikarla, T., Veltheim, V., Vaasjoki, O. & Heikkinen, A. 1962. On the prospecting and geology of the Kemi chromite deposit, Finland. Geological Survey of Finland, Bulletin 194, 89 p.

Kaitaro, S. 1949. Über den Charakter der eisenerzführenden Jaspisquarzite von Porkonen-Pahtavaara in Kittilä (Finnisch-Lappland). Bulletin of the Geological Society of Finland 22, 139–147; also Geological Survey of Finland, Bulletin 144, 139–147.

Kärkkäinen, N. 1997. The Koivusaarenneva gabbro, Finland. In: Papunen, H. (editor) Mineral deposits: Research and exploration – where do they meet? Proceedings of the 4th Biennial SGA Meeting, Turku/Finland/ August 11–13, 1997. Rotterdam: A. A. Balkema, 443–444.

Kärkkäinen, N. 1999. Titanium ore potential of small mafic intrusions based on two examples in western Finland. Houghton, MI: Michigan Technological University. 193 p.

Kärkkäinen, N. 2001. The gabbro hosted ilmenite deposits in Finland. In: Korneliussen, A. (editor) Abstracts – GEODE field workshop on ilmenite deposits in the Rogaland anorthosite province, southern Norway, July 8–12, 2001. Geological Survey of Norway (NGU), Report 2001.042, 66–70.

Kärkkäinen, N. & Appelqvist, H. 1999. Genesis of a low-grade apatite-ilmenite-magnetite deposit in the Kauhajärvi gabbro, western Finland. Mineralium Deposita 34 (8), 754–769.

Kärkkäinen, N. & Bornhorst, T. J. 2003. The Svecofennian gabbro-hosted Koivusaarenneva magmatic ilmenite deposit, Kälviä, Finland. Mineralium Deposita 38 (2), 169–184.

Kärkkäinen, N., Sarapää, O., Huuskonen, M., Koistinen, E. & Lehtimäki, J. 1997. Ilmenite exploration in western Finland, and the mineral resources of the Kälviä deposit. In: Autio, S. (editor) Geological Survey of Finland, Current Research 1995–1996. Geological Survey of Finland, Special Paper 23, 15–24.

Karppanen, T. 1986. The Hammaslahti mine. In: Kojonen, K. (editor) Prospecting in areas of glaciated terrain 1986: Guide to the field excursion for the symposium in eastern Finland, September 3–5, 1986. Geological Survey of Finland, Guide 17, 34–40.

Karvinen, W. O. 1997. The Haveri copper-gold mine property, southern Finland. In: Ehlers, C. (editor) Research and exploration – where do they meet? 4th Biennial SGA Meeting, August 11–13, 1997, Turku, Finland, Excursion guide B3 – Gold and base metal deposits in southwestern Finland. Geological Survey of Finland, Guide 44, 20–22.

Keinänen, V. J. & Holma, M. J. 2001. Levijärvi and Soretialehto – two epigenetic lode-gold deposits controlled by the Sirkka Thrust Zone within the Paleoproterozoic Central Lapland Greenstone Belt, Kittilä, northern Finland. In: Williams, P. J. (editor) 2001: A hydrothermal odyssey – New developments in metalliferous hydrothermal systems research, Extended conference abstracts, May 17–19th, 2001, Townsville, Queensland, Australia. Queensland: James Cook University of North Queensland, Economic Geology Research Unit (EGRU), Contribution 59, 102–103.

Ketola, M. 1979. On the application of geophysics in the indirect exploration for copper sulphide ores in Finland. In: Hood, P. J. (editor) Geophysics and geochemistry in the search for metallic ores. Geological Survey of Canada, Economic Geology Report 31, 665–684.

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.

Ketola, M. 1986. The development of exploration geophysics in Finland. Geological Survey of Finland, Bulletin 336, 205–231.

Kinnunen, K. A. 1982. Primary sedimentary features in Kittilä jasper, Finnish Lapland. Bulletin of the Geological Society of Finland 54 (1–2), 69–76.

Kinnunen, K. A. 1996. Classification scheme for surface textures of gold nuggets from Finnish Lapland. Bulletin of the Geological Society of Finland 68 (2), 18–33.

Kinnunen, K. A. 2003. Mercury-rich coating on some gold nuggets from Ivalojoki placers, northern Finland. In: Autio, S. (editor) Geological Survey of Finland, Current Research 2001–2002. Geological Survey of Finland, Special Paper 36, 29–33.

Kinnunen, K. A., Johanson, B., Terho, M. & Puranen, R. 1997. Nondestructive analysis of morphology, chemical composition and physical properties of large gold nuggets from Finnish Lapland. In: Autio, S. (editor) Geological Survey of Finland, Current Research 1995–1996. Geological Survey of Finland, Special Paper 23, 29–35.

Kinnunen, K. A., & Saltikoff, B. 1989. Preliminary paleotectonic scheme for SW Finland: a basis for metallogenic zonation. In: Autio, S. (editor) Geological Survey of Finland, Current Research 1988. Geological Survey of Finland, Special Paper 10, 111–112.

Klemm, D. D. 1965. Hochtemperierte Glanzkobalt-Gersdorffit-Mischkristalle von Outokumpu/Finnland. Neues Jahrbuch für Mineralogie, Monatsheft 8, 236–241.

Knorring von, O. 1955. A mineralogical and geochemical study of the metamorphic iron-ores of S.W. Finland. University of Leeds, Department of Geology, Manuscript. 163 p.

Knorring von, O., Condliffe, E. & Tong, Y. L. 1986. Some mineralogical and geochemical aspects of chromium-bearing skarn minerals from northern Karelia, Finland. Bulletin of the Geological Society of Finland 58, 277–292.

Koistinen, T. J. 1987. A review of the geology of North Karelia. In: Häkli, T. A. (editor) The Otto Trüstedt symposium held in Finland on June 3–5, 1985. Geological Survey of Finland, Special Paper 1, 35–40.

Koistinen, T. J. 1981. Structural evolution of an early Proterozoic stratabound Cu-Co-Zn deposit, Outokumpu, Finland. Transac-

tions of the Royal Society of Edinburgh, Earth sciences 72 (2), 115–158.

Koistinen, T. J., Kurki, J. A. & Parkkinen, O. J. 1983. Exogenic features in the stratabound Cu-Co-Zn ore deposit of Outokumpu – A short review. In: Laajoki, K. & Paakkola, J. (editors) Exogenic processes and related metallogeny in the Svecokarelian geosynclinal complex. Geological Survey of Finland, Guide 11, 100–109.

Kojonen, K. 1981. Geology, geochemistry and mineralogy of two Archean nickel-copper deposits in Suomussalmi, eastern Finland. Geological Survey of Finland, Bulletin 315. 58 p.

Kojonen, K. (editor) 1989. The early Proterozoic Zn-Cu-Pb sulphide deposit of Rauhala in Ylivieska, western Finland. Geological Survey of Finland, Special Paper 11. 92 p.

Articles:

- Kojonen, K., Johanson, B. & Törnroos, R. 1989. Ore mineralogy of the Rauhala Zn-Cu-Pb sulphide deposit, 19–42.
- Rasilainen, K. & Västi, K. 1989. Geochemistry, wall rock alteration and metal zonality at the Rauhala Zn-Cu-Pb sulphide deposit, 43–58.
- Vaasjoki, M. 1989. Pb and S isotopic studies on the Rauhala Zn-Cu-Pb sulphide deposit and its environment, 59–65.
- Västi, K. J. 1989. Geology of the Rauhala stratiform massive Zn-Cu-Pb sulphide deposit, 5–18.

Kojonen, K., Gornostayev, S. S., Pitkäjärvi, J. & Knauf, V. V. 2005. The PGE-mineralogy of the Kemi chromite deposit: an overview. In: Törmänen, T. O. & Alapieti, T. T. (editors) The 10th International Platinum Symposium – Platinum-group elements, from genesis to beneficiation and environmental impact, August 8–11, 2005, Oulu, Finland, Extended abstracts. Espoo: Geological Survey of Finland, 412–416.

Kojonen, K. & Iljina, M. 2001. Platinum-group minerals in the Early Proterozoic Kuusijärvi Marginal Series, Koillismaa Layered Igneous Complex, northeastern Finland. In: Piestrzynski, A. ... [et al.] (editors) Mineral deposits at the beginning of the 21st century: Proceedings of the joint 6th Biennial SGA-SEG Meeting, Kraków, Poland, August 26–29, 2001. Lisse: A. A. Balkema, 653–656.

Kojonen, K. & Isomäki, O.-P. 2005. PGE-minerals and tarkianite, $(Cu,Fe)(Re,Mo)_4S_8$, a new mineral species from Hitura mine, Nivala, Central Finland. In: Törmänen, T. O. & Alapieti, T. T. (editors) The 10th International Platinum Symposium: Platinum-group elements, from genesis to beneficiation and environmental impact, August 8–11, 2005, Oulu, Finland, Extended abstracts. Espoo: Geological Survey of Finland, 417–420.

Kojonen, K. & Johanson, B. 1999a. Determination of refractory gold distribution by microanalysis, diagnostic leaching and image analysis. In: Petruk, W. & Ferraris, G. (editors) IMA Toronto '98: Applied mineralogy, mineralogy of alkaline rocks. Mineralogy and Petrology 67 (1–2), 1–19.

Kojonen, K. Johanson, B., Leinonen, O. & Huhtelin, T. 1999b. Platinum-group and nickel minerals in the early Proterozoic Kemi chromitite deposit, northern Finland. In: Stanley, C. J. ... [et al.] (editors) Mineral deposits – Processes to processing: Proceedings of the 5th Biennial SGA Meeting and the 10th Quadrennial IAGOD Symposium, London, United Kingdom, August 22–25, 1999, Vol. 1. Rotterdam: A. A. Balkema, 181–184.

Kojonen, K., Johanson, B. & Pakkanen, L. 1994. Three new telluride minerals from Archean gold deposits in the Hattu Schist Belt, Ilomantsi, eastern Finland. In: International Mineralogical Association 16th general meeting, September 4–9, 1994, Pisa, Italy, Abstracts. Pisa: Societá Italiana di Mineralogia e Petrologia, 209–210.

Kojonen, K., Johanson, B. & Sipilä, E. 1991. The Kiimala gold deposit in Haapavesi, western Finland. In: Autio, S. (editor) Geological Survey of Finland, Current Research 1989–1990. Geological Survey of Finland, Special Paper 12, 75–79.

Kojonen, K., Johanson, B. & Västi, K. 1989. Ore mineralogy of the Rauhala Zn-Cu-Pb sulphide deposit, western Finland. In: Autio, S. (editor) Geological Survey of Finland. Current Research 1988. Geological Survey of Finland, Special Paper 10, 67–70.

Kojonen, K., Rasilainen, K. & Vaasjoki, M. 1990. Genesis of the Rauhala Early Proterozoic massive Zn-Cu-Pb-deposit, Ylivieska, western Finland. In: The 8th IAGOD symposium in conjunction with international conference on mineral deposit modeling, August 12–18, 1990, Ottawa, Canada, Program with abstracts, A223–A224.

Kojonen, K., Roberts, A., Isomäki, O.-P., Knauf, V., Johanson, B. & Pakkanen, L. 2004. Tarkianite, (Cu,Fe)(Re,Mo)4S8, a new mineral species from the Hitura mine, Nivala, Finland. In: Mungall, J. E., Meurer, W. P. & Martin, R. F. (editors) Platinum-group elements – Petrology, geochemistry, mineralogy. The Canadian Mineralogist 42 (2), 539–544.

Kojonen, K., Sorjonen-Ward, P., Saarnio, H. & Himmi, M. 1999c. The early Proterozoic Kutema gold deposit, southern Finland. In: Stanley, C. J. ... [et al.] (editors) Mineral deposits – Processes to processing: Proceedings of the 5th Biennial SGA Meeting and the 10th Quadrennial IAGOD Symposium, London, United Kingdom, August 22–25, 1999, Vol. 1. Rotterdam: A. A. Balkema, 177–180.

Kokkola, M. & Korkalo, T. 1976. Pahtavuoma: Copper in stream sediment and till. Journal of Geochemical Exploration 5, 280–287.

Koljonen, T. 1976. Luikonlahti: Selenium in the vicinity of copper ore. Journal of Geochemical Exploration 5 (3), 263–265.

Kontinen, A. 1987. An early Proterozoic ophiolite: The Jormua mafic-ultramafic complex, northern Finland. Precambrian Research 35, 313–341.

Kontoniemi, O. 1989. The Osikonmäki gold occurrence in Rantasalmi, southeastern Finland. In: Autio, S. (editor) Geological Survey of Finland, Current Research 1988. Geological Survey of Finland, Special Paper 10, 107–110.

Kontoniemi, O. 1997. The Osikonmäki Paleoproterozoic shear zone related gold deposit, southeastern Finland. In: Papunen, H. (editor) Mineral Deposits: Research and exploration – where do they meet? Proceedings of the 4th Biennial SGA Meeting, Turku/Finland/11–13 August 1997. Rotterdam: A. A. Balkema, 213–216.

Kontoniemi, O. 1998. An overview of the geology in the Osikonmäki area, Rantasalmi, southeastern Finland, as a promising environment for epigenetic gold mineralization. Geological Survey of Finland, Special Paper 25, 7–18.

Kontoniemi, O., Ekdahl, E. 1990. The Osikonmäki Tonalite-hosted early Proterozoic gold deposit, southeastern Finland. Bulletin of the Geological Society of Finland 62, 61–70.

Kontoniemi, O., Johanson, B., Kojonen, K., Pakkanen, L. 1991. Ore mineralogy of the Osikonmäki gold deposit, Rantasalmi, southwestern Finland. In: Autio, S. (editor) Geological Survey of Finland, Current Research 1989–1990. Geological Survey of Finland, Special Paper 12, 81–89.

Kontoniemi, O. & Nurmi, P.A. (editors) 1998. Geological setting and characteristics of the tonalite-hosted Paleoproterozoic gold deposit at Osikonmäki, Rantasalmi, southeastern Finland. Geological Survey of Finland, Special Paper 25. 119 p.

Articles:

- Bornhorst, T. J., Nurmi, P. A., & Kontoniemi, O. 1998. Geochemistry of gold and associated elements in the Paleoproterozoic Osikonmäki gold deposit, southeastern Finland, 81–90.
- Kontoniemi, O. 1998. An overview of the geology in the Osikonmäki area, Rantasalmi, southeastern Finland, as a promising environment for epigenetic gold mineralization, 7–18.
- Kontoniemi, O. 1998. Geological setting and characteristics of the Paleoproterozoic tonalite-hosted Osikonmäki gold deposit, southeastern Finland, 39–80.
- Liimatainen, J. 1998. Fluid inclusion data from the Osikonmäki

gold deposit, Rantasalmi, southeastern Finland, 91–99.

Kopperoinen, T. & Tuokko, I. 1988. The Ala-Luoma and Taivaljärvi Zn-Pb-Ag-Au deposits, eastern Finland. In: Marttila, M. (editor) Archaean geology of the Fennoscandian Shield: Proceedings of a Finnish-Soviet symposium in Finland on July 28 – August 7, 1986. Geological Survey of Finland, Special Paper 4, 131–144.

Korhonen, J. (compiler) 1980. Suomen aeromagneettinen kartta – Flygmagnetiska kartan över Finland – The aeromagnetic map of Finland 1 : 2 000 000. Espoo: Geological Survey of Finland.

Korhonen, J. & Säävuori, H. 1985. Regional interpretation of aerogeophysical and petrophysical data from the Peräpohja area, northern Finland. Geoexploration 23 (3), 440.

Korkalo, T. 1977. The Pahtavuoma Cu-mineralisation. Studies conducted in the area. In: Prospecting in Areas of Glaciated Terrain, August 1977, Finland, Excursion guide. London: The Institute of Mining and Metallurgy, 14–17.

Korkiakoski, E.A. 1992. Geology and geochemistry of the metakomatiite-hosted Pahtavaara gold deposit in Sodankylä, northern Finland, with emphasis on hydrothermal alteration. Geological Survey of Finland, Bulletin 360. 96 p.

Korkiakoski, E.A., Karvinen, A. & Pulkkinen, E. 1989. Geochemistry and hydrothermal alteration of the komatiite-hosted Pahtavaara gold mineralization, Finnish Lapland. In: Autio, S. (editor) Geological Survey of Finland. Current Research 1988. Geological Survey of Finland, Special Paper 10, 83–89.

Korkiakoski, E. A. & Kilpelä, M. 1997. The komatiite-hosted Pahtavaara gold mine near Sodankylä, northern Finland. In: Korkiakoski, E. & Sorjonen-Ward, P. (editors) Research and exploration – where do they meet? 4th Biennial SGA Meeting, August 11–13, 1997, Turku, Finland, Excursion guide B1 – Ore deposits of Lapland in northern Finland and Sweden. Geological Survey of Finland, Guide 43, 27–29.

Korsman, K. (editor) 1988. Tectono-metamorphic evolution of the Raahe-Ladoga zone. Geological Survey of Finland, Bulletin 343. 96 p.

Korsman, K., Koistinen, T., Kohonen, J., Wennerström, M., Ekdahl, E., Honkamo, M., Idman, H. & Pekkala, Y. 1997. Suomen kallioperäkartta – Berggrundskarta över Finland – Bedrock map of Finland 1:1 000 000. Espoo: Geological Survey of Finland.

Korvuo, E. 1997. The Saattopora gold ore and the Pahtavuoma Cu-Z-U occurrences in the Kittilä region. Northern Finland. In: Korkiakoski, E. & Sorjonen-Ward, P. (editors) Research and exploration – where do they meet? 4th Biennial SGA Meeting, August 11–13, 1997, Turku, Finland. Excursion Guide B1 – Ore deposits in Finnish and Swedish Lapland. Geological Survey of Finland, Guide 43, 21–25.

Kousa, J., Luukas, J., Mäki, T., Ekdahl, E., Pelkonen, K., Papunen, H., Isomäki, O.-P., Penttilä, V.-J. & Nurmi, P. 1997. Geology and mineral deposits of the central Ostrobothnia. In: Weihed, P., Mäki, T. (editors) Research and exploration – where do they meet? 4th Biennial SGA Meeting, August 11–13, 1997, Turku, Finland, Excursion guide A2 – Volcanic hosted massive sulphide and gold deposits in the Skellefte district, Sweden and in western Finland. Geological Survey of Finland, Guide 41, 43–67.

Kouvo, O., Huhma, M. & Vuorelainen, Y. 1959. Natural cobalt analogue of pentlandite. American Mineralogist 44, 897–900.

Kouvo, O., & Vuorelainen, Y., 1958. Eskolaite, a new chromium mineral. American Mineralogist 43, 1098–1106.

Kramm, U., Kogarko, L.N., Kononova, V.A. & Vartiainen, H. 1993. The Kola alkaline province of the CIS and Finland: precise Rb-Sr ages define 380–360 Ma age range for all magmatism. Lithos 30 (1), 33–44.

Kranck, E. H. 1945. The molybdenum deposit at Mätäsvaara in Karelia (E. Finland). Geologiska Föreningens i Stockholm Förhandlingar 67, 325–350.

Kröner, A., Puustinen, K. & Hickman, M. 1981. Geochronology of an Archean tonalitic gneiss dome in northern Finland and its relation with unusual overlying volcanic conglomerate and komatiitic greenstone. Contributions to Mineralogy and Petrology 76, 33–41

Kujanpää, J. 1986. The Kemi chromite deposit. In: Gaál, G. (editor) Proterozoic mineral deposits in Central Finland. 7th IAGOD Symposium and Nordkalott Project Meeting (Luleå, 1986), Excursion guide no 5. Geological Survey of Sweden (SGU), Ser. Ca 63, 15–19.

Kulonpalo, M. & Marmo, V. 1955. Suomen molybdeenihohteista. Summary: On the molybdenite of Finland. Geological Survey of Finland, Geotechnical Publications 58. 46 p.

Kuosmanen, V. (editor) 1988. Exploration target selection by integration of geodata using statistical and image processing techniques: An example from Central Finland, Part II, Atlas. Geological Survey of Finland, Report of Investigation 84. 47 p.

Kuosmanen, V., Arkimaa, H., Lindqvist, E. 1985. Structural positions of predicted and known Cu-Zn ore indications. In: Proceedings of the International Symposium on Remote Sensing of Environment. 4th thematic conference: Remote sensing for exploration geology, 1–4 April 1985, San Francisco, California, Vol. 1. Ann Arbor, MI: Environment Research Institute of Michigan, 57–71.

Kuosmanen, V., Arkimaa, H., Vanhanen, E., Talvitie, J. & Laaksonen, J. 1991. Study on integrated landsat imagery, NIR aerovideo and aerogeophysical data for selecting gold prospecting targets in the Kuusamo area, northeastern Finland. In: Putkonen, J. (editor) 11th Annual International Geoscience and Remote Sensing Symposium IGARSS'91, Espoo, Finland, June 3–6, 1991. 4. New York: IEEE, 2069–2073.

Kuosmanen, V., Kuivamäki, A. & Tumanto, M. 1982. Potential Ni-ore fields in Lake Ladoga-Bothnian Bay zone inferred from Bouguer gravity and remote sensing data. The Photogrammetric Journal of Finland 9 (1), 9–20.

Kurki, J. 1989. Granitoids and Mo mineralization at Aittojärvi. In: Gaál, G. (editor) Symposium Precambrian granitoids. Petrogenesis, geochemistry and metallogeny, August 14–17, 1989, Helsinki, Finland, Excursion C-3 – Archean granitoids and associated Mo, W and Au mineralization in eastern Finland. Geological Survey of Finland, Guide 25, 16–18.

Kurki, J. & Papunen, H. 1985. Geology and nickel-copper deposits of the Kianta area, Suomussalmi. In: Papunen, H. & Gorbunov, G. I. (editors) Nickel-copper deposits of the Baltic Shield and Scandinavian Caledonides. Geological Survey of Finland, Bulletin 333, 155–161.

Laajoki, K. 1975a. On the stratigraphic position of kaolin in Väyrylänkylä, South Puolanka area, Finland. Bulletin of the Geological Society of Finland 47 (1–2), 83–91.

Laajoki, K. 1975b. Rare-earth elements in Precambrian iron formations in Väyrylänkylä, South Puolanka area, Finland. Bulletin of the Geological Society of Finland 47 (1–2), 93–107.

Laajoki, K. 1985. Precambrian banded iron formations of Finland. Krystalinikum 18, 75–95.

Laajoki, K. 1986. Main features of the Precambrian banded iron-formations of Finland. Journal of The Geological Society of India 28 (2–3), 251–270.

Laajoki, K., Ervamaa, P., Havola, M., Heino, T., Kangas, R. & Strand, K. 1983. The Proterozoic Kainuu Schist Belt. In: Laajoki, K. & Paakkola, J. (editors) Exogenic processes and related metallogeny in the Svecokarelian geosynclinal complex. Geological Survey of Finland, Guide 11, 34–85.

Laajoki, K. & Gehör, S. 1990. The Precambrian iron-formations of Finland and their tectono-sedimentary settings. In: Farrell, L. (editor) Ancient banded iron formations (regional presentations). Athens: Theophrastus Publications, 445–462.

Laajoki, K. & Lavikainen, S. 1977. Rare-earth elements in the

Archean iron formation and associated Schists in Ukkolanvaara, Ilomantsi, SE Finland. Bulletin of the Geological Society of Finland 49 (2), 105–123.

Laajoki, K. & Saikkonen, R. 1977. On the geology and geochemistry of the Precambrian iron formations in Väyrylänkylä, South Puolanka area, Finland. Geological Survey of Finland, Bulletin 292. 137 p.

Lahti, S. I. 1981. On the granitic pegmatites of the Eräjärvi area in Orivesi, southern Finland. Geological Survey of Finland, Bulletin 314. 82 p.

Lahti, S. I., Johanson, B. & Virkkunen, M. 1983. Contributions to the chemistry of tapiolite – manganotapiolite, a new mineral. Bulletin of the Geological Society of Finland 55 (2), 101–109.

Lahtinen, J. J. 1985. PGE-bearing copper-nickel occurrences in the marginal series of the Early Proterozoic Koillismaa layered intrusion, northern Finland. In: Papunen, H. & Gorbunov, G. I. (editors) Nickel-copper deposits of the Baltic Shield and Scandinavian Caledonides. Geological Survey of Finland, Bulletin 333, 161–178.

Lahtinen, J. J., Alapieti, T. T., Halkoaho, T. A. A., Huhtelin, T. A. & Iljina, M. J. 1989. PGE mineralization in the Tornio-Näränkävaara layered intrusion Belt. In: Alapieti, T. (editor) 5th International Platinum Symposium: Guide to the post-symposium field trip, August 4–11, 1989. Geological Survey of Finland, Guide 29, 43–58.

Lahtinen, R. 1989. Application of the zoning of ore-associated elements to exploration for volcanogenic massive sulphide deposits – A case study of the Pukkiharju Zn-Cu prospect, Central Finland. Journal of Geochemical Exploration 32 (1–3), 395–398.

Laine, E. 2002. 3D structural modelling of gold deposits relative to tectonic history at Kutemajärvi and Pampalo gold deposits in Finland. In: Bayer, U., Burger, H. & Skala, W. (editors) 8th Annual Conference of the International Association for Mathematical Geology, September 15–20, 2002, Berlin, Germany, Vol. 2. Terra nostra, Schriften der Alfred-Wegener-Stiftung 04/2002, 99–104.

Laitakari, A. 1929. Über den Schwefelkies von Outokumpu. Bulletin of the Geological Society of Finland 1, 42–43; also Geological Survey of Finland, Bulletin 85, 42–43.

Laitakari, A. 1931. Verdrängungen in sulphidmineralien von Pitkäranta und Outokumpu. Bulletin of the Geological Society of Finland 4, 55–64; also Geological Survey of Finland, Bulletin 93, 55–63.

Lamberg, P., Välimaa, J., Parkkinen, J. & Kojonen, K. 2005. Structural, geochemical and magmatic modelling of the early Proterozoic Keivitsa Ni-Cu-PGE deposits in Sodankylä, northern Finland. In: Törmänen, T. O. & Alapieti, T. T. (editors) The 10th International Platinum Symposium: Platinum-group elements, from genesis to beneficiation and environmental impact, August 8–11, 2005, Oulu, Finland, Extended abstracts. Espoo: Geological Survey of Finland, 160–163.

Lamoen van, H. 1977. Microtextures and microintergrowths of iron-titanium-aluminium oxide minerals in a magmatic titaniferous iron ore from Attu island, southwestern Finland. Bulletin of the Geological Society of Finland 49 (2), 89–104.

Lamoen van, H. 1979. Coronas in olivine gabbros and iron ores from Susimäki and Riuttamaa, Finland. Contributions to Mineralogy and Petrology 68 (3), 259–268.

Latvalahti, U. 1979. Cu-Zn-Pb ores in the Aijala-Orijarvi area, southwestern Finland. Economic Geology 74 (5), 1035–1068.

Launay de, L. 1913. Traité de métallogénie, gîtes minéraux et métallifères, 3 Vol. Paris: Ch. Béranger. Paris.

Lawrie, K. C. 1987. The origin, nature and tectonic significance of the Hällinmäki Cu-deposit, Virtasalmi District, South-Central Finland. Glasgow: University of Glasgow. ix, 297 p.

Laznicka, P. 1993. Precambrian empirical metallogeny: Precambrian lithologic associations and metallic ores, Vol. 2 – Empirical metallogeny, Part a. Developments in Economic Geology 29. Amsterdam: Elsevier. 996 s.

Lee, M. J., Garcia, D., Moutte, J., Wall, F., Williams, C. T. & Woolley, A. R. 1999. Pyrochlore and whole rock chemistry of carbonatites and phoscorites at Sokli, Finland. In: Stanley, C. J. [et al.] (editors) Mineral deposits – Processes to processing: Proceedings of the 5th Biennial SGA Meeting and the 10th Quadrennial IAGOD Symposium, London, United Kingdom, 22–25 August 1999, Vol. 1. Rotterdam: A.A. Balkema, 651–653.

Lehtinen, M., Nurmi, P. A. & Rämö, O. T. (editors) 2005. Precambrian geology of Finland – Key to the evolution of the Fennoscandian Shield. Amsterdam: Elsevier Science. 736 p.

Lehto, T. & Niiniskorpi, V. 1977. Pohjois- ja Itä-Suomen rautamuodostumat. Summary: The iron-formations of northern and eastern Finland. Geological Survey of Finland, Report of Investigation 22. 49 p.

Lehtonen, M. 1988. On the geology of the Muonio Area, western Finnish Lapland. In: Marttila, E. (editor) Archaean geology of the Fennoscandian Shield: Proceedings of the Finnish-Soviet symposium, Finland, July 28 – August 7, 1986. Geological Survey of Finland, Special Paper 4, 189–199.

Lehtonen, M., Airo, M-L., Eilu, P., Hanski, E., Kortelainen, V., Lanne, E., Manninen, T., Rastas, P., Räsänen, J. & Virransalo, P. 1998. Kittilän vihreäkivialueen geologia. Summary: The stratigraphy, petrology and geochemistry of the Kittilä greenstone area, northern Finland. Geological Survey of Finland, Report of Investigation 140. 144 p.

Lehtonen, M., Rastas, P. & Väänänen, J. 1985. Geological map of western Finnish Lapland, 1:200 000. Espoo: Geological Survey of Finland.

Lerssi, J., Pernu, T., Keränen, T. & Iljina, M. 1991. A geophysical study of the Suhanko-Konttijärvi layered intrusion in connection with PGE investigations. Geologiska Föreningens i Stockholm Förhandlingar 113 (1), 55–56.

Liipo, J. 1999. Mineralogical studies from the early Proterozoic and Archean ultramafic rocks from eastern Finland, emphasis on chromite as a petrogenetic indicator. Res Terrae, Ser. A 15. 100 p.

Liipo, J. & Laajoki, K. 1991. Mineralogy, geochemistry and metamorphism of the early Proterozoic Vähäjoki iron ores, northern Finland. Bulletin of the Geological Society of Finland 63 (2), 69–85.

Liipo, J., Vuollo, J., Nykänen, V., Piirainen, T., Pekkarinen, L. & Tuokko, I. 1995. Chromites from the early Proterozoic Outokumpu-Jormua Ophiolite Belt: A comparison with chromites from Mesozoic ophiolites. Lithos 36 (1), 15–27.

Liipo, J., Papunen, H., Kilpeläinen, T. & Lamberg, P. 1997. The Stormi ultramafic complex and associated Ni-Cu deposits. In: Ehlers, C. (editor) Research and exploration – where do they meet? The 4th Biennial SGA Meeting, August 11–13, 1997, Turku, Finland, Excursion guide B3 – Gold and base metal deposits in southwestern Finland. Geological Survey of Finland, Guide 44, 12–15.

Lindmark, B. 1986. Tungsten mineralization at Kangasala. In: Gaál, G. (editor) The 17th Nordic Geologists' Meeting, Helsinki, 1986, Excursion guide, excursion C 3 – Metallogeny and ore deposits of South Finland. Geological Survey of Finland, Guide 16, 61–62.

Lindroos, A., Romer, R. L., Ehlers, C. & Alviola, R. 1996. Late-orogenic Svecofennian deformation in southwestern Finland constrained by pegmatite emplacement ages. Terra Nova 8 (6), 567–574.

Long, J.V.P., Vuorelainen, Y. & Kouvo, O. 1963. Karelianite, a new vanadium mineral. American Mineralogist 48, 33–41.

Loukola-Ruskeeniemi, K. 1989. Early Proterozoic metamorphosed black shales in the Kainuu Schist Belt and in the

Outokumpu region. In: Autio, S. (editor) Geological Survey of Finland. Current Research 1988. Geological Survey of Finland, Special Paper 10, 103–106.

Loukola-Ruskeeniemi, K. 1991. Geochemical evidence for the hydrothermal origin of sulphur, base metals and gold in Proterozoic metamorphosed black shales, Kainuu and Outokumpu areas, Finland. Mineralium Deposita 26 (2), 152–164.

Loukola-Ruskeeniemi, K. 1995a. Origin of the Talvivaara black-shale-hosted Ni-Cu-Zn deposit, eastern Finland. In: Autio, S. (editor) Geological Survey of Finland, Current Research 1993–1994. Geological Survey of Finland, Special Paper 20, 31–46.

Loukola-Ruskeeniemi, K. 1995b. Platinum, palladium, rhodium, and iridium concentrations in Early Proterozoic black schists, Finland – Origin in seafloor hydrothermal processes. In: Pasava, J., Kríbek, B. & Zák, K. (editors) Mineral deposits: From their origin to their environmental impacts. Rotterdam: A. A. Balkema, 777–780.

Loukola-Ruskeeniemi, K. 1997. The Talvivaara black schist-hosted Ni-Cu-Zn occurrence: geochemistry, genesis and environmental considerations. In: Loukola-Ruskeeniemi, K. & Sorjonen-Ward, P. (editors) Research and exploration – where do they meet? The 4th Biennial SGA Meeting, August 11–13, 1997, Turku, Finland, Excursion guide A4 – Ore deposits in eastern Finland. Geological Survey of Finland, Guide 42, 57–59.

Loukola-Ruskeeniemi, K. 1999. Origin of black shales and the serpentinite-associated Cu-Zn-Co ores in Outokumpu, Finland. In: Gize, A. P. (editor) A special issue on organic matter and ore deposits: Interactions, applications, and case studies. Economic Geology 94 (7), 1007–1028.

Loukola-Ruskeeniemi, K., Gaál, G. & Karppanen, T. 1991. Geochemistry, structure and genesis of the Hammaslahti copper mine – explorational tools for a sediment-hosted massive sulphide deposit. Geological Survey of Finland, Special Paper 12, 101–106.

Loukola-Ruskeeniemi, K., Gaál, G. & Karppanen, T. 1992. Geochemical and structural characteristics of a sediment-hosted copper deposit at Hammaslahti, Finland: Comparison with Besshi-type massive sulphide deposits. In: Maurice, Y. T. (editor) Proceedings of the 8th Quadrennial IAGOD Symposium, Ottawa, Canada, August 12–18, 1990. Stuttgart: E. Schweizerbart'sche Verlagsbuchhandlung, 551–569.

Loukola-Ruskeeniemi, K. & Heino, T. 1993. Black shale-hosted, low grade Ni-Cu-Zn deposit at Talvivaara, Finland. In: Fenoll Hach-Ali, P., Torres-Ruiz, J. & Gervilla, F. (editors) Current research in geology applied to ore deposits: Proceedings of the 2nd Biennal SGA Meeting, Granada, 9–11 September 1993. Granada: University of Granada, 339–342.

Loukola-Ruskeeniemi, K. & Heino, T. 1996. Geochemistry and genesis of the black shale-hosted Ni-Cu-Zn deposit at Talvivaara, Finland. Economic Geology 91, 80–110.

Loukola-Ruskeeniemi, K., Heino, T., Talvitie, J. & Vanne, J. 1991. Base-metal-rich metamorphosed black shales associated with Proterozoic ophiolites in the Kainuu Schist Belt, Finland: A genetic link with the Outokumpu rock assemblage. Mineralium Deposita 26, 143–151.

Loukola-Ruskeeniemi, K., Kantola, M., Halonen, T., Seppänen, K., Henttonen, P., Kallio, E., Kurki, P. & Savolainen, H. 2003. Mercury-bearing black shales and human Hg intake in eastern Finland: impact and mechanisms. Environmental Geology 43 (3), 283–297.

Loukola-Ruskeeniemi, K., Kontinen, A. & Airo, M.-L. 1997a. Kainuu district. In: Loukola-Ruskeeniemi, K. & Sorjonen-Ward, P. (editors) Research and exploration – where do they meet? The 4th Biennial SGA Meeting, August 11–13, 1997, Turku, Finland, Excursion guide A4 – Ore deposits in eastern Finland. Geological Survey of Finland, Guide 42, 57–64.

Loukola-Ruskeeniemi, K., Kuronen, U. & Arkimaa, H. 1997b. Geochemical comparison of metamorphosed black shales associated with the Vihanti zinc deposit and prospects in western Finland. In: Autio, S. (editor) Geological Survey of Finland, Current Research 1995–1996. Geological Survey of Finland, Special Paper 23, 5–13.

Loukola-Ruskeeniemi, K., Pakkanen, L. & Hladikova, J. 1999a. Genesis of Cu-Co-Zn ores and associated black shales in Outokumpu, Finland. In: Stanley, C. J....[et al.] (editors) Mineral deposits – Processes to processing: Proceedings of the 5th Biennial SGA Meeting and the 10th Quadrennial IAGOD Symposium, London, United Kingdom, 22–25 August 1999. Vol. 1. Rotterdam: A. A. Balkema, 247–250.

Loukola-Ruskeeniemi, K., Paukola, T., Uutela, A., Tenhola, M. 1999b. The palaeo-environmental impact of a black shale-hosted Ni-Cu-Zn deposit at Talvivaara, Finland. In: Stanley, C. J. ... [et al.] (editors) Mineral deposits – Processes to processing: Proceedings of the 5th Biennial SGA Meeting and the 10th Quadrennial IAGOD Symposium, London, United Kingdom, 22–25 August 1999, Vol. 2. Rotterdam: A. A. Balkema, 1199–1202.

Loukola-Ruskeeniemi, K., Uutela, A., Tenhola, M. & Paukola, T. 1998. Environmental impact of metalliferous black shales at Talvivaara in Finland, with indication of lake acidification 9000 years ago. In: Gough, L. P. & Marsh, S. P. (editors) The 4th International Symposium on Environmental Geochemistry (4th ISEG), Part I. Journal of Geochemical Exploration 64 (1–3), 395–407.

Lukkarinen, H. 1986. The leptite zone in the Orijärvi-Aijala area, southwestern Finland. In: Laitala, M. (editor) The 17th Nordic Geologists' Meeting, 1986: Excursion guide, Excursion A 1 – Precambrian geology, southern Finland. Geological Survey of Finland, Guide 14, 9–15.

Lundqvist, T. & Autio, S. (editors); Bøe, R., Kousa, J., Lukkarinen, H., Pipping, F., Roberts, D., Stephens, M. B., Tontti, M. & Winterhalter, B. 2000. Description to the bedrock map of central Fennoscandia (Mid-Norden). Geological Survey of Finland. Special Paper 28. 176 p.

Lupander, K. & Räisänen, W. K. 1954. The Haveri mine. In: Aurola, E. (editor) The mines and quarries of Finland. Geological Survey of Finland, Geotechnical Publications 55, 47–52.

Luukkonen, A. 1994. Main geological features, metallogeny and hydrothermal alteration phenomena of certain gold and gold-tin-tungsten prospects in southern Finland. Geological Survey of Finland, Bulletin 377. 153 p.

Luukkonen, A., Grönholm, P. & Hannila, T. 1992. Eräiden Etelä-Suomen kulta- ja sen seuralaismetalliesiintymien geologiset pääpiirteet. Summary: Main geological features of certain gold and tungsten-tin-gold prospects in southern Finland. Geological Survey of Finland, Report of Investigation 113. 90 p.

Luukkonen, A., Grönholm, P. & Hannila, T. 1997a. Gold prospect west of the Jokisivu village, Huittinen. In: Ehlers, C. (editor) Research and exploration – where do they meet? The 4th Biennial SGA Meeting, August 11–13, 1997, Turku, Finland, Excursion guide B3 – Gold and base metal deposits in southwestern Finland. Geological Survey of Finland, Guide 44, 8–11.

Luukkonen, A., Grönholm, P. & Hannila, T. 1997b. The Kutemajärvi gold deposit. In: Ehlers, C. (editor) Research and exploration – where do they meet? The 4th Biennial SGA Meeting, August 11–13, 1997, Turku, Finland, Excursion guide B3 – Gold and base metal deposits in southwestern Finland. Geological Survey of Finland, Guide 44, 16–19.

Mäkelä, K. 1980. Geochemistry and origin of Haveri and Kiipu, Proterozoic strata-bound volcanogenic gold-copper and zinc mineralizations from southwestern Finland. Geological Survey of Finland, Bulletin 310. 79 p.

Mäkelä, M. 1974. A study of sulfur isotopes in Outokumpu ore deposit, Finland. Geological Survey of Finland, Bulletin 267. 45 p.

Mäkelä, M. 1977. Sulfur isotope stratigraphy in some Finnish ore deposits. Geologiska Föreningens i Stockholm Förhandlingar 99 (2:569), 163–171.

Mäkelä, M., Sandberg, E. & Rantala, O. 1988a. Geochemical exploration of gold-bearing veins associated with granitoids in western Finland. In: MacDonald, D. R. & Mills, K. A. (editors) Prospecting in Areas of Glaciated Terrain 1988: Papers presented at the 8th International Symposium on Prospecting in Areas of Glaciated Terrain, Halifax, Nova Scotia, August 28 – September 3, 1988. London: The Institution of Mining and Metallurgy, 255–270.

Mäkelä, M., Sandberg, E. & Rantala, O. 1988b. Proterozoic, gold-bearing vein occurrences associated with the granitoids in western Finland. In: Goode, A. D. T. ... [et el.] (editors) Bicentennial Gold 88, Melbourne, Victoria, May 16–20, 1988, Extended abstracts, poster programme 1. Geological Society of Australia, Abstracts Series 23, 153–155.

Mäkelä, M. & Tammenmaa, J. 1978. Lapin rikki-isotooppitutkimus vuosina 1974–1976. Summary: Sulfur isotope studies in Finnish Lapland, 1974–1976. Geological Survey of Finland, Report of Investigation 24. 64 p.

Mäkelä, U. 1983. On the geology of the Aijala-Orijärvi area, southwest Finland. In: Laajoki, K. & Paakkonen, J. (editors) Exogenic processes and related metallogeny in the Svecokarelian geosynclinal complex. Geological Survey of Finland, Guide 11, 140–160.

Mäkelä, U. 1989. Geological and geochemical environments of Precambrian sulphide deposits in southwestern Finland. Annales Academiae Scientiarum Fennicae, Series A.III, Geologica – Geographica 151. 102 p.

Mäki, T. 1986. Lithogeochemistry of the Pyhäsalmi zinc-copper-pyrite deposit, Finland. In: Prospecting in areas of glaciated terrain 1986: Papers presented at the 7th international symposium organized by The Institution of Mining and Metallurgy and The Geological Survey of Finland, Kuopio, 1–2 September, 1986. London: The Institution of Mining and Metallurgy, 69–82.

Mäki, T. & Luukas, J. 2001. Structural control of the Pyhäsalmi VMS-deposit in the Palaeoproterozoic Raahe-Ladoga Zone, Central Finland. In: Williams, P. J. (editor) 2001: A hydrothermal odyssey – New developments in metalliferous hydrothermal systems research, Extended conference abstracts, May 17–19th, 2001, Townsville, Queensland, Australia. Queensland: James Cook University of North Queensland, Economic Geology Research Unit (EGRU), Contribution 59, 122–123.

Mäkinen, E. 1938. Die Kupfererzlagerstätte Outokumpu in Finnland und ihre Verwertung. Metall und Erz, 1938 (2), 25–33.

Mäkinen, J. 1987. Geochemical characteristics of Svecokarelidic mafic-ultramafic intrusions associated with Ni-Cu occurrences in Finland. Geological Survey of Finland, Bulletin 342. 109 p.

Mäkinen, J. & Makkonen, H. V. 2004. Petrology and structure of the Palaeoproterozoic (1.9 Ga) Rytky nickel sulphide deposit, Central Finland – A comparison with the Kotalahti nickel deposit. Mineralium Deposita 39 (4), 405–421.

Mäkitie, H., Kärkkäinen, N., Lahti, S. I. & Alviola, R. 2001. Compositional variation of granitic pegmatites in relation to regional metamorphism in the Seinäjoki region, western Finland. In: Mäkitie, H. (editor) Svecofennian granitic pegmatites (1.86–1.79 Ga) and quartz monzonite (1.87 Ga), and their metamorphic environment in the Seinäjoki region, western Finland. Geological Survey of Finland, Special Paper 30, 31–59.

Makkonen, H. V. 1996. 1.9 Ga tholeiitic magmatism and related Ni-Cu deposition in the Juva area, SE Finland. Geological Survey of Finland, Bulletin 386. 101 p.

Makkonen, H. & Ekdahl, E. 1988. Petrology and structure of the Early Proterozoic Pirilä gold deposit in southeastern Finland. Bulletin of the Geological Society of Finland 60, 55–66.

Mancini, F. & Papunen, H. 2000. Metamorphism of Ni-Cu sulfides in mafic-ultramafic intrusions: The Svecofennian Sääksjärvi complex, southern Finland. In: Spry, P. G., Marshall, B. & Vokes, F. M. (editors) Metamorphosed and metamorphogenic ore deposits. Reviews in Economic Geology 11, 217–231.

Mänttäri, I. 1995. Lead isotope characteristics of epigenetic gold mineralization in the Palaeoproterozoic Lapland Greenstone Belt, northern Finland. Geological Survey of Finland, Bulletin 381. 70 p.

Mänttäri, I., Luukkonen, A., Grönholm, P. 1997. Isotopic studies on the Kutemajärvi gold deposit, Orivesi, southern Finland. In: Autio, S. (editor) Geological Survey of Finland, Current Research 1995–1996. Geological Survey of Finland, Special Paper 23, 55–58.

Marcos, N. 1996. The Hyrkkölä native copper mineralization as a natural analogue for copper canisters. Tiivistelmä: Hyrkkölän luonnonkupariesiintymä kuparikanisterin luonnonanalogiana. Posiva-raportti 96–15. 39 p.

Marcos, N. & Ahonen, L. 1999. New data on the Hyrkkölä U-Cu mineralization: the behaviour of native copper in a natural environment. Tiivistelmä: Hyrkkölän U-Cu analogia: metallisen kuparin käyttäytyminen luonnollisessa ympäristössä. Posiva-raportti 99–23. 78 p.

Marcos, N., Ahonen, L., Bros, R., Roos, P., Suksi, J. & Oversby, V. 1999. New data on the Hyrkkölä native copper mineralization: a natural analogue for the long-term corrosion of copper canisters. In: Wronkiewicz, D. J. & Lee, D. J. (editors) Scientific Basis for Nuclear Waste Management XXII. Materials Research Society Symposium Proceedings 556, 825–832.

Marmo, V. 1955. A small nickeliferous subsilicic cluster in Puumala, southeastern Finland. Bulletin of the Geological Society of Finland 28, 1–12; also Geological Survey of Finland, Bulletin 168, 1–12.

Marmo, V., Hoffrén, V., Hytönen, K., Kallio, P., Lindholm, O. & Siivola, J. 1966. On the granites of Honkamäki and Otanmäki, Finland, with special reference to the mineralogy of accessories. Geological Survey of Finland, Bulletin 221. 34 p.

Marshall, B. & Mancini, F. 1994. Major- and minor-element mobilization with implications for Ni-Cu-Fe-sulphide remobilization during retrograde metasomatism at the Vammala mine, southwestern Finland. Chemical Geology 116 (3–4), 203–227.

Marshall, B. & Mancini, F. 1995. Metasomatic depletion of Ni-Cu-Fe sulphides, Vammala Mine, Finland. Mineralogy and Petrology 55 (4), 309–321.

Merkle, R. 1982. Geochemische Untersuchungen zur Genese des Erzvorkommens Riihilahti/Finnland. Mainz: Johannes Gutenberg-Universität. 304 p.

Mikkola, A. K. 1948. The Vähäjoki iron ore in Tervola, northern Finland. Bulletin of the Geological Society of Finland 20, 261–280; also Geological Survey of Finland, Bulletin 140, 261–280.

Mikkola, A. K. 1963. On the sulphide mineralization in the Vihanti zinc deposit, Finland. Geological Survey of Finland, Bulletin 205. 44 p.

Mikkola, A. K. 1966. Jussarön malmikenttä – Jussarö malmfält. Summary: Jussarö ore field. Vuoriteollisuus – Bergshanteringen 24 (2), 55–70.

Mikkola, A. K. 1969. Aspects of the wallrock alteration associated with some Finnish sulphide deposits: A review. Institution of Mining and Metallurgy, Transactions 78, Sect. B, Bulletin 750, 65–71.

Mikkola, A. K. 1980. The metallogeny of Finland. Geological Survey of Finland Bulletin 305. 22 p.

Mikkola, A. K. & Niini, H. 1968. Structural position of ore-bearing areas in Finland. Bulletin of the Geological Society of Finland 40, 17–33.

Mikkola, A. K. & Rouhunkoski, P. 1980. The copper deposits and their metallogeny in southern Finland. In: Jankovic, S. &

Sillitoe, R. H. (editors) European copper deposits: Proceedings of an international symposium held at Bor, Yugoslavia, 18–22 September 1979. Belgrade University, Faculty of Mining and Geology, 180–187.

Mikkola, A. K. & Väisänen, S. E. 1972. Remobilization of sulphides in the Outokumpu and Vihanti ore deposits, Finland. In: Gill, J. E. (editor) International Geological Congress, 24th session, Montreal 1972, Section 4 – Mineral deposits, 488–497.

Mining Magazine 1982. Rautuvaara and Hannukainen mines. Mining Magazine 147 (2), 101–111.

Mozgova, N. N., Borodayev, Yu. S., Ozerova, N. A., Pääkkönen, V., Sveshnikova, O. L., Balitskiy, V. S. & Dorogovin, B. A. 1977. Seinäjokite, (Fe0.8Ni0.2) (Sb1.7As0.3), and antimonian westerveldite, Fe(As0.95Sb0.05) from Seinäjoki, Finland. International Geology Review 19 (11), 1357-1368.

Mutanen, T. 1989. The Koitelainen intrusion and the Keivitsa-Satovaara complex, Excursion Guide to the 5th International Platinum Symposium. Geological Survey of Finland, Guide 28. 49 p.

Mutanen, T. 1996. The Akanvaara and Koitelainen intrusions and the Keivitsa-Satovaara complex: Guide to the pre-symposium field trip in Finland, August 20–21, 1996. Rovaniemi: Geological Survey of Finland. 113 p.

Mutanen, T. 1997. Geology and ore petrology of the Akanvaara and Koitelainen mafic layered intrusions and the Keivitsa-Satovaara layered complex, northern Finland. Geological Survey of Finland, Bulletin 395. 233 p.

Mutanen, T. 2005. Field trip guidebook: The Akanvaara intrusion and the Keivitsa-Satovaara Complex, with stops at the Kaikkivaltiaanlehto and Särkivaara intrusions. Geological Survey of Finland, Guide 51b. 124 p.

Mutanen, T. & Huhma, H. 2001. U-Pb geochronology of the Koitelainen, Akanvaara and Keivitsa layered intrusions and related rocks. In: Vaasjoki, M. (editor) Radiometric age determinations from Finnish Lapland and their bearing on the timing of Precambrian volcano-sedimentary sequences. Geological Survey of Finland, Special Paper 33, 229–246.

Niiranen, T. & Eilu, P. 2003. Iron oxide-copper-gold deposits in northern Finland. In: Eliopoulos, D. G. ... [et al.] (editors) Mineral exploration and sustainable development: Proceedings of the 7th Biennial SGA Meeting, Athens, Greece, 24–28 August 2003, Vol. 2. Rotterdam: Millpress, 1091–1094.

Niiranen, T., Hanski, E. & Eilu, P. 2003. General geology, alteration, and iron deposits in the Palaeoproterozoic Misi region, northern Finland. Bulletin of the Geological Society of Finland 75 (1–2), 69–92.

Niiranen, T., Mänttäri, I., Poutiainen, M., Oliver, N. H. S. & Miller, J. A. 2005. Genesis of Palaeoproterozoic iron skarns in the Misi region, northern Finland. Mineralium Deposita 40 (2), 192–217.

Niiranen, T., Poutiainen, M. & Mänttäri, I. 2005b. Geochemistry, alteration, fluid inclusion characteristics, and U-Pb age data on iron oxide-Cu-Au deposits in the Kolari region, northern Finland. Ore Geology Reviews (accepted).

Nironen, M. 1989a. Emplacement and structural setting of granitoids in the early Proterozoic Tampere and Savo Schist Belts, Finland – Implications for contrasting crustal evolution. Geological Survey of Finland, Bulletin 346. 83 p.

Nironen, M. 1989b. The Tampere Schist Belt: Structural style within an Early Proterozoic volcanic arc system in southern Finland. Precambrian Research 43 (1–2), 23–40.

Nironen, M. 1994. Structural control and (re)mobilization of the extinct Haveri Au-Cu deposit, southern Finland. Bulletin of the Geological Society of Finland 66 (1), 39–44.

Nironen, M. & Csongrádi, J. 1984. Characteristics of the Proterozoic porphyry-type Cu occurrence at Tienpää, Halsua, western Finland. Bulletin of the Geological Society of Finland 56 (1–2), 89–97.

Nironen, M. & Front, K. 1992. The 1.88 Ga old Mäntylä complex, Central Finland: emplacement and deformation of mafic to felsic plutonic rocks and associated Mo mineralization. Bulletin of the Geological Society of Finland 64 (1), 75–90.

Nironen, M., Lahtinen, R. & Koistinen, T. 2002. Suomen geologiset aluenimet – yhtenäisempään nimikäytäntöön. Summary: Subdivision of Finnish bedrock – An attempt to harmonize terminology. Geologi 54 (1), 8–14.

Nurmi, P. A. 1984. Applications of lithogeochemistry in the search for Proterozoic porphyry-type molybdenum, copper and gold deposits, southern Finland. Geological Survey of Finland, Bulletin 329. 40 p.

Nurmi, P. A. 1985. Lithogeochemistry in exploration for Proterozoic porphyry-type molybdenum and copper deposits, southern Finland. Journal of Geochemical Exploration 23 (2), 163–191.

Nurmi, P. A. & Haapala, I. 1986. The Proterozoic granitoids of Finland – Granite types, metallogeny and relation to crustal evolution. Bulletin of the Geological Society of Finland 58 (1), 203–233.

Nurmi, P. A., Lestinen, P. & Niskavaara, H. 1991a. Geochemical characteristics of mesothermal gold deposits in the Fennoscandian Shield, and a comparison with selected Canadian and Australian deposits. Geological Survey of Finland, Bulletin 351. 101 p.

Nurmi, P. A., Lestinen, P. & Niskavaara, H. 1991b. Rare elements in mesothermal gold deposits of Finland: geochemical implications revealed by multivariate techniques. In: Autio, S. (editor) Geological Survey of Finland, Current Research 1989–1990. Geological Survey of Finland, Special Paper 12, 97–100.

Nurmi, P. A. & Sorjonen-Ward, P. (editors) 1993. Geological development, gold mineralization and exploration methods in the late Archean Hattu Schist Belt, Ilomantsi, eastern Finland. Geological Survey of Finland, Special Paper 17. 386 p.

Articles:

- Bornhorst, T. J. & Rasilainen, K. 1993. Mass transfer during hydrothermal alteration associated with Au mineralization within the late Archean Hattu Schist Belt, Ilomantsi, eastern Finland, 273–289.
- Bornhorst, T. J., Rasilainen, K. & Nurmi, P. A. 1993. Geochemical character of lithologic units in the late Archean Hattu Schist Belt, Ilomantsi, eastern Finland, 133–145.
- Bornhorst, T. J. & Wilkin, R. T. 1993. Fluid inclusion data for selected quartz from gold prospects in the late Archean Hattu Schist Belt, Ilomantsi, eastern Finland, 317–322.
- Hartikainen, A. & Nurmi, P. A. 1993. Till geochemistry in gold exploration in the late Archean Hattu Schist Belt, Ilomantsi, eastern Finland, 323–352.
- Huhta, P. 1993. The use of heavy mineral concentrates from till in gold exploration in the late Archean Hattu Schist Belt, Ilomantsi, eastern Finland, 363–372.
- Karhu, J. A., Nurmi, P. A. & O'Brien, H. E. 1993. Carbon and oxygen isotope ratios of hydrothermal carbonates associated with gold mineralization in the late Archean Hattu Schist Belt, Ilomantsi, eastern Finland, 307–316.
- Kojonen, K., Johanson, B., O'Brien, H. E. & Pakkanen, L. 1993. Mineralogy of gold occurrences in the late Archean Hattu Schist Belt, Ilomantsi, eastern Finland, 233–271.
- Nurmi, P. A. 1993. Genetic aspects of mesothermal gold mineralization and implications for exploration in the late Archean Hattu Schist Belt, Ilomantsi, eastern Finland, 373–386.
- Nurmi, P. A., Sorjonen-Ward, P. & Damstén, M. 1993. Geological setting, characteristics and exploration history of mesothermal gold occurrences in the late Archean Hattu Schist Belt, Ilomantsi, eastern Finland, 193–231.
- O'Brien, H. E., Nurmi, P. A. & Karhu, J. A. 1993. Oxygen, hydrogen and strontium isotopic compositions of gold min-

eralization in the late Archean Hattu Schist Belt, Ilomantsi, eastern Finland, 291–306.
- Rasilainen, K., Nurmi, P. A. & Bornhorst, T. J. 1993. Rock geochemical implications for gold exploration in the late Archean Hattu Schist Belt, Ilomantsi, eastern Finland, 353–362.
- Sorjonen-Ward, P. 1993. An overview of structural evolution and lithic units within and intruding the late Archean Hattu Schist Belt, Ilomantsi, eastern Finland, 9–102.

Nuutilainen, J. 1968. On the geology of the Misi iron ore province, northern Finland. Annales Academiae Scientiarum Fennicae, Series A.III, Geologica – Geographica 96. 98 p.

OECD 2002. Finland. In: Uranium 2001 – Resources, production and demand. Paris: Organisation for Economic Co-operation and Development (OECD), 154–158.

Ojala, J. (editor). Gold in the Central Lapland Greenstone Belt, Finland. Geological Survey of Finland, Special Paper (in press).

Articles:
- Airo, M.-L.: Application of aerogeophysical data for gold exploration.
- Eilu, P., Pankka, H., Keinänen, V., Kortelainen, V., Niiranen, T. & Pulkkinen, E.: The characteristics of the gold deposits in the Central Lapland Greenstone Belt.
- Holma M.: The Levijärvi Au-Ni occurrence, Kittilä, northern Finland.
- Hölttä, P. & Väisänen, M.: Structural and metamorphic evolution of the Central Lapland Greenstone Belt.
- Hulkki, H. & Keinänen, V.: The Hirvilavanmaa gold occurrence, Kittilä, northern Finland.
- Hulkki, H. & Pulkkinen, E.: The Kaaresselkä gold occurrence, Kittilä, northern Finland.
- Nurmi, P., Ojala, J. & Vanhanen, E.: An introduction to gold exploration in the Central Lapland Greenstone Belt.
- Ojala, J.: Paleostress modelling of the Central Lapland Greenstone Belt.
- Nykänen, V. & Salmirinne, H.: A prospectivity analysis of the Central Lapland Greenstone Belt.
- Patison, N.: Structural controls on gold mineralisation in the Central Lapland Greenstone Belt.
- Pulkkinen, E. & Kontio, M.: Use of till geochemistry for gold exploration in the Central Lapland Greenstone Belt.
- Salamis, G., Patison, N., Kortelainen, V. & Lindroos, H.: The world class Suurikuusikko gold deposit, Kittilä, northern Finland.
- Salmirinne, H.: The ground geophysical characteristics of gold occurrences in the Central Lapland Greenstone Belt.

Ojala, V. J., Pekkarinen, L. J., Piirainen, T. & Tuukki, P. A. 1990. The Archaean gold mineralization in Rämepuro, Ilomantsi Greenstone Belt, eastern Finland. Terra nova 2 (3), 240–244.

Outokumpu Oy & GoldFields Ltd. 2002, press release.

Paakkola, J. 1971. The volcanic complex and associated manganiferous iron formation of the Porkonen-Pahtavaara area in Finnish Lapland. Geological Survey of Finland, Bulletin 247. 83 p.

Pääkkönen, V. 1956. Otanmäki, the ilmenite-magnetite ore field in Finland. Geological Survey of Finland, Bulletin 171. 71 p.

Pääkkönen, V. 1966. On the geology and mineralogy of the occurrence of native antimony in Seinäjoki, Finland. Geological Survey of Finland, Bulletin 225. 70 p.

Paarma, H. 1954. The ilmenite-magnetite ore deposit in Otanmäki. Geological Survey of Finland, Geotechnical Publications 55, 36–42.

Paarma, H. & Levanto, A. 1958. Underground exploration in the Otanmäki mine. Mine & Quarry Engineering 24 (12). 9 p.

Pajunen, M. 1988. Tectono-metamorphic evolution of the Hallaperä pyrrhotite-pyrite ore deposit, Central Finland. In: Korsman, K. (editor) Tectono-metamorphic evolution of the Raahe-Ladoga zone. Geological Survey of Finland, Bulletin 343, 51–76.

Pakkanen, L. & Luukkonen, E. 1995. Native nickel and copper in the Kauniinvaara ultramafic body of the late Archaean Suomussalmi Greenstone Belt, eastern Finland. In: Autio, S. (editor) Geological Survey of Finland, Current Research 1993–1994. Geological Survey of Finland, Special Paper 20, 23–29.

Palmunen, M. K. 1925. On the Ilmenite-Magnetite-Olivinite of Susimäki. Fennia 45 (9), 1–27.

Pankka, H. S. 1992. Geology and mineralogy of the Au-Co-U deposits in the Proterozoic Kuusamo volcanosedimentary belt, northeastern Finland. Houghton: Michigan Technological University. 233 p.

Pankka, H. S. 1997. The epigenetic Au-Co-U deposits in an early Proterozoic continental rift of the northern Fennoscandian Shield: A new class of ore deposit? In: Papunen, H. (editor) Mineral deposits: Research and exploration – where do they meet? Proceedings of the 4th Biennial SGA Meeting, Turku /Finland/ August 11–13, 1997. Rotterdam: A. A. Balkema, 277–280.

Pankka, H. S. & Vanhanen, E. J. 1989. The aulacogen related epigenetic Au-Co-U deposits in northeastern Finland. In: Autio, S. (editor) Geological Survey of Finland, Current Research 1988. Geological Survey of Finland, Special Paper 10, 91–94.

Pankka, H. S. & Vanhanen, E. J. 1992. Early Proterozoic Au-Co-U mineralization in the Kuusamo district, northeastern Finland. In: Gaál, G. & Schulz, K. J. (editors) Precambrian metallogeny related to plate tectonics. Precambrian Research 58, 387–400.

Papunen, H. 1970. Sulfide mineralogy of the Kotalahti and Hitura nickel-copper ores, Finland. Annales Academiae Scientiarum Fennicae, A.III, Geologica – Geographica 109. 74 p.

Papunen, H. 1974. Charakteristische geochemische Züge der Nickel-Magnetkies-Lagerstätte Kylmäkoski, SW-Finnland. Fortschritte der Mineralogie 52 (2), 98.

Papunen, H. 1977. The sulfide mineral assemblages of some Finnish Ni-Cu deposits. In: Bogdanov, B. (editor) Problems of ore deposition. The 4th Symposium of the International Association on the Genesis of Ore Deposits, Varna, 1974, 2. Sofia: Publishing House of the Bulgarian Academy of Sciences, 311–319.

Papunen, H. 1980. The Kylmäkoski nickel-copper deposit in southwestern Finland. Bulletin of the Geological Society of Finland 52 (1), 129–145.

Papunen, H. 1985. The Kylmäkoski nickel-copper deposit. In: Papunen, H. & Gorbunov, G. I. (editors) Nickel-copper deposits of the Baltic Shield and Scandinavian Caledonides. Geological Survey of Finland, Bulletin 333, 264–273.

Papunen, H. 1986. One hundred years of ore exploration in Finland. Geological Survey of Finland, Bulletin 336, 165–203.

Papunen, H. 1987. The Outokumpu-type ores. In: Häkli, T. A. (editor) The Otto Trüstedt symposium, Finland, June 3–5, 1985. Geological Survey of Finland, Special Paper 1, 41–50.

Papunen, H. 1993. The origin of sulphides in ultramafic metavolcanics of the Pulju Belt, western Lapland, Finland. In: IAGOD International Symposium on Mineralization Related to Mafic and Ultramafic Rocks with a Special Session on Alkaline and Carbonatitic Magmatism and Associated Mineralization, Orléans, France, September 1–3, 1993. Terra abstracts, Abstract supplement no: 3 to Terra 5, 40–41.

Papunen, H. 1998. Metamorphic sulphides in the komatiitic cumulates of the Proterozoic Pulju Greenstone Belt, western Lapland. In: The 17th General Meeting of the International Mineralogical Association, August 9–14, 1998, Toronto, Canada, Abstracts & Programme. Toronto: International Mineralogical Association (IMA), A5.

Papunen, H. & Gorbunov, G. I. (editors) 1985. The nickel-copper deposits of the Baltic Shield and Scandinavian Caledonides. Geological Survey of Finland, Bulletin 333. 394 p.

Papunen, H., Kopperoinen, T. & Tuokko, I. 1989. The Taivaljärvi

Ag-Zn deposit in the Archean Greenstone Belt, eastern Finland. Economic Geology 84 (5), 1262–1276.

Papunen, H. & Koskinen, J. 1985. Geology of the Kotalahti nickel-copper ore. In: Papunen, H. & Gorbunov, G. I. (editors) Nickel-copper deposits of the Baltic Shield and Scandinavian Caledonides. Geological Survey of Finland, Bulletin 333, 228–240.

Papunen, H. & Lindsjö, O. 1972. Apatite, monazite and allanite: three rare earth minerals from Korsnäs, Finland. Bulletin of the Geological Society of Finland 44 (2), 123–129.

Papunen, H. & Mäkelä, M. 1980. Sulfur isotopes in Finnish nickel-copper occurrences. Bulletin of the Geological Society of Finland 52 (1), 55–66.

Papunen, H. & Penttilä, V. 1996. Mineralogy and geology of the serpentinite associated Hitura Ni-Cu deposit, Finland: Implications for beneficiation. In: Grimsey, E. J. & Neuss, I. (editors) Nickel '96 – Mineral to market, Kalgoorlie, Western Australia, November 27–29, 1996. The Australasian Institute of Mining and Metallurgy, Publication Series 6/96, 79–88.

Papunen, H. & Vorma, A. 1985. Nickel deposits in Finland, a review. In: Papunen, H. & Gorbunov, G. I. (editors) Nickel-copper deposits of the Baltic Shield and Scandinavian Caledonides. Geological Survey of Finland, Bulletin 333, 123–143.

Park, A. F. 1984. Nature, affinities and significance of metavolcanic rocks in the Outokumpu assemblage, eastern Finland. Bulletin of the Geological Society of Finland 56 (1–2), 25–52.

Park, A. F. 1988. Nature of the Early Proterozoic Outokumpu assemblage, eastern Finland. Precambrian Research 38 (2), 131–146.

Park, A. F. 1992. Metagabbros, metasyenites and related rocks in the Outokumpu assemblage, eastern Finland. Bulletin of the Geological Society of Finland 64 (1), 91–111.

Parkkinen, J. 1986. The Outokumpu (Keretti) mine. In: Gaál, G. (editor) Proterozoic mineral deposits in Central Finland. The 7th IAGOD Symposium and Nordkalott Project Meeting (Luleå, 1986), Excursion Guide no 5. Geological Survey of Sweden (SGU), Ser Ca 63, 26–30.

Parkkinen, J. & Reino, J. 1985. Nickel occurrences of the Outokumpu type at Vuonos and Keretti. In: Papunen, H. & Gorbunov, G. I. (editors) Nickel-copper deposits of the Baltic Shield and Scandinavian Caledonides. Geological Survey of Finland, Bulletin 333, 178–188.

Pasava, J., Loukola-Ruskeeniemi, K. & Chernyshov, N. M. 1997. Important controls on PGE enrichment in Proterozoic metal-rich black shales. In: Papunen, H. (editor) Mineral deposits: Research and exploration – where do they meet? Proceedings of the 4th Biennial SGA Meeting, Turku/Finland/ August 11–13, 1997. Rotterdam: A. A. Balkema, 11–14.

Patison, N. L. & Oliver, N. H. S. 2001. Structural features associated with Palaeoproterozoic gold deposits in the Central Lapland Greenstone Belt, northern Finland. In: Williams, P. J. (editor) 2001: A hydrothermal odyssey – New developments in metalliferous hydrothermal systems research, Extended conference abstracts, May 17–19th, 2001, Townsville, Queensland, Australia. Queensland: James Cook University of North Queensland, Economic Geology Research Unit (EGRU), Contribution 59, 162–163.

Pehrman, G. 1927. Om en titanjärnmalm och omgivande bergarter på Attu landet i sydvästra Finland. Acta Academiae Aboensis, Mathematica et Physica IV (5). 83 p.

Pehrman, G. 1931. Über eine Sulfidlagerstätte auf der Insel Attu im südwestlichen Finnland. Acta Academiae Aboensis, Mathematica et Physica VI (6). 52 p.

Pehrman, G. 1945. Die Granitpegmatite von Kimito (SW-Finnland) und ihre Minerale. Acta Academiae Aboensis, Mathematica et Physica 15 (2). 84 p.

Pekkarinen, L. 1989. The Hattuvaara Au occurrence, Ilomantsi. In: Gaál, G. (editor) Symposium Precambrian granitoids. Petrogenesis, geochemistry and metallogeny, August 14–17, 1989, Helsinki, Finland. Excursion C-3 – Archean granitoids and associated Mo, W and Au mineralization in eastern Finland. Geological Survey of Finland, Guide 25, 60–68.

Pekkarinen, L. 2002. Haukivuoren ja Pieksämäen kartta-alueiden kallioperä. Suomen geologinen kartta 1:100 000: kallioperäkarttojen selitykset lehdet 3231+3232. Summary: Pre-Quaternary rocks of the Haukivuori and Pieksämäki map-sheet areas. Espoo: Geological Survey of Finland. 98 p.

Peltola, E. 1960. On the black schists in the Outokumpu region, eastern Finland. Geological Survey of Finland, Bulletin 192. 107 p.

Peltola, E. 1968. On some geochemical features in the black schists of the Outokumpu area, Finland. Bulletin of the Geological Society of Finland 40, 39–50.

Peltola, E. 1978. Origin of Precambrian copper sulfides in the Outokumpu district, Finland. Economic Geology 73 (4), 461–477.

Peltola, E. 1980. Geology of the Vuonos ore deposit. In: Häkli, T. A. (editor) Precambrian ores of Finland: Guide to excursions 078 A+C, Part 2 (Finland). Espoo: Geological Survey of Finland, 33–41.

Peltola, E., Vuorelainen, Y. & Häkli, T. A. 1968. A chromian tourmaline from Outokumpu. Bulletin of the Geological Society of Finland 40, 35–38.

Peltonen, P. 1994. Mafic-ultramafic intrusions in southwestern Finland. In: Pajunen, M. (editor) High temperature-low pressure metamorphism and deep crustal structures: Meeting of IGCP project 304 Deep Crustal Processes in Finland, September 16–20, 1994. Geological Survey of Finland, Guide 37, 57–59.

Peltonen, P. 1995a. The magma-country rock interaction and the genesis of Ni-Cu deposits in the Vammala Nickel Belt, SW Finland. Mineralogy and Petrology 52 (1–2), 1–24.

Peltonen, P. 1995b. The petrogenesis of ultramafic rocks in the Vammala Nickel Belt: Implications for crustal evolution of the early Proterozoic Svecofennian arc terrane. Lithos 34 (4), 253–274.

Peltonen, P. 1995c. The petrology, geochemistry and mineralogy of ultramafic rocks and associated Ni-Cu deposits in the Vammala Ni-Belt, southwestern Finland. Espoo: Geological Survey of Finland. 100 p.

Peltonen, P., Pakkanen, L. & Johanson, B. 1995. Re-Mo-Cu-Os sulphide from the Ekojoki Ni-Cu deposit, southwestern Finland. Mineralogy and Petrology 52 (3–4), 257–264.

Pertsev, N. N., Kulakovskiy, A. L. & Boronikhin, V. A. 1988. The quartz-hematite ores at Gematitovoye (Central Aldan) and Taporova (northern Finland). International Geology Review 30 (8), 888–899.

Perttunen, V. 1980. The stratigraphy of the Peräpohja Schist area. In: Silvennoinen, A. (editor) Jatulian geology in the eastern part of the Baltic Shield: Proceedings of the Finnish-Soviet Symposium held in Finland, August 21–26, 1979, 139–144.

Perttunen, V. 1985. On the Proterozoic stratigraphy and exogenic evolution of the Peräpohja area, Finland. In: Laajoki, K. & Paakkola, J. (editors) Proterozoic exogenic processes and related metallogeny: Proceedings of the symposium held in Oulu, Finland, August 15–16, 1983. Geological Survey of Finland, Bulletin 331, 131–141.

Perttunen, V. & Lappalainen, M. 1997. The geology of the Peräpohja Schist Belt. In: Evins, P. & Laajoki, K. (editors) Archaean and early Proterozoic (Karelian) evolution of the Kainuu-Peräpohja area, northern Finland: A guide to the Nordic research field seminar organized by the universities of Oslo, Oulu and Turku, June 2–10, 1997. Res Terrae, A 13, 71–74.

Perttunen, V. & Vaasjoki, M. 2001. The U-Pb geochronology of the Peräpohja Schist Belt, northwestern Finland. In: Vaasjoki, M. (editor) Radiometric age determinations from Finnish Lapland and their bearing on the timing of Precambrian volcano-

sedimentary sequences. Geological Survey of Finland, Special Paper 33, 45–84.

Piirainen, T. 1968. Die Petrologie und die Uranlagerstätten des Koli-Kaltimogebiets im finnischen Nordkarelien. Geological Survey of Finland, Bulletin 237. 99 p.

Piirainen, T., Alapieti, T., Hugg, R. & Kerkkonen, O. 1977. The marginal border group of the Porttivaara layered intrusion and related sulphide mineralization. Bulletin of the Geological Society of Finland 49 (2), 125–142.

Piirainen, T., Hugg, R., Isohanni, M. & Juopperi, A. 1974. On the geotectonics and ore forming processes in the basic intrusive belts of Kemi-Suhanko, and Syöte-Näränkävaara, northern Finland. Bulletin of the Geological Society of Finland 46 (2), 93–104.

Piirainen, T. & Juopperi, A. 1968. Die Titaneisenerzlagerstätte von Porttivaara und ihre Entstehung. Nordia (Oulu) 5, 1–24.

Piispanen, R. 1985. The potassium/rubidium ratios and metallogeny of the Rautio batholith, western Finland. Geologiska Föreningens i Stockholm Förhandlingar 107 (1), 11–15.

Piispanen, R. & Tarkian, M. 1984. Cu-Ni-PGE mineralization at Rometölväs, the Koillismaa layered igneous complex, Finland. Mineralium Deposita 19 (2), 105–111.

Pomiès, C., Hamelin, B., Lancelot, J. & Casanova, J. 1998. Pb-Pb dating of uranium ore deposits: ion probe measurements of fracture fillings in the Palmottu granite (southern Finland). In: Schott, J. (editor) V. M. Goldschmidt conference, Toulouse 1998, Extended abstracts. Mineralogical Magazine 62A (2), 1200–1201.

Pöschl, A. 1964. Die Titanomagnetit-Lagerstätte Otanmäki in Finnland, Stoffbestand, Bau und Entstehungsgeschichte. Inaugural-Dissertation, Wissenschaftliche Fakultät der Ludvig-Maximilians-Universität München. München: Stenbauer-Rau. 47 p.

Poutiainen, M. 1993. Fluid inclusion geochemistry of the early Proterozoic Pirilä gold deposit in Rantasalmi, southeastern Finland. Mineralium Deposita, 129–135.

Poutiainen, M. & Grönholm, P. 1996. Hydrothermal fluid evolution of the Paleoproterozoic Kutemajärvi gold telluride deposit, southwestern Finland. Economic Geology 91 (8), 1335–1353.

Poutiainen, M. & Luukkonen, E. 1994. The geology and fluid inclusion studies of some epigenetic gold deposits in the Archean Kuhmo and Suomussalmi Greenstone Belts, eastern Finland. In: Izquierdo M., G. … [et al.] (editors) The 5th Biennial Pan-American Conference on Research on Fluid Inclusions, Cuernavaca, Morelos, Mexico, May 19–21, 1994, Abstracts, 77–78.

Poutiainen, M. & Partamies, S. 2003. Fluid evolution of the late Archaean Rämepuro gold deposit in the Ilomantsi Greenstone Belt in eastern Finland. Mineralium Deposita 38 (2), 196–207.

Puustinen, K. 1981. Gold deposits of Finland. Journal of Geochemical Exploration 39, 255–272.

Puustinen, K. 1985. Kittilän Riikonkosken alueen vulkanismi. Summary: Volcanism and ore deposits in the Riikonkoski area, Kittilä, Finnish Lapland. Geologi 37, 37–44.

Puustinen, K. 1997. Mining in Finland during the period 1530–1995. In: Autio, S. (editor) Geological Survey of Finland, Current Research 1995–1996. Geological Survey of Finland, Special Paper 23, 43–54.

Puustinen, K., Saltikoff, B. & Tontti, M. 1995. Distribution and metallogenic types of nickel deposits in Finland. Geological Survey of Finland, Report of Investigation 132. 38 p.

Puustinen, K., Saltikoff, B. & Tontti, M. 2000. Suomen malmiesiintymäkartta – Malmförekomstkarta över Finland – Metallic mineral deposits map of Finland 1:1 000 000. Espoo: Geological Survey of Finland.

Räisänen, E. 1989. The uraniferous granitic veins in the Svecofennian Schist Belt in Nummi-Pusula, southern Finland. In: Uranium deposits in magmatic and metamorphic rocks: Proceedings of a technical committee meeting, Salamanca, September 29 – October 3, 1986. Vienna: International Atomic Energy Agency (IAEA), 37–44.

Ramdohr, P. 1956. Die Beziehungen von Fe-Ti-Erzen aus magmatischen Gesteinen. Geological Survey of Finland, Bulletin 173. 19 p.

Räsänen, J. & Huhma, H. 2001. U-Pb datings in the Sodankylä Schist area, Central Finnish Lapland. In: Vaasjoki, M. (editor) Radiometric age determinations from Finnish Lapland and their bearing on the timing of Precambrian volcano-sedimentary sequences. Geological Survey of Finland, Special Paper 33, 153–188.

Rasilainen, K. 1991. The geochemistry and wall rock alteration at the Kangasjärvi massive sulphide deposit, Central Finland. In: Autio, S. (editor) Geological Survey of Finland, Current Research 1989–1990. Geological Survey of Finland, Special Paper 12, 107–110.

Rasilainen, K. 1993. Differences in geochemistry of Au and the semimetals As, Bi and Te in gold occurrences in the late Archean Hattu Schist Belt, Ilomantsi, eastern Finland. In: Autio, S. (editor) Geological Survey of Finland, Current Research 1991–1992. Geological Survey of Finland, Special Paper 18, 113–117.

Rasilainen, K. 1996. The alteration geochemistry of gold occurrences in the late Archean Hattu Schist Belt, Ilomantsi, eastern Finland. Espoo: Geological Survey of Finland. 145 p.

Rasilainen, K., Puustjärvi, H., Kousa, J., Luukas, J. & Mäki, T. 2003. The Paleoproterozoic Pyhäsalmi volcanic complex, Central Finland – bimodal volcanism and associated VMS deposits. In: Eliopoulos, D. G. ... [et al.] (editors) Mineral exploration and sustainable development: Proceedings of the 7th Biennial SGA Meeting, Athens, Greece, August, 24–28 2003, Vol. 2. Rotterdam: Millpress, 1095–1098.

Rauhamäki, E., Mäkelä, T. & Isomäki, O.-P. 1978. The geology of the Vihanti mine. In: Metallogeny of the Baltic Shield, Helsinki symposium 1978, June 12–21, Finland: IGCP Project 74/1/91 – Metallogeny of the Precambrian, Excursion guide. Helsinki: The Academy of Finland, 35–56.

Rauhamäki, E., Mäkelä, T. & Isomäki, O.-P. 1980. The geology of the Vihanti mine. In: Häkli, T. A. (editor) Precambrian ores of Finland: Guide to excursions 078 A+C, Part 2 (Finland). Espoo: Geological Survey of Finland, 14–24.

Rehtijärvi, P. 1984a. Enrichment of bromine and chlorine in Proterozoic serpentinites from the Outokumpu Cu-Co ore district, Finland. Economic Geology 79 (3), 549–552.

Rehtijärvi, P. 1984b. The distributions of phosphorus, sulphur and sulphur isotopes in a strata-bound base metal deposit, Kangasjärvi, Finland. Geological Survey of Finland, Report of Investigation 65. 16 p.

Rehtijärvi, P., Äikäs, O. & Mäkelä, M. 1979. A middle Precambrian uranium and apatite bearing horizon associated with the Vihanti zinc ore deposit, western Finland. Economic Geology 74 (5), 1102–1117.

Rehtijärvi, P. & Saastamoinen, J. 1985. Tectonized actinolite-albite rocks in the Outokumpu district, Finland: Field and geochemical evidence for mafic extrusive origin. Bulletin of the Geological Society of Finland 57 (1–2), 47–54.

Rekola, T. & Hattula, A. 1995. Geophysical surveys for strata-bound Outokumpu-type Cu-Co-Zn deposits at Kylylahti, eastern Finland. In: Conference papers from the ASEG 11th Geophysical Conference and Exhibition, Adelaide, September 3–6, 1995, Exploration geophysics 26 (2–3), 60–65.

Riddarhyttan Resources AB 2005. Press release 19 August 2005; web – pages: http://hugin.info/86971/R/1007305/155545.pdf

Riekkola-Vanhanen, M. 2005. Bioleaching of the Talvivaara black schist ore. Materia (former Vuoriteollisuus – Bergshanteringen) 3/2005, 40–45.

Roberts, M. D. 2002. Architecture, geochemistry and dynamics of Paleoproterozoic seafloor hydrothermal systems preserved in a high-grade metamorphic terrane, Vihanti-Pyhäsalmi district, Central Finland. Townsville, Queensland: James Cook University of North Queensland, Dissertation. 411 p.

Roberts, M. D., Oliver, N. H. S. & Lahtinen, R. 2003a. Reconstructing the architecture of highly deformed and metamorphosed Zn-Cu massive sulphide deposits in the Vihanti-Pyhäsalmi district, Central Finland. In: Eliopoulos, D. G. ... [et al.] (editors) Mineral exploration and sustainable development: Proceedings of the 7th Biennial SGA Meeting, Athens, Greece, August 24–28, 2003, Vol. 2. Rotterdam: Millpress, 1099–1102.

Roberts, M. D., Oliver, N. H. S., Fairclough, M. C., Hölttä, P. S. & Lahtinen, R. 2003b. The geochemical and oxygen isotope signature of sea-floor alteration associated with a polydeformed and highly metamorphosed massive sulfide deposit, Ruostesuo, Central Finland. Economic Geology 98 (3), 535–556.

Roberts, M. D., Oliver, N. H. S. & Lahtinen, R. 2004. The geology, lithogeochemistry and paleotectonic setting of the host sequence to the Kangasjärvi Zn-Cu deposit, Central Finland: Implications for volcanogenic massive sulphide exploration in the Vihanti-Pyhäsalmi district. Bulletin of the Geological Society of Finland 76 (1–2), 31–62.

Rosenberg, P. 1997. The Kaapelinkulma gold deposit, Valkeakoski. In: Ehlers, C. (editor) Research and exploration – where do they meet? The 4th Biennial SGA Meeting, August 11–13, 1997, Turku, Finland. Excursion Guide B3 – Gold and base metal deposits in southwestern Finland. Geological Survey of Finland, Guide 44, 23–26.

Rouhunkoski, P. 1968. On the geology and geochemistry of the Vihanti zinc ore deposit, Finland. Geological Survey of Finland, Bulletin 236. 121 p.

Rouhunkoski, P. 1982. SEG distinguished lecture in applied geology – Exploration practices in Finland. Economic Geology 77, 735–744.

Rouhunkoski, P. & Isokangas, P. 1974. The copper-gold vein deposit of Kivimaa at Tervola, northern Finland. Bulletin of the Geological Society of Finland 46 (1), 29–35.

Routhier, P. & Moiseyev, A. (translator) 1983. Where are the metals for the future? The metal provinces – An essay on global metallogeny. Orléans: Bureau de recherches géologiques et minières (BRGM). 411 p.

Ruskeeniemi, T., Lindberg, A., Pérez del Villar, L., Blomqvist, R., Suksi, J., Blyth, A. & Cera, E. 2002. Uranium mineralogy with implications for mobilisation of uranium at Palmottu. In: Maravic, H. von & Alexander, W. R. (editors) 8th EC Natural Analogue Working Group Meeting: Proceedings of an international workshop held in Strasbourg, France, March 23–25, 1999. Luxembourg: Office for Official Publications of the European Communities, 143–154.

Saarnisto, M. & Tamminen, E. 1987. Placer gold in Finnish Lapland. In: Kujansuu, R. & Saarnisto, M. (editors) INQUA Till Symposium, Finland, 1985. Geological Survey of Finland, Special Paper 3, 181–194.

Saarnisto, M., Tamminen, E. & Vaasjoki, M. 1991. Gold in bedrock and glacial deposits in the Ivalojoki area, Finnish Lapland. Journal of Geochemical Exploration 39 (3), 303–322.

Saini-Eidukat, B., Alapieti, T. T., Thalhammer, O. A. R. & Iljina, M. J. 1997. Siliceous, high-magnesian parental magma compositions of the PGE-rich Early Paleoproterozoic layered intrusion belt of northern Finland. In: Rongfu, P. (editor) Proceedings of the 30th International Geological Congress, Beijing, China, August 4–14, 1996, Vol. 9 – Energy and mineral resources for the 21st century, geology of mineral deposits, mineral economics. Utrecht: VSP, 177–197.

Saini-Eidukat, B., Thalhammer, O. A. R., Alapieti, T., Halkoaho, T. & Iljina, M. 1993. Controls on PGE mineralization in the early Paleoproterozoic Kemi-Koillismaa-Oulanka mafic intrusion Belt, Fennoscandian Shield. In: Fenoll Hach-Ali, P., Torres-Ruiz, J. & Gervilla, F. (editors) Current research in geology applied to ore deposits: Proceedings of the 2nd biennal SGA meeting, Granada, September 9–11, 1993. Granada: University of Granada, 555–558.

Sakko, M. & Laajoki, K. 1975. Whole rock Pb-Pb isochron age for the Pääkkö iron formation in Väyrylänkylä, South Puolanka area, Finland. Bulletin of the Geological Society of Finland 47 (1–2), 113–116.

Saksela, M. 1939. Über einige Eisenerze im Jussaarigebiet, SW-Finnland. Bulletin of the Geological Society of Finland 125, 9–38; also Geological Survey of Finland, Bulletin 125, 9–38.

Saksela, M. 1951. Späthydrothermale Bildungen im Kieserz von Otravaara, Ostfinnland. Bulletin of the Geological Society of Finland 24, 115–122; also Geological Survey of Finland, Bulletin 154, 115–122.

Saksela, M. 1952. Das Fahlerzvorkommen von Seinäjoki, Süd-Ostbothnien, Finnland. Bulletin of the Geological Society of Finland 25, 41–52; also Geological Survey of Finland, Bulletin 157, 41–52.

Saksela, M. 1957. Die Entstehung der Outokumpu-Erze im Lichte der tektonisch-metamorphen Stoffmobilisierung. Neues Jahrbuch für Mineralogie, Abhandlungen 91 (Festband Schneiderhöhn), 278–302.

Saksela, M. & Hackzell, E. 1938. Tutkimuksia Nivalan malmista ja sen rikastamismahdollisuuksista. Referat: Untersuchungen über das Nickelerz von Nivala und seine Aufbereitungsmöglichkeiten. Suomen Kemistilehti 11, 73–79.

Saltikoff, B. & Koistinen, E. 1989. A geomathematical study on the lithological setting of mineral deposits in southwestern Finland. In: Autio, S. (editor) Geological Survey of Finland. Current Research 1988. Geological Survey of Finland, Special Paper 10, 119–121.

Saltikoff, B., Puustinen, K. & Tontti, M. 2000. Suomen metallimalmiesiintymät – Saatteeksi Suomen malmiesiintymäkarttaan. Abstract: The Metallic Mineral Deposits of Finland – Explanatory remarks to the Mineral Deposits Map of Finland. Geological Survey of Finland, Guide 49. 29 p.

Saltikoff, B. & Tarvainen, T. 1990. Explorational data bases at the Geological Survey of Finland. In: Gaál, G. & Merriam, D. F. (editors) Computer applications in resource estimation – Prediction and assessment for metals and petroleum. Oxford: Pergamon Press, 409–420.

Saltikoff, B., Tontti, M., & Puustinen, K. 2002. The Metallogenic Map of Finland 1 : 1 000 000. Espoo: Geological Survey of Finland.

Sarala, P. & Rossi, S. 1998. Kupari- ja kultapitoisen hiertovyöhykkeen paikantaminen moreenigeokemiallisin tutkimuksin Peräpohjan liuskealueelta Pohjois-Suomessa. Summary: Discovery of a copper- and gold-bearing shear zone as a result of research into till geochemistry of the Peräpohja Schist Belt, northern Finland. Geological Survey of Finland, Report of Investigation 142. 44 p.

Saxén (Saksela), M. 1923. Über die Petrologie des Otravaaragebietes im östlichen Finnland. Geological Survey of Finland, Bulletin 65. 63 p.

Scandinavian Gold Ltd. 2005. Scandianvian Gold secures significant funding for its Keivitsa nickel-copper-PGE project in northern Finland. November 2, 2005 web pages: http://www.scangold.com/keivitsa/; Keivitsa Ni-Cu-PGE.

Sipilä, P., Ervamaa, P. & Papunen, H. 1985. The Petolahti nickel-copper occurrence. In: Papunen, H. & Gorbunov, G. I. (editors) Nickel-copper deposits of the Baltic Shield and Scandinavian Caledonides. Geological Survey of Finland, Bulletin 333, 293–312.

Smirnov, V. I. 1976. Geology of mineral deposits. Moscow: Mir Publishers. 520 p.

Söderholm, K. & Inkinen, O. 1982. The Tornio layered intrusion

– A recently discovered intrusion with chromitite horizons in northern Finland. Bulletin of the Geological Society of Finland 54 (1–2), 15–24.

Sorjonen-Ward, P. 1997. An overview of the geological setting and nature of gold mineralisation in the late Archean Hattu Schist Belt, eastern Finland. In: Loukola-Ruskeeniemi, K. & Sorjonen-Ward, P. (editors) Research and exploration – where do they meet? The 4th Biennial SGA Meeting, August 11–13, 1997, Turku, Finland, Excursion guide A4 – Ore deposits in eastern Finland. Geological Survey of Finland, Guide 42, 49–55.

Sorjonen-Ward, P., Hanski, E. & Keinänen, V. 2001. The geodynamic evolution of the Lapland Greenstone Belt and its relevance to gold mineralization. In: Williams, P. J. (editor) 2001: A hydrothermal odyssey – New developments in metalliferous hydrothermal systems research, Extended conference abstracts, May 17–19th, 2001, Townsville, Queensland, Australia. Queensland: James Cook University of North Queensland, Economic Geology Research Unit (EGRU), Contribution 59, 213–214.

Springer, G. 1968. Electronprobe analyses of mackinawite and valleriite [Outokumpu]. Neues Jahrbuch für Mineralogie, Monatsheft 1968, 252–258.

Stein, H. J., Sundblad, K., Markey, R. J., Morgan, J. W. & Kouvo, O. 1995. New method for precise Re-Os dating reveals two generation of molybdenite at Mätäsvaara, eastern Finland. In: Glebovitsky, V. A. & Kotov, A. B. (editors) Precambrian Europe: Stratigraphy, structure, evolution and mineralization. MAEGS 9: 9th Meeting of the Association of European Geological Societies, September 4–15, 1995, St. Petersburg, Russian Federation, Abstracts. St. Petersburg: The Russian Academy of Sciences, 112–113.

Stein, H., Morgan, J., Markey, R. & Hannah, J. 1999. Re-Os dating of Au deposits in Precambrian terranes. In: Cook, N. J. & Sundblad, K. (editors) Gold '99 Trondheim – Precambrian gold in the Fennoscandian and Ukrainian Shields and related areas, The Nordic mineral resources symposium, Trondheim, Norway, May 4–6, 1999, Abstract volume. Trondheim: Norges Geologiske Undersøkelse (NGU), 144–147.

Stenberg, A. & Häkli, T. A. 1985. The Hyvelä nickel-copper occurrence. In: Papunen, H. & Gorbunov, G. I. (editors) Nickel-copper deposits of the Baltic Shield and Scandinavian Caledonides. Geological Survey of Finland, Bulletin 333, 287–293.

Stigzelius, H. 1944. Über die Erzgeologie des Viljakkala-Gebietes im südwestlichen Finnland. Bulletin of the Geological Society of Finland 17, 1–19; also Geological Survey of Finland, Bulletin 134, 1–19.

Stigzelius, H. 1954. Gold occurrences in North Lapland. In: Aurola, E. (editor) The mines and quarries of Finland. Geological Survey of Finland, Geotechnical Publications 55, 109–116.

Sundblad, K., Weihed, P., Billström, K., Markkula, H. & Mäkelä, M. 1993. The source of metals and age constraints for epigenetic gold deposits in the Skellefte and Pohjanmaa districts, central part of the Fennoscandian Shield. Mineralium Deposita 28 (3), 181–190.

Sundell, I. G. 1936. The fineness and composition of alluvial gold from the Ivalojoki, Finnish Lapland. Bulletin of the Geological Society of Finland 9, 155–160; also Geological Survey of Finland, Bulletin 115, 155–160.

Taipale, K. 1983a. Itä-Suomen arkeeisista granitoideista ja niihin liittyvistä molybdeeniesiintymistä. Summary: On the Archaean granitoids and associated molybdenum occurrences in eastern Finland. Arkeeisten alueiden malmiprojekti [The ore project on Archaean terrains], Raportti 14. 26 p.

Taipale, K. 1983b. The geology and geochemistry of the Archean Kuhmo greenstone-granite terrain in the Tipasjärvi area, eastern Finland. Acta Universitatis Ouluensis, Series A, Scientiae Rerum Naturalium 151, Geologica 5. 96 p.

Tammekann, A. 1925. Über die Petrographie des Grubenfeldes von Sillböle bei Helsinki. Fennia 45 (10). 26 p.

Taylor, L. A. & Finger, L. W. 1971. Structural refinement and composition of mackinawite. In: Carnegie Institution Year Book 69, 1969–1970. Papers from the Geophysical Laboratory, Carnegie Institution 1580, 318–322.

Tchimichkian, G. 1936. Note sur les gisements cupriféres d' Outokumpu. Congress of International Mines. Métallurgie et Géologic, Appliquée VII, Paris 1935, Vol. 1, 115–120.

Thalhammer, O. A. R., Saini-Eidukat, B., Iljina, M. J. & Alapieti, T. T. 1993. PGE mineralization associated with silicates within the Siika-Kämä PGE Reef, Portimo layered complex, Fennoscandian Shield, Finland: An unusual mineralization type. In: Fenoll Hach-Ali, P., Torres-Ruiz, J. & Gervilla, F. (editors) Current research in geology applied to ore deposits: Proceedings of the 2nd Biennal SGA Meeting, Granada, September, 9–11 1993. Granada: University of Granada, 571–574.

Thayer, T. P. 1964. Zincian chromite from Outokumpu, Finland. American Mineralogist 49, 1178–1183.

Thoreld, A. F. 1866. Berättelse öfver verkställd undersökning af de uti Porkonen, Pahtavaara, Silmänpaistama och Kuoreslaki berg inom Kittilä Kapell af Sodankylä socken upptäckta järnmalmsanledningar om sommaren år 1866. Geological Survey of Finland, Open-File Report. 16 p.

Thoreld, A. F. 1891. De kopparkisförande qvartsgångarne i Kontiolax och Eno socknar. Geological Survey of Finland, Open-File Report. 22 p.

Tiainen, M. & Viita, H. 1994. Determination of ore potential areas in the Häme Belt, southwestern Finland, by integration of geological, geophysical and till geochemical data. Geological Survey of Finland, Report of Investigation 125. 49 p.

Tilas, D. 1738. Mineral historia öfver Björneborgs och Tavastehus Lähner med några andre få ställen i de öfrige lähnen uti Finland – Socknevis anmärkt vid Durchfarts undersökningen i Finland Åhren 1737 och 1738. Stockholm: Manuscript 12 Maj 1740; also copy in the Geological Survey of Finland.

Tontti, M. 1981. Comments on the relationship between the cluster-ridge pattern of mantled gneiss domes in eastern Finland and the Ni-Cu deposits clusters of the Kotalahti Nickel Belt. Earth and Planetary Science Letters 53, 275–278.

Tontti, M., Gautneb, H., Grenne, T., Juve, G., Kauniskangas, E., Nikander, J., Nilsson, G. & Sandstad, J. S. 1996. Map of Ore Deposits in Central Fennoscandia. Scale 1: 1 00064 000. Espoo: Geological Survey of Finland; Trondheim: Geological Survey of Norway; Uppsala: Geological Survey of Sweden.

Tontti, M., Koistinen, E. & Lehtonen, M. K. A. 1979. Kotalahden nikkelivyöhykkeen monimuuttuja-analyysi. Abstract: A multivariate analysis of the Kotalahti Nickel Belt. Geological Survey of Finland, Report of Investigation 36. 34 p.

Tontti, M., Koistinen, E. & Seppänen, H. 1981. Vihannin Zn-Cu-malmivyöhykkeen geomatemaattinen arviointi. Summary: Geomathematical evaluation of the Vihanti Zn-Cu ore zone. Geological Survey of Finland, Report of Investigation 54. 58 p.

Törnroos, R. 1982. Properties of alabandite: Alabandite from Finland. Neues Jahrbuch für Mineralogie, Abhandlungen 144 (1), 107–123.

Törnroos, R., Johanson, B. & Kojonen, K. 1998. Alluvial nuggets of platinum-group minerals and alloys from Finnish Lapland. In: Hanski, E. & Vuollo, J. (editors) International ophiolite symposium and field excursion: Generation and emplacement of ophiolites through time, August 10–15, 1998, Oulu, Finland, Abstracts, Excursion guide. Geological Survey of Finland, Special Paper 26, 63–64.

Törnroos, R. & Vuorelainen, Y. 1987. Platinum-group metals and their alloys in nuggets from alluvial deposits in Finnish Lapland. Lithos 20 (6), 491–500.

Treloar, P. J. 1985. The chrome minerals of Outokumpu – their chemistry and significance. Journal of the Geological Society 142 (6), 1240.

Treloar, P. J. 1987a. Chromian muscovites and epidotes from Outokumpu, Finland. Mineralogical Magazine 51 (4), 593–599.

Treloar, P. J. 1987b. The Cr-minerals of Outokumpu – their chemistry and significance. Journal of Petrology 28 (5), 867–886.

Treloar, P. J. & Charnley, N. R. 1987. Chromian allanite from Outokumpu, Finland. The Canadian Mineralogist 25 (3), 413–418.

Treloar, P. J., Koistinen, T. J. & Bowes, D. R. 1981. Metamorphic development of cordierite-amphibole rocks and mica Schists in the vicinity of the Outokumpu ore deposit, Finland. Transactions of the Royal Society of Edinburgh, Earth sciences 72 (3), 201–215.

Treloar, P. J. & Putnis, A. 1982. Chemistry and microstructure of orthoamphiboles from cordierite-amphibole rocks in Outokumpu, the Province of North Karelia, eastern Finland. Mineralogical Magazine 45 (337), 55–62.

Tuokko, I. 1989. The Taivaljärvi Ag-Zn deposit in Sotkamo, eastern Finland. In: Gaál, G. (editor) Symposium Precambrian granitoids. Petrogenesis, geochemistry and metallogeny, August 14–17, 1989, Helsinki, Finland, Excursion C-3 – Archean granitoids and associated Mo, W and Au mineralization in eastern Finland. Geological Survey of Finland, Guide 25, 34–40.

Turchenko, S. I., Juve, G., Saltikoff, B. & Chesalov, L. 1995. The Precambrian metallogenesis and metallogenic zoning of the Fennoscandian Shield. In: Glebovitsky, V. A. & Kotov, A. B. (editors) Precambrian of Europe: Stratigraphy, structure, evolution and mineralization. MAEGS 9: The 9th Meeting of the Association of European Geological Societies, September 4–15, 1995. St. Petersburg, Russian Federation, Abstracts. St. Petersburg: Russian Academy of Sciences, 121–122.

Tyni, M., Parkkinen, J., Mäkelä, M., Pekkarinen, L., Loukola-Ruskeeniemi, K., Kuronen, E. & Tuokko, I. 1997. Outokumpu district. In: Loukola-Ruskeeniemi, K. & Sorjonen-Ward, P. (editors) Research and exploration – where do they meet? The 4th Biennial SGA Meeting, August 11–13, 1997, Turku, Finland, Excursion guide A4 – Ore deposits in eastern Finland. Geological Survey of Finland, Guide 42, 23–41.

UNESCO 1973. Carte métallogénique de l'Europe au 1/2 500 000, Feuille 2, Europe N. Paris: United Nations Educational, Scientific and Cultural Organization (UNESCO) and Bureau de recherches géologiques et minières (BRGM).

UNESCO 1984. Memoire explicatif de la carte metallogenique de l'Europe et des pays limitrophes 1 : 2 500 000. Paris: United Nations Educational, Scientific and Cultural Organization (UNESCO).

Väänänen, J. & Lehtonen, M. I. 2001. U-Pb isotopic age determinations from the Kolari-Muonio area, western Finnish Lapland. In: Vaasjoki, M. (editor) Radiometric age determinations from Finnish Lapland and their bearing on the timing of the Precambrian volcano-sedimentary sequences. Geological Survey of Finland, Special Paper 33, 85–93.

Vaasjoki, M. 1977. Phanerozoic resetting of U-Pb ages in some South Finnish uraninites. In: ECOG V. The 5th European Colloquium of Geochronology, Cosmochronology and Isotope Geology, Pisa, September 5–10, 1977. Pisa. 2 p.

Vaasjoki, M. 1981. The lead isotopic composition of some Finnish galenas. Geological Survey of Finland, Bulletin 316. 25 p.

Vaasjoki, M. (editor) 2001. Radiometric age determinations from Finnish Lapland and their bearing on the timing of Precambrian volcano-sedimentary sequences. Geological Survey of Finland. Special Paper 33. 279 p.

Vaasjoki, M., Äikäs, O. & Rehtijärvi, P. 1980. The age of mid Proterozoic phosphatic metasediments in Finland as indicated by radiometric U-Pb data. Lithos 13, 257–262.

Vaasjoki, M. & Sakko, M. 1988. The evolution of the Raahe-Ladoga zone in Finland: Isotopic constraints. In: Korsman, K. (editor) Tectono-metamorphic evolution of the Raahe-Ladoga zone. Geological Survey of Finland, Bulletin 343, 7–32.

Vaasjoki, M. & Kontoniemi, O. 1991. Isotopic studies on the Proterozoic Osikonmäki gold prospect in Rantasalmi, southeastern Finland. In: Autio, S. (editor) Geological Survey of Finland, Current Research 1989–1990. Geological Survey of Finland, Special Paper 12, 53–57.

Vaasjoki, O. 1953. On migmatites and ore mineralizations in the Pernaja district, southern Finland. Geological Survey of Finland, Bulletin 163. 62 p.

Vähätalo, V. O. 1953. On the geology of the Outokumpu ore deposit in Finland. Geological Survey of Finland, Bulletin 164. 98 p.

Vähätalo, V. O. 1954. The Outokumpu copper ore deposit. In: Aurola, E. (editor) The mines and quarries of Finland. Geological Survey of Finland, Geotechnical Publications 55, 9–14.

Väisänen, M. 1988. The geology of the Orijärvi-Aijala area. In: Gaál, G. & Gorbatschev, R. (editors) Tectonic setting of Proterozoic volcanism and associated ore deposits: IGCP field conference held in Sweden and Finland, August 15–21, 1988. Geological Survey of Finland, Guide 22, 81–86.

Vanhanen, E. 1989. The uraniferous mineralizations in the Kuusamo Schist Belt, northeastern Finland. In: Metallogenesis of Uranium Deposits: Proceedings of a Technical Committee Meeting on Metallogenesis of Uranium Deposits, Vienna, March 9–12, 1987. Vienna: International Atomic Energy Agency (IAEA), 169–186.

Vanhanen, E. 2001. Geology, mineralogy and geochemistry of the Fe-Co-Au-(U) deposits in the Paleoproterozoic Kuusamo Schist Belt, northeastern Finland. Geological Survey of Finland, Bulletin 399. 229 p.

Vanhanen, E. 1992. Cobalt-, gold- and uranium-bearing mineralizations and their relation to the deep fractures in the Kuusamo area. In: Silvennoinen, A. (editor) Deep fractures in the Paanajärvi – Kuusamo – Kuolajärvi area: Proceedings of the Finnish-Soviet symposium held in Finland, September 18–21, 1989. Geological Survey of Finland, Special Paper 13, 91–97.

Varma, A. 1954a. The copper-zinc-lead ore deposit of Orijärvi. In: Aurola, E. (editor) The mines and quarries of Finland. Geological Survey of Finland, Geotechnical Publications 55, 17–19.

Varma, A. 1954b. The copper-zinc ore deposits of Aijala and Metsämonttu. In: Aurola, E. (editor) The mines and quarries of Finland. Geological Survey of Finland, Geotechnical Publications 55, 20–24.

Vartiainen, H. 1970. The Schist Belt of Tipasjärvi in the parish of Sotkamo, Finland. Bulletin of the Geological Society of Finland 42, 13–22.

Vartiainen, H. 1980. The petrography, mineralogy and petrochemistry of the Sokli carbonatite massif, northern Finland. Geological Survey of Finland, Bulletin 313. 126 p.

Vartiainen, H. 1989. The phosphate deposits of the Sokli Carbonatite Complex, Finland. In: Notholt, A. J. G., Sheldon, R.P. & Davidson, D. F. (editors) Phosphate deposits of the world, Vol. 2 – Phosphate rock resources. Cambridge: Cambridge University Press, 398–402.

Vartiainen, H. 2001. The Sokli carbonatite complex, northern Finland. In: Gehör, S., Liferovich, R. & Wall, F. (editors) Formation, exploration and exploitation of economic deposits associated with mantle carbon. EuroCarb Finland Workshop, 14–20 September 2001, Excursion guide. Res Terrae A 20, 8–24.

Väyrynen, H. 1935. Über die Mineralparagenesis der Kieserze in den Gebieten von Outokumpu und Polvijärvi. Geological Survey of Finland, Bulletin 109. 24 p.

Väyrynen, H. 1939. On the geology and tectonics of the Outokumpu ore field and region. Geological Survey of Finland, Bulletin 124. 91 p.

Vermaak, C. F. 1995. The platinum-group metals – A global perspective. Mintek, Randburg. 247 p.

Volborth, A. 1951. Montebrasit (Amblygonit) von Eräjärvi. Bul-

letin of the Geological Society of Finland 24, 171–176; also Geological Survey of Finland, Bulletin 154, 171–176.

Volborth, A. 1954. Phosphatminerale aus dem Lithiumpegmatit von Viitaniemi, Eräjärvi, Zentral-Finnland. Annales Academiae Scientiarum Fennicae, Series A.III, Geologica – Geographica 39. 90 p.

Volborth, A. 1960. Gediegen wismutantimon und andere Erzmineralien im Li-Be-Pegmatit von Viitaniemi, Eräjärvi, Zentralfinnland. Neues Jahrbuch für Mineralogie, Abhandlungen 94 (Festb. Ramdohr), 140–149.

Vorma, A. 1970. Pyrrhotite-troilite intergrowth from Luikonlahti copper deposit, eastern Finland. Bulletin of the Geological Society of Finland 42, 3–12.

Vorma, A. 1975. On two roof pendants in the Wiborg rapakivi massif, southeastern Finland. Geological Survey of Finland, Bulletin 272. 86 p.

Vuollo, J. 1994. Palaeoproterozoic basic igneous events in eastern Fennoscandian Shield between 2.45 Ga and 1.97 Ga, studied by means of mafic dyke swarms and ophiolites in Finland. Acta Universitatis Ouluensis, Series A, Scientiae Rerum Naturalium 250. 116 p.

Vuollo, J., Liipo, J., Nykänen, V., Piirainen, T., Pekkarinen, L., Tuokko, I. & Ekdahl, E. 1995. An Early Proterozoic podiform chromitite in the Outokumpu Ophiolite Complex, Finland. Economic Geology 90 (2), 445–452.

Vuollo, J. & Piirainen, T. 1989. Mineralogical evidence for an ophiolite from the Outokumpu serpentinites in the Province of North Karelia, eastern Finland. Bulletin of the Geological Society of Finland 61 (1), 95–112.

Vuorelainen, Y., Häkli, T. A., Hänninen, E., Papunen, H., Reino, J. & Törnroos, R. 1982. Isomertieite and other platinum-group minerals from the Konttijärvi layered mafic intrusion, northern Finland. Economic Geology 77 (6), 1511–1518.

Vuorelainen, Y., Häkli, T. A. & Kataja, M. 1968. A hydrated oxide of chromium as a pseudomorph after eskolaite, Outokumpu, Finland. Bulletin of the Geological Society of Finland 40, 125–129.

Vuorelainen, Y., Häkli, T. A. & Papunen, H. 1972. Argentian pentlandite from some Finnish sulfide deposits. The American Mineralogist 57 (1–2), 137–145.

Vuorelainen, Y. & Törnroos, R. 1986a. Man-made Pt-PtAs2 spherules after sperrylite from alluvial deposits in Finnish Lapland. The Canadian Mineralogist 24 (3), 523–528.

Vuorelainen, Y. & Törnroos, R. 1986b. Platinum-group element alloy spherules from alluvial deposits in Finnish Lapland. Neues Jahrbuch für Mineralogie, Monatshefte 1986 (9), 423–432.

Walker, P. 2003. Development of the Keivitsa nickel-copper-platinum project. In: 4th Fennoscandian Exploration and Mining, Rovaniemi, December 4–5, 2003: Final program and event documentation. [S.l.]. European Union, European Regional Development Fund. 5 p.

Wall, F., Williams, C. T., Woolley, A. R., Garcia, D., Moutte, J., Lee, M. J. & Sonnet, P. 2001. Niobium deposits in weathered carbonatite: An example at Sokli, northern Finland. In: Gehör, S., Wall, F. & Liferovich, R. (editors) Formation, exploration and exploitation of economic deposits associated with mantle carbon. EuroCarb Finland Workshop, September 14–20, 2001, Programme and abstracts. Res Terrae, Ser. A 19, p. 14.

Ward, P. 1988. Early Proterozoic Kalevian lithofacies and their interpretation in the Hammaslahti-Rääkkylä area, eastern Finland. In: Laajoki, K. & Paakkola, J. (editors) Sedimentology of the Precambrian formations in eastern and northern Finland: Proceedings of IGCP 160 Symposium at Oulu, January 21–22, 1986. Geological Survey of Finland, Special Paper 5, 29–48.

Ward, P., Härkönen, I., Nurmi, P. A. & Pankka, H. S. 1989. Structural studies on the Lapland Greenstone Belt, northern Finland and their application to gold mineralization. In: Autio, S. (editor) Geological Survey of Finland. Current Research 1988. Geological Survey of Finland, Special Paper 10, 71–77.

Ward, P. & Nurmi, P. 1989. The geology and gold mineralization of the Hattu Schist Belt. In: Gaál, G. (editor) Symposium Precambrian granitoids. Petrogenesis, geochemistry and metallogeny, August 14–17, 1989, Helsinki, Finland, Excursion C-3 – Archean granitoids and associated Mo, W and Au mineralization in eastern Finland. Geological Survey of Finland, Guide 25, 41–59.

Warrender, J. M., Bowes, D. R. & Farrow, C. M. 1998. Conditions of metamorphism of the Outokumpu Cu-Co-Zn deposit from sphalerite geobarometry. Bulletin of the Geological Society of Finland 70 (1–2), 77–82.

Weiser, T. 1967. Zink- und Vanadium-führende Chromite von Outokumpu, Finnland. Neues Jahrbuch für Mineralogie, Monatsheft 1967, 234–243.

Wennervirta, H. 1960. Occurrences of uranium ore in North Karelia. International Geological Congress XXI Session, Norden 1960, Guide to Excursions A 37, A 38, C 32, C 33, Helsinki, 25–27.

Wennervirta, H. & Rouhunkoski, P. 1970. Lithogeochemical aspects of the Vihanti zinc ore deposit, Finland. Economic Geology 65, 564–578.

Wennervirta, H. & Papunen, H. 1974. Heavy metals as lithogeochemical indicators for ore deposits in the Iilinjärvi and Aijala fields, southwestern Finland. Geological Survey of Finland, Bulletin 269. 21 p.

Witt, O. 1909. The iron-ore occurrences in Kittilä, northern Finland. Report after inspection during the summer 1909. Kristiania 1910. 26 p.

Wyllie, R. J. M. 1989. Saattopora – Outokumpu opens Lapland gold mine, first new Finnish mine in years. Engineering and Mining Journal, June 1989, 40–43.

Yletyinen, V. 1967. Ylitornion Kivilompolon molybdeenihohde-esiintymästä. Summary: On the molybden prospect at Kivilompolo in Ylitornio, northern Finland. Geological Survey of Finland, Geotechnical Publications 73. 21 p.