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ISOMERTIEITE AND OTHER PLATINUM-GROUP MINERALS FROM THE
KONTTIJÄRVI LAYERED MAFIC INTRUSION, NORTHERN FINLAND

Y. Vuorelainen, T.A. Häkli, E. Hänninen, H. Papunen,
J. Reino, R. Törnroos

ABSTRACT

Early Proterozoic layered mafic intrusions, 2450 Ma in age, occur in a zone, several hundred kilometers long, that trends W-E across northern Finland. They contain Cr and Fe-Ti-V deposits as well as subeconomic but often persistent Ni-Cu sulfide occurrences with frequently significant PGE abundances. Pyrrhotite, pentlandite, chalcopyrite + pyrite are the predominant sulfides. The intensely metamorphosed Konttijärvi body is one of the layered mafic intrusions. It can be subdivided into three major zones: the heterogeneous basal metagabbro; the overlying uralitized and chloritized ultramafics; and the upper metagabbro, which is the largest unit of the body. The sulfide mineralization is concentrated as medium or low-grade disseminations in the basal metagabbro and the overlying ultramafics. The upper metagabbro, on the other hand, is almost sulfide-free. The predominant sulfide assemblage in the basal metagabbro is pyrrhotite-chalcopyrite-pentlandite+pyrite. It grades upwards from pyrrhotite-rich to a more chalcopyrite and pentlandite-predominant association. In the upper portion of the lower mafic zone and in ultramafics an iron-poor sulfide assemblage, bornite-chalcopyrite-millerite-pentlandite-pyrite-violarite, is encountered as a low-grade dissemination. The abundances of Pd and Pt, and of Cu and Ni in sulfide phase, increase gradually upwards from the basal contact of lower metagabbro to the upper ultramafics; the maximum content of Pd is 3.7 ppm and that of Pt 1.2 ppm, the average Pd to Pt ratio being 2.9. The PGEs in the upper metagabbro are below the detection limit of 0.02 ppm.

As in the other intrusions in the belt, the main carrier of platinum is sperrylite; in addition a few grains of vysotskite have been encountered. The mineralogy of palladium, which

is predominantly controlled by the system Pd-As-Sb, in which Cu sometimes substitutes for Pd, is more complicated. The corresponding mineral species are isomertieite, identified by microprobe and XRD, mertieite II, palladoarsenide and arsenopalladinite or an unnamed Pd_5As_2 , recognized by microprobe and optical properties, and an unidentified phase close to the composition of Pd_7As_2 . In chemical and optical properties the palladium nickel arsenide encountered resembles the mineral species majakite. Sporadic Pd-bismuthotellurides have also been met with. In composition they all lie near the tie line $\text{Pd}_7\text{Bi}_8 - \text{Pd}_7\text{Te}_8$, of which no species have been reported so far. Unidentified oxygen-bearing coatings, possibly palladium arsenates, occur as oxidation products on arsenopalladinite crystals.

INTRODUCTION

A discontinuous belt of layered mafic intrusions extends for more than 270 km across northern Finland from Tornio on the Swedish border eastwards to Näränkäväära on the Soviet border (Fig. 1). The belt comprises 11 large and several small separate bodies. One of the largest, the Porttivaara intrusion, is 30 km long and 4 km wide. The intrusions are either surrounded by Archean granitoids or they are located between the Archean granitoids and Proterozoic Svecokarelian (2.2 Ga) metasediments and metavolcanics. Zircon datings by the U/Pb method indicate an age of 2.45 Ga (Kouvo, 1976). The large layered gabbro body of Koitelainen in central Lapland, which is outside the belt proper, is of the same age. The layered intrusions have previously been described by Piirainen et al. (1977 and 1978), Juopperi (1977) and Alapieti et al. (1979).

The intrusions differ in type of mineralization (Fig. 1). Chromite ores exist in basal ultramafic portions of the western

layered bodies in Tornio and Kemi (Kujanpää, 1980). In the Suhanko-Kuohunki area instead of the primary oxide minerals some iron-copper-nickel sulfide mineralizations occur near the basal contacts of the intrusions. A vanadiferous magnetite gabbro horizon exists in the upper portion of the intrusions of Syöte, Porttivaara and Kuusijärvi. The Porttivaara intrusion includes a vanadium ore at Mustavaara (Juopperi, 1977). A heterogenous zone of disseminated iron-copper-nickel sulfide are encountered close to the basal contacts of the Syöte, Porttivaara and Kuusijärvi intrusions and locally also in the upper internal horizons.

Alapieti et al. (1979) have divided the Syöte intrusion into a relatively thin marginal series and a more extensive overlying layered series. The marginal series comprises albite-quartz rocks, gabbros and overlying ultramafics. These are succeeded by rocks of the layered series with an angular unconformity in between. The marginal series is characterized by a weak but persistent Fe-Cu-Ni sulfide dissemination and the distribution of rock types shows a reversed fractionation trend. Olivine norites and norites are typical of the marginal series, whereas the layered series consists of leucogabbros and anorthosites. A horizon of magnetite gabbro is found in the basal portion of the leucogabbro-anorthosite sequence. Alapieti et al. (1979) have divided the layered series into three zones: the lower, middle and upper zones.

The disseminated sulfides chalcopyrite, pyrrhotite and pentlandite occur in the lower marginal series. The sulfide

phase is rich in copper, the following average composition characterizes one of the occurrences: Cu 0.31%, Ni 0.19%, S 0.87%, Pd 0.59ppm and Pt 0.23ppm. The total tenor of the platinum group elements occasionally exceeds one ppm.

The most common platinum mineral is sperrylite. Palladium usually exists as tellurides and bismuthides such as merenskyite, michenerite and froodite, which are fairly regularly bordered by hessite suggesting the existence of a solid solution in the system Pd-Ag-Bi-Te at higher temperatures.

The small intrusion of Konttijärvi is located in the western extremity of the major Suhanko intrusion. The disseminated sulfides in Konttijärvi were discovered in 1964. In the 1970's, while the first author (Y.V.) was studying the opaque minerals under the microscope, he discovered that the Konttijärvi intrusion contained more platinum group minerals, especially isomertieite and sperrylite, than did the other layered intrusions. As a consequence, more samples were taken from the outcrops. Heavy mineral fractions were separated from the samples magnetically and with a shaking table. The mineral fractions were examined under an optical microscope and the platinum group minerals were analyzed on an electron microprobe and by XRD. As the target has not been diamond drilled, the description of the geology of the deposit must be considered as preliminary. Hence, the emphasis of the present paper is on platinum group mineralogy.

THE KONTTIJÄRVI INTRUSION

The Konttijärvi layered body, which has a strike length of about 600 m, is about 300 m wide (Fig. 2). It dips 50° to north conformably with the structure of the Proterozoic meta-sediments and metavolcanics north of it. The southern footwall of the body is composed of Archean granitoids and mica gneisses. The prevailing rock types allow the body to be divided into three zones (Table 1). Owing to the poor outcrop the classification is descriptive. Even so, the lower zones probably correspond to the marginal series of the Syöte intrusion described by Alapieti et al. (1979).

The lower metagabbro is strongly deformed and altered and, as indicated by its high tenors of aluminum and alkalies, it represents a contaminated marginal portion of the intrusion. Rhythmic layering is common. Fine-grained metapyroxenite exists as lenses and inclusions in the upper portion of the marginal metagabbro, and as a whole the sequence of the marginal zone seems to be reversed in terms of fractionation. The metagabbro grades into the overlying metaperidotite, which locally displays magmatic breccia structures. The upper mafic zone consists of massive metagabbro that grades upwards into a more plagioclase-rich variety. The mafic minerals have all undergone alterations: olivine is serpentized and altered into talc and magnesite, orthopyroxene is altered into chlorite, and clinopyroxene into amphibole minerals; also plagioclase is saussuritized.

The chemical compositions of the rock types are shown in Fig. 3 and Table 2. The basal gabbroic portion of the lower mafic zone is characterized by rather high abundances of aluminum and alkalis as a result of the wall-rock contamination. The metapyroxenitic lenses display rather high chromium. As the abundance of chromite is low, the chromium was originally incorporated in cumulus pyroxene thus indicating low P_{O_2} during crystallization. The concentration of Cr in the ultramafic zone is much lower than in pyroxenite.

A weak iron-copper-nickel sulfide mineralization exists in the lower mafic zone, while the overlying ultramafic zone and the upper metagabbro are almost barren. The sulfide mineral assemblage of the basal portion of the lower mafic zone includes pyrrhotite, chalcopyrite and pentlandite. The sulfide mineralization grades upwards into assemblages richer in copper and nickel and poorer in iron (Table 3). An iron-poor assemblage: chalcopyrite-bornite-pentlandite-millerite-violarite-pyrite is encountered in the metapyroxenitic lenses in the upper portion of the lower mafic zone. In addition to the platinum group minerals, the accessory opaque minerals are idaite, parkerite, sphalerite, argentopentlandite, arsenopyrite, galena, niccolite, hessite, gold, electrum, ilmenite and chromite.

The bulk of the platinum group elements is confined to the sulfide bearing lower mafic zone. The maximum abundance of palladium is 3.7 ppm and that of platinum 1.3 ppm. Like copper and nickel the platinum group elements (Table 2) gradually increase upwards from iron sulfide predominate basal meta-

gabbro to iron-poor sulfide assemblages in the metapyroxenite lenses. The abundance of palladium in the sulfide phase (Table 3) correlates well with the corresponding abundances of copper and nickel. The correlation coefficient between palladium and nickel is 0.95 and 0.79 between palladium and copper.

PLATINUM GROUP MINERALOGY

General

As the tenors of the platinum group elements are rather low, the investigation of platinum group minerals were mainly carried out on the heavy mineral fractions. The mineral assemblages and their mode of occurrence were studied only on selected rock samples. Generally, the platinum group minerals occur together with sulfides, but certain minerals, e. g. sperrylite exist also as inclusions in silicates. The chemical compositions of the minerals were determined by a JEOL JXA-733 electron probe with 15 kV accelerating potential and 15 nA probe current. Metals were used as standards for Au, Ag, Ni, Te and Bi, pyrite for Fe and S, a Pt-Cu alloy for Pt and Cu and a synthetic isomertieite (Cabri, 1980) for Pd, As and Sb. The X-ray lines used were AgL_{β_1} , BiM_{α} , SK_{α} , FeK_{α} , NiK_{α} , CuK_{α} , AsK_{α} , PdL_{α_1} , SbL_{α_1} , TeL_{α_1} , PtL_{α_1} and AuL_{α_1} . The X-ray data were corrected with the aid of the EMPADR VII computer program by Rucklidge and Gasparri (1969).

Sperrylite

Sperrylite is the most common platinum mineral in the

occurrence. It occurs in silicates, isomertieite and sulfides as minute inclusions less than 0.05 mm in diameter. The chemical composition of the mineral is close to the stoichiometric $PtAs_2$ (Table 4) in accordance with recently published analytical data (Cabri et al., 1975, Koivisto et al., 1980). The following trace elements have been detected in sperrylite: Ag, Au, Cu, Ni, Fe, S, Te, Sb and Bi.

Vysotskite

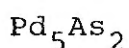
White euhedral crystals of vysotskite with a violet tint occur as inclusions in chalcopyrite. The mineral does not show birefractance and its anisotropy in air varies from light to dark violet. The identification of vysotskite is based mainly on the chemical composition (Table 5). The mineral either contains cations in excess or has a deficiency in anions. The vysotskites of Stillwater are close to stoichiometric $(Pd,Pt,Ni)S$ (Cabri et al., 1978).

The system Pd-As-Sb

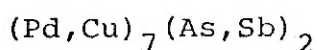
The diagram (Fig. 4) compiled according to Cabri et al. (1975) shows the five phases in the system Pd-As-Sb identified in Konttijärvi.

Palladoarsenide

The mineral occurs in association with pyrite. It is white in color with a pinkish tint, and is strongly anisotropic. The chemical composition, given in Table 6, deviates slightly from that of the stoichiometric $Pd_2(As,Sb)$ (Cabri et al., 1975).



A white mineral with a faint lilac tint and a strong anisotropy is either arsenopalladinite or an unnamed Pd_5As_2 (Cabri, 1975). The chemical composition is close to the stoichiometric Pd_5As_2 (Table 6).



This mineral is an alteration product of the Pd_5As_2 phase mentioned above. It is grayish in color and shows a very strong anisotropy (Fig. 5). The chemical composition is close to $(\text{Pd,Cu})_7(\text{As,Sb})_2$ (Table 6).

Isomertieite

The mineral isomertieite has been described from the alluvial sands from Itabira, Minas Gerais, Brazil (Clark et al., 1974) and from Lac des Iles, Ontario (Cabri and Laflamme, 1979). Konttijärvi is thus the second solid occurrence. Isomertieite is the most common platinum group mineral in the Konttijärvi intrusion. It occurs as rather large euhedral grains up to 0.4 mm in diameter together with sulfides. Inclusions of sperrylite and native gold are common. Isomertieite also exists as complex intergrowths with mertieite, majakite and palladium bismuth tellurides (Fig. 6). Except for a slight excess of cations its chemical composition (Table 7) is close that of the synthetic $\text{Pd}_{11}\text{Sb}_2\text{As}_2$ by Cabri (1980). Note also that the mineral is "impure" with rather high tenors of Cu, Au, Ag and Pt. As it also contains gold and sperrylite as inclusions, we may assume that a Pd-Pt-Au-Ag-Cu-As-Sb solid solution

existed at high temperatures and that the intergrown phases exsolved when the temperature dropped.

Mertieite II

The mineral, interpreted as mertieite II on account of its chemical composition, is white with a greenish tint especially in oil immersion if compared with isomertieite. It occurs as complex intergrowths with isomertieite, majakite and the palladium bismuthotellurides. It commonly shows micrographic intergrowths of electrum and cavities that were probably once filled with fluid. The chemical analyses suggest a formula close to $\text{Pd}_{16}\text{Sb}_5\text{As}$ as proposed by Cabri (1980).

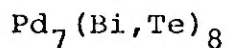
The system Pd-Ni-As

Majakite

A grayish white mineral with a distinct violet tint when compared with isomertieite occurs as intergrowths with isomertieite and mertieite II. Its chemical composition is close to the formula PdNiAs . The mineral is tentatively suggested as majakite previously described by Genkin et al. (1976) (Table 8).

The system Pd-Bi-Te

Fig.8 depicts the known natural phases of the system Pd-Bi-Te: keitchconnite and telluropalladinite (Cabri et al., 1979), sobolevskite (Evstigneeva et al., 1975), kotulskite (Genkin et al., 1963) and froodite, michenerite and merenskyite according to their stoichiometry. Also the phases found in Konttijärvi have been shown.



Numerous small inclusions of palladium bismuthotellurides occur in bornite and chalcopyrite. The inclusions are anhedral, less than 0.05 mm in diameter, and are characterized by high reflectivity, a creamy white color and strong anisotropy with yellow and grayish violet colors in air. The mineral is distinctly softer than chalcopyrite. The chemical analyses indicate a varying ratio of Bi/Te, but an almost constant cation to anion ratio of 7:8 (Table 9, Fig. 8). In the diagram the compositions plot below the tie line of sobolevskite-kotulskite. Hence, there is probably an unknown solid solution $\text{Pd}_7\text{Bi}_8\text{-Pd}_7\text{Te}_8$ in the system Pd-Bi-Te. Note also that Mihálik et al. (1974) have described a phase $\text{PdTe}_{1.04}\text{Bi}_{0.04}$ from Messina, Transvaal, South Africa that was suggested to be a palladium-poor kotulskite.

The system Pd-As-O

Palladium arsenate

A dark grayish mineral with distinct anisotropy occurs as an alteration product of the phase $(\text{Pd,Cu})_7\text{As,Sb}_2$. The phase is oxygen-bearing, and if interpreted as hydrated arsenate, has a formula of $(\text{Pd,Cu,Ni})_{18}\text{AsO}_4 \cdot 4\text{H}_2\text{O}$. (Fig. 5, Table 10).

Discussion

The Konttijärvi layered body is part of a layered intrusive complex 2.45 Ga old. It lies in the western extremity of the major Suhanko intrusion ^{and} may be separated from Suhanko by granite gneiss. The rocks are moderately deformed and altered. The lowest zone of the intrusive complex contain considerable PGEs. The host rocks of the PGMs are urali-tized and chloritized mafic and ultramafic members of the sequence. A weak sulfide dissemination controls the richest accumulation of PGEs. The sulfide mineral assemblage is poor in iron and consists of pentlandite, millerite, violarite, chalcopyrite, bornite and local pyrite. Gold and electrum accompany the PGEs.

The occurrence of PGE in the lower marginal zone of the Konttijärvi intrusion corresponds well to the accumulation of PGE in the other layered bodies of the belt. Platinum

group mineralogy of Konttijärvi is more complicated than in the other layered bodies of the belt. The observed solid solutions and substitutions of the Konttijärvi PGM probably refer to high temperature of deposition. On the other hand, complex intergrowths and micrographic textures with open cavities in isomertieite and mertieite II as well as oxidation of palladium arsenides have been interpreted as consequences of low-temperature metamorphism. The PGEs were originally concentrated, together with Ni-Cu sulfides, in the basal portion of the layered mafic complex of the belt. In Konttijärvi, however, the PGEs were enriched by by metamorphic processes. The Pd to Pt ratio of the Konttijärvi occurrence (2.5 - 8.3) and the existing Cu to Ni ratios (1.7 - 2.9) are in accord with the data presented by Naldrett and Cabri (1976) for the tholeiitic mafic rocks.

As the tenor of Pd is directly related to the tenors of nickel and copper in the sulfides, the high-grade sulfide accumulations may locally contain economically significant grades of PGE.

Acknowledgements

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TEXT OF THE FIGURES

Fig. 1. Location of the layered mafic intrusions in northern Finland

Fig. 2. Geological map and section of the Konttijärvi intrusion showing the location of sampling lines.

Fig. 3. A diagram illustrating variation of chemical composition along sampling lines A-E in Fig. 2.

Fig. 4. Cation-rich part of the ternary system Pd-As-Sb (Cabri et al. 1975). Squares refer to synthesized phases, circles denote the known species and crosses represent analyses from Konttijärvi: A = palladoarsenide, B = unknown Pd_5As_2 or arsenopalladinite, C = unknown $(\text{Pd,Cu})_7(\text{As,Sb})_2$, D = isomertieite and E = mertieite II.

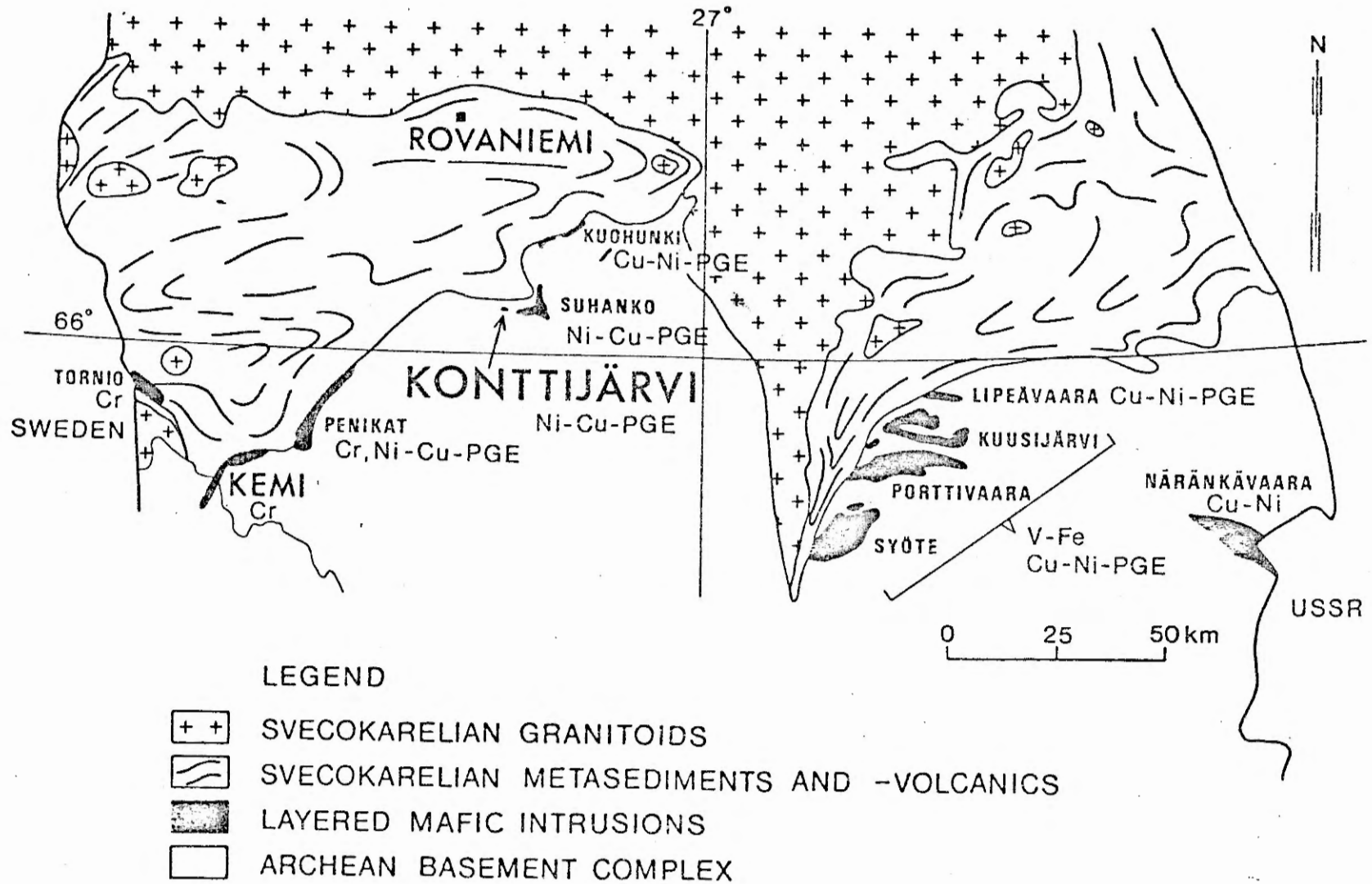
Fig. 5. Backscattered electron image (BEI, compositional) and X-ray distribution images of an arsenopalladinite or an unknown Pd_5As_2 crystal (white in BEI) which is replaced by unreported phases of $(\text{Pd,Cu})_7(\text{As,Sb})_2$ (gray in BEI) and palladium arsenate (dark gray).

Fig. 6. X-ray distribution images of a complex intergrowth of isomertieite, mertieite, majakite and $\text{Pd}_7(\text{Bi,Te})_8$

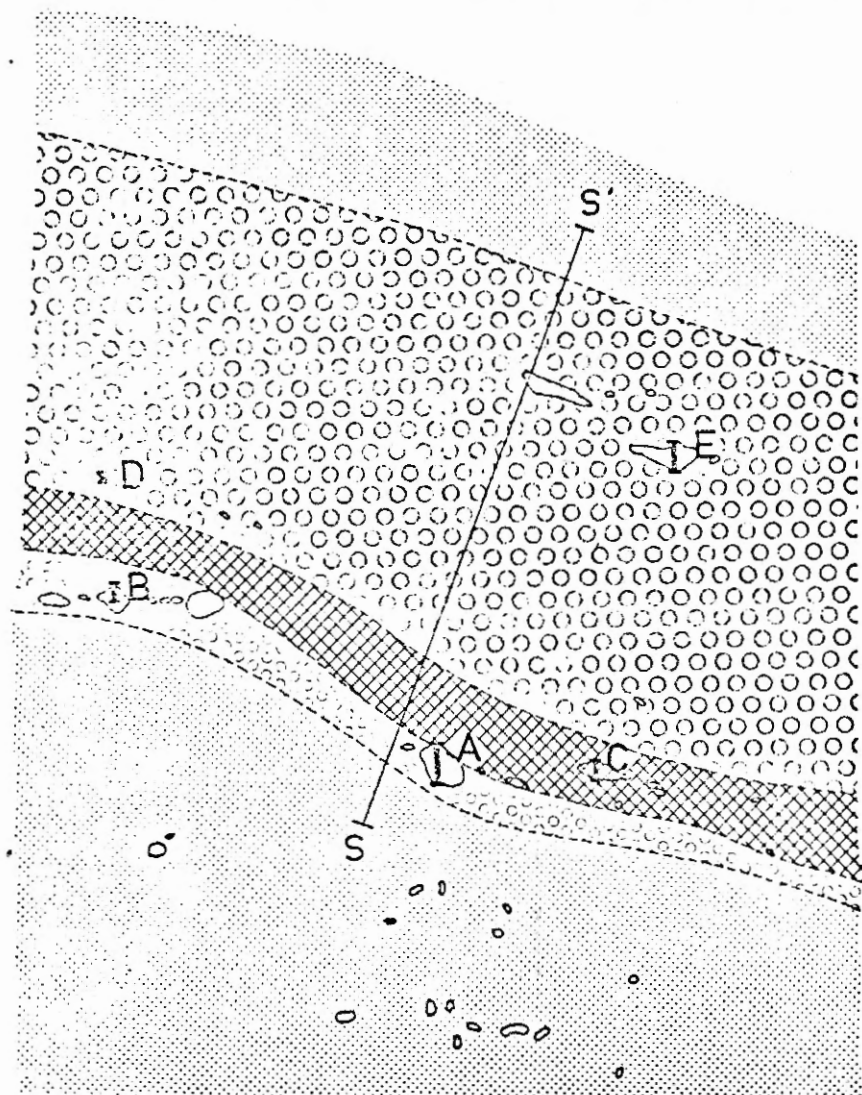
Fig. 7. Backscattered electron image (BEI, compositional) and X-ray distribution images showing a micrographic intergrowth of mertieite, electrum and cavities in an isomertieite crystal.

Fig. 8. Mineral in the ternary system Pd-Bi-Te. (Genkin et al., 1963; Evstigneeva et al., 1975; Cabri et al., 1979). Crosses represent analyses from Konttijärvi.







Fig. 1



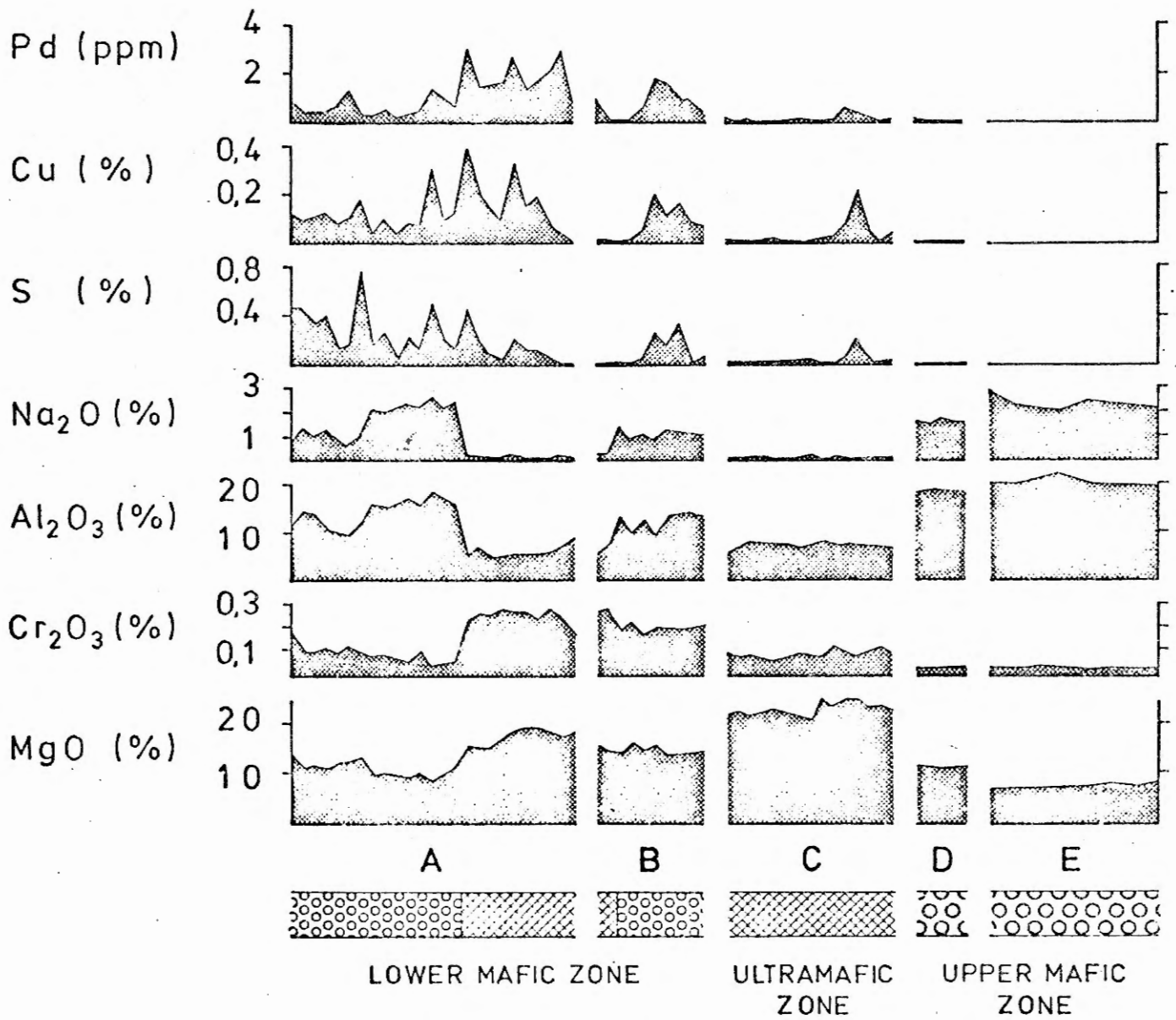
GEOLOGICAL MAP OF THE KONTTIJÄRVI INTRUSION



LEGEND

-  UPPER MAFIC ZONE
-  ULTRAMAFIC ZONE
-  LOWER MAFIC ZONE
-  ARCHEAN BASEMENT COMPLEX
-  OUTCROP
-  SAMPLING LINE

0 100 200 300 400 m



10 m

Chemical composition diagrams. Sampling lines A - E.

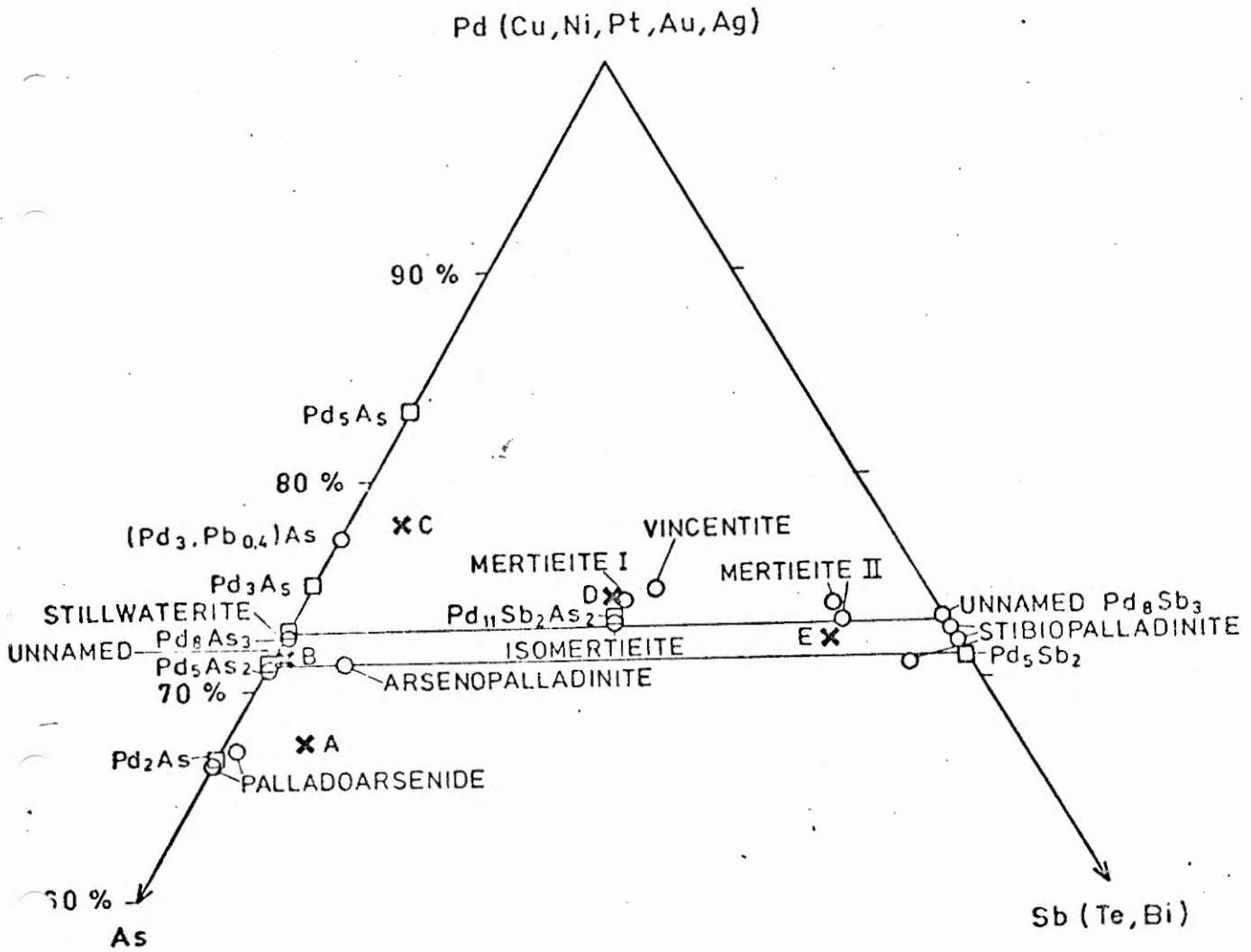


Fig. 8

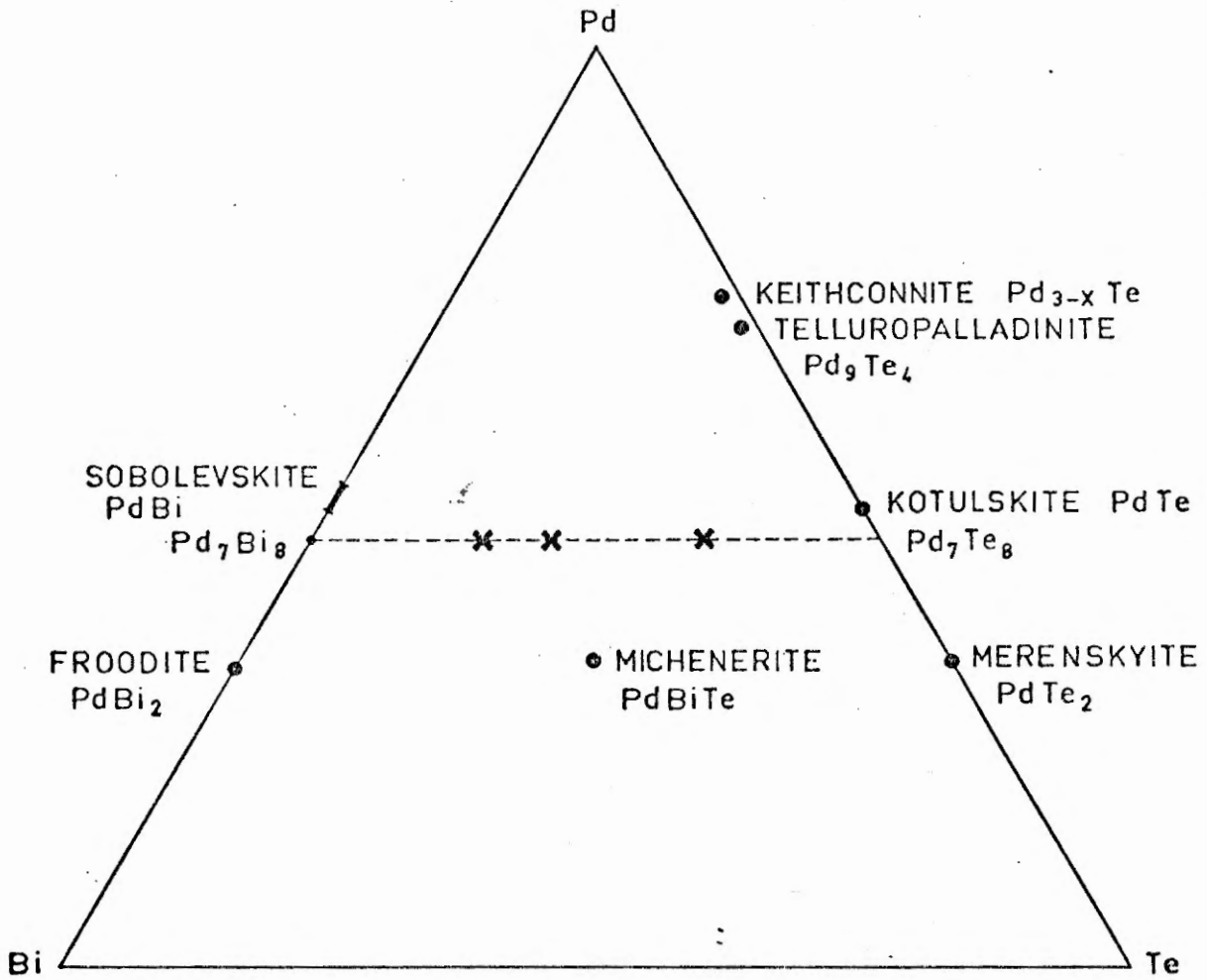


Table 1. Generalized section of the Konttijärvi body

Unit	Thickness	Rock type	Main minerals
Upper mafic zone	230 m	metagabbro	hornblende, plagioclase
Ultramafic zone	50 m	metaperidotite metapyroxenite	chlorite, hornblende, talc, magnesite, oxide chlorite, hornblende
Lower mafic zone	20-30 m	lenses of meta- pyroxenite metagabbro	chlorite, hornblende plagioclase, hornblende biotite, quartz

Table 2. Chemical compositions of the mafic and ultramafic rocks in the Fonttijarvi intrusion.

	1	2	3	4	5	6	7	8
SiO ₂ (wt-%)	51.50	52.51	56.73	50.10	52.25	45.00	48.30	50.70
TiO ₂ "	0.19	0.19	0.23	0.19	0.23	0.15	0.20	0.21
P ₂ O ₅ "	0.03	0.04	0.04	0.09	0.04	0.02	0.04	0.04
Al ₂ O ₃ "	13.84	16.52	4.72	4.24	11.50	7.10	18.60	20.20
Cr ₂ O ₃ "	0.10	0.07	0.25	0.23	0.20	0.09	0.04	0.04
Fe ₂ O ₃ "	1.98	1.11	1.22	1.37	x	x	x	x
FeO "	7.34	5.11	9.09	10.33	6.61	13.30	7.31	5.55
MnO "	0.17	0.13	0.23	0.22	0.19	0.20	0.14	0.12
MgO "	10.39	8.53	15.07	20.60	14.65	22.92	11.42	7.42
CaO "	8.29	10.76	7.79	7.37	10.40	4.49	8.79	9.28
Na ₂ O "	1.32	2.47	0.09	0.07	1.01	0.12	1.67	2.35
K ₂ O "	0.54	0.32	0.02	0.02	0.20	0.06	0.41	0.30
H ₂ O ⁺ "	2.63	1.44	3.65	4.23	1.80	5.78	2.97	1.18
H ₂ O ⁻ "	0.06	0.05	0.09	0.15				
CO ₂ "	0.06	0.04	0.04	0.03	0.04	1.38	0.08	0.06
S "	0.54	0.24	0.10	0.16	0.11	0.04	0.01	0.02
Cu "	0.08	0.10	0.14	0.16	0.13	0.03	0.01	0.01
Ni "	0.09	0.08	0.11	0.14	0.10	0.19	0.07	0.03
Pd (ppm)	0.88	0.74	1.10	1.30	0.83	0.50	0.08	0.07
Pt "	0.24	0.19	0.45	0.49	0.26	0.06	0.02	0.02
Rh "	0.03	0.00	0.03	0.04	0.01	0.01	0.00	0.00
Total (wt-%)	99.35	99.67	99.61	99.70	99.66	100.87	100.06	98.21

x = Fe₂O₃ not determined, Fe calculated as FeO

1. Lower portion of metagabbro in the lower mafic zone, sampling line A.
2. Upper portion of metagabbro in the lower mafic zone, sampling line A.
3. Quartz-bearing metapyroxenite in the lower mafic zone, sampling line A.
4. Metapyroxenite in the lower mafic zone, sampling line A.
5. Metagabbro in the lower mafic zone, sampling line B.
6. Metaperidotite in the ultramafic zone, sampling line C.
7. Metagabbro in the upper mafic zone, sampling line D.
8. Metagabbro in the upper mafic zone, sampling line E.

Table 3. Calculated chemical compositions of the sulfide phase in the rocks of the lower mafic zone (the sulphur content of the sulfide phase was estimated as 37 %).

	1	2	3	4	5
Cu (wt-%)	7.93	16.44	25.93	34.80	30.51
Ni "	4.63	5.58	9.54	12.19	10.64
Fe "	50.44	40.98	27.53	16.01	21.85
Pd (ppm)	63	144	313	401	341
Pt "	17	37	128	151	107
Rh "	2	1	9	13	6

1. Lower portion of metagabbro, line A.
2. Upper portion of metagabbro, line A.
3. Quartz-bearing metapyroxenite, line A
4. Metapyroxenite, line A
5. Metagabbro, line B

Table 4. Electron microprobe analyses of sperrylite.

	1		2	
	wt-%	at. prop.	wt-%	at. prop.
Pt	55.46	0.98	55.32	0.99
Ag	0.19	0.01	0.10	0.00
Au	0.20	0.00	0.10	0.00
Cu	0.09	0.00	0.02	0.00
Fe	0.02	0.00	0.01	0.00
Ni	0.00	0.00	0.01	0.00
Pd	0.00	0.00	0.00	0.00
As	42.42	1.96	42.43	1.97
S	0.34	0.04	0.08	0.01
Te	0.00	0.00	0.44	0.01
Sb	0.13	0.00	0.13	0.00
Bi	0.00	0.00	0.13	0.00
Total	98.85		98.77	
Sum of cations		1.00		1.00
Sum of anions		2		2

Table 5. Electron microprobe analysis of vyotskite.

	wt-%	at. prop.
Pd	62.67	0.87
Ni	4.76	0.12
Pt	8.81	0.07
Au	0.21	0.00
Ag	0.07	0.00
Cu	0.07	0.00
Fe	0.01	0.00
S	21.61	1.00
Te	0.13	0.00
As	0.00	0.00
Sb	0.00	0.00
Bi	0.00	0.00
Total	98.34	
Sum of cations		1.06
Sum of anions		1

Table 6. Electron microprobe analyses of palladoarsenide, Pd₅As₂ and unnamed (Pd,Cu)₇As₂

	Palladoarsenide		Pd ₅ As ₂		(Pd,Cu) ₇ As ₂	
	wt-%	at. prop.	wt-%	at. prop.	wt-%	at. prop.
Pd	70.96	1.99	71.56	4.66	71.80	6.06
Cu	1.11	0.05	1.48	0.16	6.36	0.90
Ni	0.32	0.02	1.08	0.12	0.25	0.04
Au	0.21	0.01	2.34	0.08	0.22	0.01
Ag	0.00	0.00	0.17	0.01	0.17	0.02
Pt	0.00	0.00	0.00	0.00	0.00	0.00
Fe	0.03	0.00	0.08	0.01	0.24	0.04
As	22.47	0.90	21.20	1.96	14.77	1.76
Sb	3.96	0.10	0.14	0.01	2.72	0.20
S	0.03	0.00	0.03	0.01	0.00	0.00
Te	0.16	0.00	0.50	0.03	0.50	0.04
Bi	0.00	0.00	0.00	0.00	0.00	0.00
Total	99.25		98.58		97.02	
Sum of cations		2.07		5.04		7.06
Sum of anions		1		2		2

Table microprobe analyses of merticite II and isomerticite.

	Merticite II (1)		Merticite (2)		Isomerticite	
	wt-%	at. prop.	wt-%	at. prop.	wt-%	at. prop.
Pd	70.44	15.46	71.32	15.64	71.35	10.61
Cu	0.15	0.06	0.00	0.00	2.73	0.68
Ag	-		-		1.10	0.16
Au	-		-		0.81	0.06
Pt	0.00	0.00	0.00	0.00	0.61	0.05
Fe	0.03	0.01	0.00	0.00	0.05	0.01
Ni	0.00	0.00	0.03	0.01	0.00	0.00
Sb	25.37	4.86	25.59	4.90	15.08	1.96
As	3.50	1.09	3.39	1.05	9.43	1.99
S	0.05	0.04	0.02	0.01	0.03	0.01
Te	0.00	0.00	0.00	0.00	0.00	0.00
Bi	0.27	0.03	0.13	0.01	0.38	0.05
Total	99.81		100.50		101.57	
Sum of cations		15.53		15.65		11.58
Sum of anions		6		6		4

Table 8. Electron microprobe analysis of majakite.

	wt-%	at. prop.
Pd	45.01	1.01
Ni	23.33	0.95
Pt	0.18	0.00
Fe	0.06	0.00
Cu	0.00	0.00
As	30.85	0.99
Sb	0.58	0.01
Te	0.14	0.00
S	0.00	0.00
Bi	0.00	0.00
Total	100.15	
Sum of cations		1.96
Sum of anions		1

Table 1. Electron microprobe analyses of palladium tellurobismuthides.

	1		2		3	
	wt-%	at. prop.	wt-%	at. prop.	wt-%	at. prop.
Pd	37.60	6.46	33.11	6.63	33.65	7.08
Ni	0.60	0.19	0.08	0.03	0.03	0.01
Cu	0.39	0.11	0.12	0.04	0.12	0.04
Ag	0.48	0.03	-	-	-	-
Pt	0.59	0.06	0.77	0.08	0.77	0.09
Au	0.20	0.02	-	-	-	-
Fe	0.00	0.00	0.30	0.11	0.00	0.00
Te	43.10	6.19	20.41	3.41	14.12	2.49
Bi	19.10	1.67	43.50	4.44	50.40	5.40
As	0.39	0.10	0.00	0.00	0.00	0.00
Sb	0.38	0.06	0.77	0.13	0.49	0.09
S	0.00	0.00	0.04	0.02	0.02	0.01
Total	102.83		99.45		99.60	
Sum of cations		6.92		6.93		7.22
Sum of anions		8		8		8

Table 10. Electron microprobe analysis of palladium arsenate.

	wt-%	at. prop.
Pd	84.85	1.78
Cu	3.52	0.12
Ni	2.37	0.09
Fe	0.03	0.00
Pt	0.00	0.00
O	6.34	0.89
As	3.71	0.11
Sb	0.09	0.00
Te	0.07	0.00
S	0.00	0.00
Bi	0.00	0.00
Total	100.98	
Sum of cations		2.00
Sum of anions		1.00

Table 1. Generalized section of the Konttijärvi body

Unit	Thickness	Rock type	Main minerals
Upper mafic zone	230 m	metagabbro	hornblende, plagioclase
Ultramafic zone	50 m	metaperidotite metapyroxenite	chlorite, hornblende, talc, magnesite, oxide chlorite, hornblende
Lower mafic zone	20-30 m	lenses of meta- pyroxenite metagabbro	chlorite, hornblende plagioclase, hornblende biotite, quartz