DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2010/138

Gold, PGE and sulfide phases of the precious metal mineralization of the Skaergaard intrusion

Part 11: Sample 90-24 1062

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Abstract

The report presents the results of mineralogical investigations of sample # 90-24 1062 from the lower parts of the Pd5 level in the precious metal mineralization in the Skaergaard intrusion. The bulk sample was collected between 1062 and 1063 meters in core 90-24. Assays give 720 ppb Pd, 24 ppb Au, and 110 ppb Pt for this interval.

The sample (1300 g) was crushed in small portions using a shatter box (200 ml) with small cavities for short periods (0.3-0.5 min), sieved to remove the fine fraction (sieve - 125 μm) after each crushing session. The residual coarse fraction >125 μm was re-crushed until the entire sample attained the desired maximum grain size.

After complete crushing the material was passed through the following sieves: 1) <40, 2) 40-63, 3) 63-80, 4) 80-125 μm. All fractions were subjected to wet magnetic separation.

The non-magnetic material from every grain size fraction was hydroseparated using the computer controlled device CNT-HS-11. Monolayer polished sections were produced from the heavy HS-concentrates of each fraction. These polished sections (and one polished section of the primary rock) were investigated under the scanning electron microprobe. All magnetic fractions proved not to contain precious metal grains.

The HS-concentrates contain numerous sulfide grains identified as sulfide droplets. They are composed of one or more Cu-sulfides - bornite, chalcosine, chalcopyrite, and occasionally of pentlandite. Several of these droplets and sulfide grains contain inclusions of PGMs. One grain of baddeleyite (~50 μm) was identified in the heavy mineral concentrate. It can be used for determination of the age of the ore horizon.

A selection of 33 precious metal grains, were studied in detail under the microprobe. The grains are believed to be representative for the precious metal mineral paragenesis in the sample. The absolutely dominating precious metal mineral is skaergaardite (Pd,Pt,Au)(Cu,Fe,Zn) (96.9 vol. %), followed by several minerals: (Pd,Cu,Pt) alloy (2.4 vol. %), kethconnite $Pd_3(Te,Pb)$ (0.5 vol. %), vasilite $(Pd,Cu)_{16}S_7$ (0.1 vol. %), and zvyagintsevte (?) (Pd,Pb,Cu). The grain size of precious metal minerals (ECD = effective diameter) varies from 2 to 44 μm with an average of 21 μm.

The average composition of skaergaardite (analyses from 31 grains) is (wt. %): Pd 59.0, Pt 2.0, Au 1.9, Cu 29.1, Fe 5.2, Zn 1.5, Sn nd, Te 0.34, Pb 0.25, Total 99.3; equivalent to the formula:

$$(Pd_{0.96}Pt_{0.02}Au_{0.02})_{1.00}(Cu_{0.80}Fe_{0.16}Zn_{0.04})_{1.00}.$$

The estimated bulk composition (ppb, assays of whole rock in brackets) is: Pd 800 (720), Au 24 (24), Pt 30 (110). Pd, Pt and Au are distributed between skaergaardite and (Cu,Pd,Pt) alloy.

All the observations and the intergrain relations suggest that all PGMs form a single paragenesis. The sulfide droplets contain rare droplets of PGMs. The characteristic structure suggests the occurrence of two immiscible melts: 1) Cu-Fe sulfide melt and 2) metal melt enriched by Cu, Pd, Pt and Au that separated from bulk sulfide melt.

Intodoction

The report describes the mineralogy of sample 90-24 1062 from Pd5 level in the “Platinova Reef” of the Skaergaard intrusion. The Platinova Reef is located in the lower half of the Triple Group that forms the upper 100 meters of the Middle Zone (MZ) of the Layered Series (LS) (see Nielsen et al., 2005 for further details). The sample collects bulk sample from 1062 to 1063 meters in core 90-24

The report on the PGE and Au mineral and sulfide mineralogy is based on concentrates produced using a new patented model of Hydroseparator CNT-HS-11 and polished section of the host gabbro. Mounts with concentrates and the polished section of host gabbro were studied using electron microscopy and electron microprobe analysis (Camscan-4DV, Link AN-10 000). The report gives descriptions of the grain characteristics, the parageneses and the compositional variation within the identified groups of minerals, alloys, sulfide droplets and host gabbro.

Sample 90-24 1062

Sample 90-24 1062 was collected from BQ drill core # 90-24 between 1062 and 1063 meters. The core was drilled with an azimuth of 0^o and an inclination of –70 from a location at 504 meters a.s.I, on the western slope of Basistoppen (Watts, Griffis and McOuat, 1991).The core has previously been sampled for other purposes. The sample collects 1/3 of the diameter of the preserved core.

The gabbro in sample 90-24 1062 has a characteristic structure showing reaction relationships between cumulus and inter-cumulus phases. Rinds of olivine and anorthite-rich plagioclase occur at the boundaries between interstitial matrix Fe-Ti-oxides and rock-forming clinopyroxene with low-Ca pyroxene exsolution lamellae. In general, this is a “dry” rock. H_2O-bearing minerals are only locally represented in very insignificant amounts in intergrowths with Cu-Fe-sulfides

Assays give 720 ppb Pd, 24 ppb Au, and 110 ppb Pt for this interval

Mineralogical investigation

Sample preparation and analytical techniques

Small portions of the sample (1300g) were crushed for short periods (0.3-0.5 min) using a shatter box with small cavities (200ml) and systematically sieved to remove the fine fraction (sieving -100μm) after each crushing session. The residual coarse fraction >100μm was re-crushed until the entire sample attained the desired maximum grain size. After complete grinding, the sample was passed through standard sieves with water (wet sieving): <40 μm (521 g), 40-63 μm (170 g), 63-80 μm (88 g), 80-125 μm (378 g),

After wet magnetic separation, the fractions with grain size <40 μm, 40-63 μm, 63-80 μm, 80-125 μm were passed through hydroseparator CNT-HS-11. Several monolayer polished sections were produced from all heavy HS-concentrates. The polished sections (and one polished section of the bulk rock) were investigated under the scanning electron micro-probe.

No precious metal grains were found in the magnetic fractions.

The analytical techniques are described in Nielsen et al. (2003)

Results

Rock forming minerals and sulfide mineralogy

Silicates and oxides

The silicates and oxides related to the sulfides are: 1) *plagioclase*, An_{42-43} (Table 1, analyses 1-3); 2) *monoclinic ferrous pyroxene*, Mg# = 0.64-0.66 (Table 1, analyses 4, 5), 3) *orthorhombic ferrous pyroxene*, Mg# = 0.54 (Table 1, analyses 6, 7) 4) *Fe-rich olivine*, Mg# = 0.42 (Table 1, analysis 8); Fe-Ti oxides including 5) *ilmenite* (Table 1, analyses 9-11) and 6) *titaniferous magnetite* (Table 1, analyses 12-16). Monoclinic and orthorhombic pyroxenes form typical exsolution textures (see Plate 1).

The Fe-Ti-oxides occur as aggregates of 1-3 mm, anhedral grains. They fill the space between grains of plagioclase and pyroxenes (Plate 1, #1, 2). At the contact between pyroxenes and Fe-Ti-oxides these aggregates are rimmed by Fe-rich olivine and anorthite (Plate 1, #1, 2).

One baddeleyite grain, ~50 μm in size (Fig. 1), was found in the heavy mineral concentrate. It can be used for dating of the ore horizon.

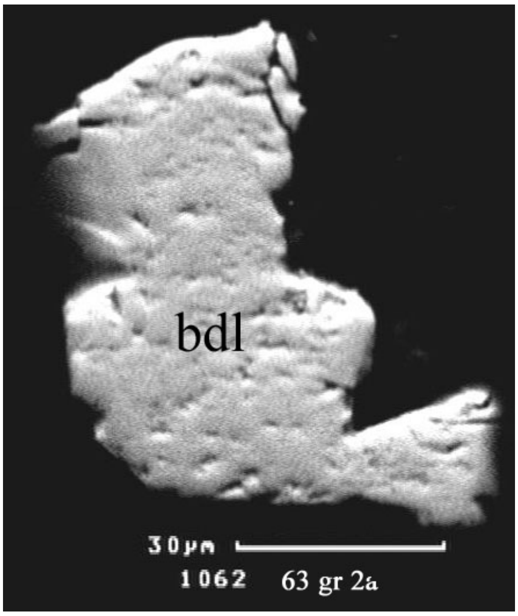

Fig. 1. Baddeleyite grain in the heavy concentrate of the sample 90-24 1062; polished section, SEM-image (BIE).

The host gabbro of sample 90-24 1062 is fairly “dry” rock. In the studied polished section, no minerals containing volatile elements were found (Plate 1). However, chamosite and calcite were found in of some sulfide globules (Plate 2, #4, 5, 10), and in paragenesis with Cu-sulfides and PGMs (Plate 3, #1, 2, 15).

Sulfides

The gabbro is relatively poor in sulfides. Several sulfide grains (bornite+chalcosine) were found In the concentrates. They form irregular aggregate, 20-100 μm in size). They occur as inclusions in pyroxenes and plagioclase (Plate 1, #3, 4).

The non-magnetic concentrates are rich in ilmenite (> 95 %), and enriched in grains of sulfides and PGMs. The sulfide grains include irregular grains (Plate 2, #9-11) and some droplet-like microglobules up to 0.1 μm in size (Plate 2, #1-5).

The sulfide grains and aggregates are dominantly composed of bornite and chalcosine group minerals (see Plates 1, #3, 4; Plate 2), less often of chalcopyrite (Plate 2, #9) and Co-bearing pentlandite (Plate 2, #6; Plate 5, #4). The volume ratio varies significantly from grain to grain (see Plate 2), but bornite and chalcosine dominate. Inside microglobules bornite and chalcosine group minerals form classic exsolution textures (Plate 2, #1, 2; Plate 5, #2).

The chemical composition of bornite (Table 2, analyses 3, 5, 7-9, 11-13, 15) and chalcosine (Table 2, analyses 1, 2, 4, 14, 16, 17) are close to stoikiometric. Co-pentlandite (Plate 2, #6; Plate 5, #4; Table 2, analyses 6, 10) occurs as intergrowths with Cu-Fe sulfides and skaergaardite and contains from 20.5 to 21.7 % Co.

PGMs: recovery, grain size and relations to host rock

Recovery

Skaergaardite have not been identified in polished section of gabbro (90-24 1062), whereas the heavy mineral concentrates have yielded many PGM grains. A representative selection of 33 grains of a wide size range (from –40 μm up to 80-125 μm) was studied in detail. Five different PGMs are documented in sample 90-24 1062 and include:

1. *Skaergaardite* (Pd,Pt,Au)(Cu,Fe,Zn) - 31 grains,
2. *(Cu,Pd,Pt) alloy* - 2 grains;
3. *Keithconnite* Pd_3(Te,Pb) – 2 grains;
4. *Vasilite* $(Pd,Cu,Fe)_{16}S_7$- 1 grains;
5. *Zvyagintsevite (?)* Pd_3Pb – 2 grains.

The volumetric proportions are calculated from the area of grains of the minerals (Table 3, 4 and Fig. 2).

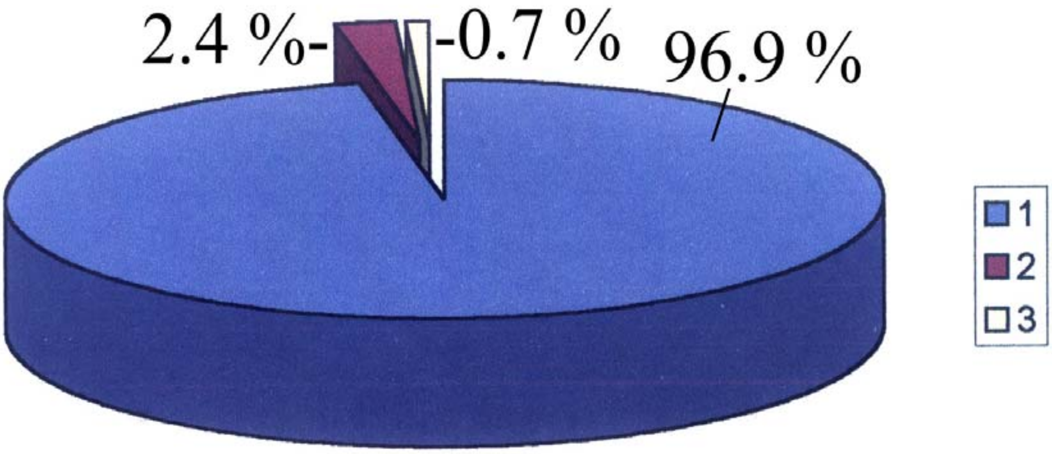

Fig. 2. Relative contents of PGM, the sample 90-24 1062 (see Table 4).
1: skaergaardite; 2: (Pd,Cu,Pt)-alloy; 3: keithconnite, vasilite, zvyagintsevite (?).

Grain size

Grain sizes were measured by the effective diameter of the grains (ECD) using imageJ software. They vary from 2 to 44 μm with an average of 21.2 μm (Table 3, 4; Fig. 3).
The histogram of grain sizes of PGMs (Fig. 3) is showing a normal statistical distribution for the thirty-three grains. 33. The size distribution of the PGM grains is as follows:

Grain size, μm	Number of grains
0-10	6
10-20	10
20-30	10
30-40	6
40-50	1

The SEIs (scanning electron images) show that the majority of PGM grains are well preserved and have kept their primary shape and size (Plates 3-5). Grains have not been broken during the production of the concentrates. The largest proportions of grains of PGMs are concentrated in the <40 μm fraction.

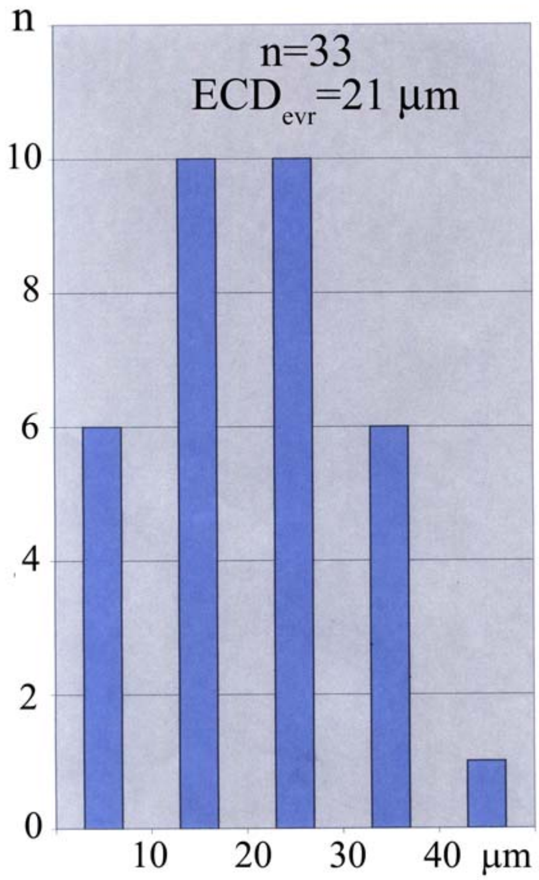

Fig 3. Histogram showing the sizes of PGM grains (n=33) in the heavy concentrates of sample 90-24 1062.

Petrographic observations

Perfect separation of accessory minerals has been achieved by gentle crushing and sieving of the studied sample. This has allowed preservation of grains and ensured recovery of the information needed for the modeling of the genesis of minerals. The concentrates provide full information for the reconstruction of the primary shapes and sizes of accessory minerals, together with their paragenesises and paragenetic relations with the host rock.

In the concentrates of the sample 90-24 1062 the precious metal mineral grains occur in the following mineral associations (Fig. 4; Table 5):

Table 5. *Mineral associations of PGM in the sample 90-24 1062*

Association	PGM- grains, vol. %
L	20.9
LP	1.9
bms	50.2
bms-L	16.2
sag-L	10.8

***L** - completely liberated (free) particles; **LP** – two or more PGMs completely liberated (free) particles; **bms** - intergrowths with base metal sulfides (bornite, chalcosine, chalcopyrite, sometimes pentlandite); **bms-L** - liberated particles with <10 % attached base metal sulfides; **sag-L** - sulfide and gangue attached to PGMs, but. <10 %.*

Based on SEIs, the precious metal minerals in the concentrates are divided into the following groups:

1. skaergaardite grains in intergrowths with base metal sulfides (**bms, bms-L**), and sulfides + gangue (**sag-L**) - (Plate 3);
2. completely liberated skaergaardite grains (**L**) – (Plate 4).
3. mineral grains containing PGMs other than skaergaardite (Plate 5).

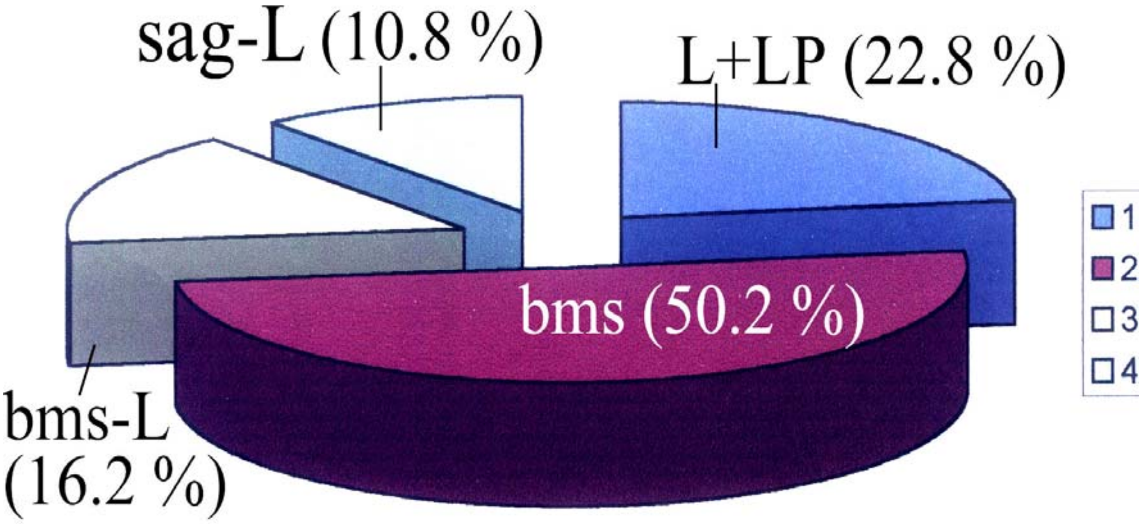

Fig. 4. PGMs grouped by associations (sample 90-24 1062) – see Table 5.
1- completely liberated (free) particle **(L)** and two or more PGMs completely liberated (free) particle **(LP)**; 2 – PGMs attached to base metal sulfides **(bms)**; 3 - base metal sulfides attached to PGMs **(bms-L)**; 4 – PGMs attached to sulfides and gangue (**sag**).

Description and chemistry of PGMs

Skaergaardite (Pd,Pt,Au)(Cu,Fe,Zn)

Description

Skaergaardite is the totally dominant Pd mineral in the concentrates of sample 90-24 1062 (96.9 vol.%). It is found in the following forms:

1. liberated (free) grains: **L** (Plate 4);
2. intergrowths with base metal sulfides (bornite, chalcosine, chalcopyrite, Co-pentlandite,: **bms** (Plate 3, #1-12); **bms-L** (Plate 3, #13, 14, 16-18; Plate 5, #3-5);
3. intergrowths with sulfide and gangue (chamosite): **sag-L** (Plate 3, #15);
4. intergrowths with other PGMs, including vasilite, keithconnite, and zvyagintsevite (Plate 5, #3-6).

Skaergaardite-bearing sulfide grains can be either droplet-like (Plate 3, #1, 2, 4, 5) or irregular-shaped aggregates (Plate 3, #3, 6-12). Mostly, the skaergaardite grains are localized at the margin of sulfide globules (Plate 3, #2-9, 11).

Skaergaardite grains form:

1. isometric droplet-like grains with the rounded outlines (Plate 3, #2);
2. euhedral crystals or partially euhedral grains (Plate 3, #1, 6-10, 12, 16-18);
3. irregular grains (Plate 3, #13-15; Plate 4).

The grain size of skaergaardite varies from 5 to 44 μm with an average of 21.6 μm (Table 4).

Mineral chemistry

The chemical composition of skaergaardite is given by 31 analyses from 31 different grains (Table 6, analyses 1-32). The average composition (wt%, Table 6, analysis 32) is:
Pd: 59.0; Pt: 2.0, Au: 1.9, Cu: 29.1, Fe: 5.2, Zn: 1.5, Te: 0.34, Pb: 0.25, Total: 99.3. The composition corresponds to the formula

$$(Pd_{0.96}Pt_{0.02}Au_{0.02})_{1.00}(Cu_{0.80}Fe_{0.16}Zn_{0.04})_{1.00}$$

Typical substitutions in skaergaardite from sample 90-24 1062 are Pt (up to 10.4 %,Table 6, analysis 21), Au (up to 5.9 %, Table 6, analysis 22), Fe (up to 7.2 %, Table 6, analysis 16), Zn (up to 3.4 %, Table 6, analysis 5), Te (up to 1.5 %, Table 6, analysis 23), Pb (up to 2.2 %, Table 6, analysis 4).

Pt and Au concentrations in skaergaardite and (Cu,Pd,Pt) alloy (n=33) are as follows (Fig. 5 and table 6):

Interval, Pt wt %	Number of analyses - Pt	Interval, Au wt %	Number of analyses - Au
0-0.9	15	0-0.9	12
0.9-2	8	0.9-2	6
2-4	1	2-3	7
4-6	3	3-4	5
6-8	3	4-5	2
8-10	2	5-6	1
10-12	1		

Summary data from Table 6: Pt and Au in skaergaardite (n=33), sample 90-24 1062.

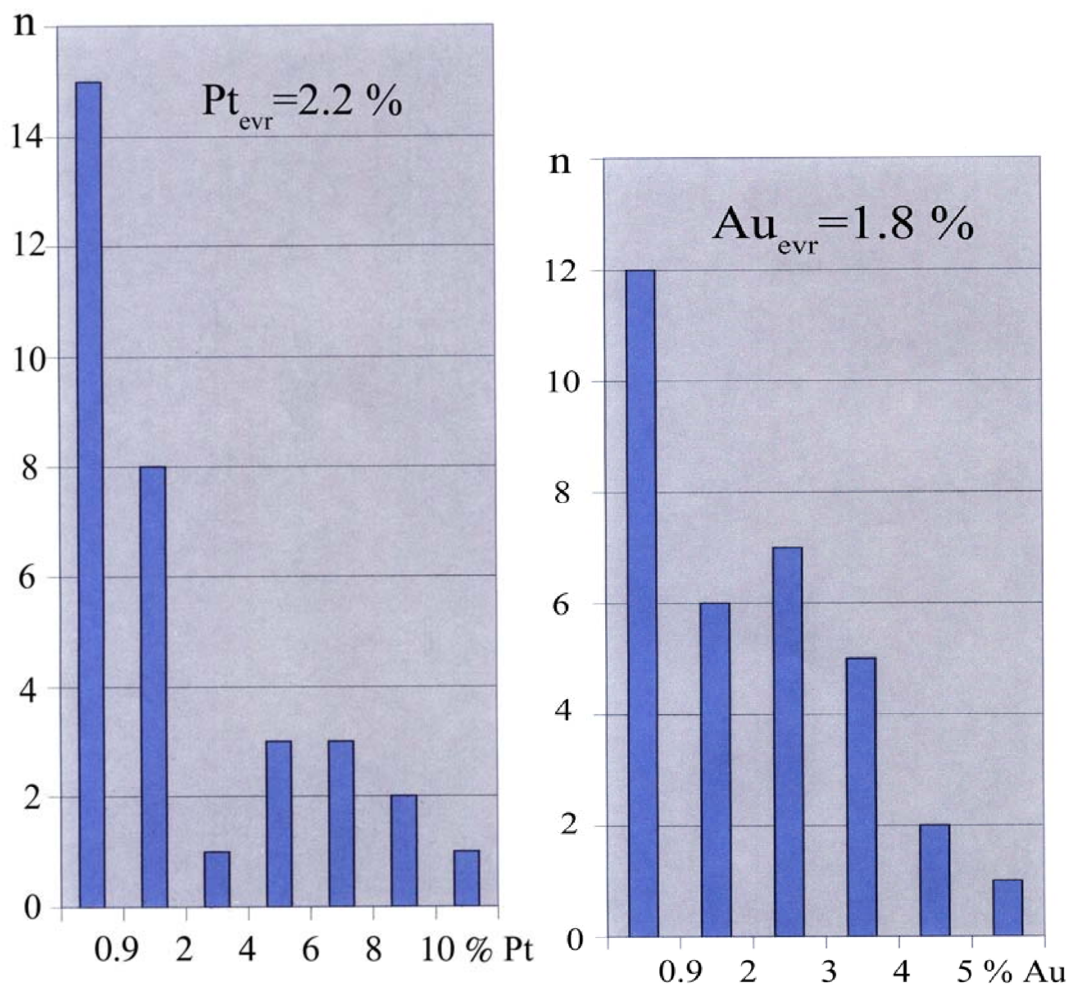

Fig. 5. Histograms of Pt and Au in skaergaardite (n=33, sample 90-24 1062), according in the Table 6, analyses 1-31

(Cu,Pd,Pt) alloys

As opposed to skaergaardite, (Cu,Pd,Pt) alloy is not stoikiometric. 2 grains of this mineral (2.4 vol % of PGMs) were found in the concentrates of the sample 90-24 1062 (see Table 4). It is associated with base metal sulfides (bornite and chalcosine, Plate 5, #1, 2). Sizes of grains are 6 and 20 µm, with an average of 13 µm. The chemical composition of (Cu,Pd,Pt) alloy is given in Table 6 (analyses 33, 34).

Rare PGMs

Three other PGMs, were found in the heavy mineral concentrates. They constitute in total 0.7 vol. % of the precious metal paragenesis and include: 1) keithconnite, 2) vasilite and 3) zvyagintsevite.

Keithconnite $Pd_3(Te,Pb)$

Keithconnite $Pd_3(Te,Pb)$), totalling 0.5 vol. % of all PGMs, is identified in 2 grains in association with skaergaardite, vasilite and chalcosine (Plate 5, #5, 6)..Keithconnite grains have irregular shapes, and their sizes vary from 2 to 10 µm with an average of 6 µm. The composition of keithconnite is found in Table 6 (analysis 35).

Vasilite $(Pd,Cu,Fe)_{16}S_7$

One grain of vasilite $(Pd,Cu,Fe)_{16}S_7$ was found. It occurs in association with skaergaardite and keithconnite(?) (Plate 5, #6). It has an irregular shape, and the size is 4 µm. The composition of the grain is stoikiometric ($(Pd,Cu,Fe)_{16}S_7$, Table 6, analysis 36).

Zvyagintsevite $Pd_3(Pb,Te,Sn)$

Zvyagintsevite $Pd_3(Pb,Te)$ (?) occurs as fine inclusions (<3 µm) in two grains of skaergaardite (Plate 5, #3, 4). The chemical composition of these inclusions (Table 6, analyses 37, 38) can only be considered as semi-quantitative due to interference with the skaergaardite host.

Bulk composition of the sample 90-24 1062

The relative concentrations of Pd, Au and Pt in sample 90-24 1062 can be calculated from the total concentration of precious metal, the determined recovery, the modal proportions and the chemical compositions (Tables 4, 6). The estimated bulk composition of sample 90-24 1062 (ppb, assays of whole rock in brackets) is: Pd 800 (720), Au 24 (24), Pt 30 (110

The significant variation Pt concentration in individual grains could reflect irregular distribution of minor elements (Pt and Au) in the Pd-poor ores (<1 ppm Pd).

Discussion

The PGM- paragenesis

The dominant PGM in the studied sample is skaergaardite. Skaergaardite shows a wide compositional range (Table 6). All the observations of the inter-grain relations (Plates 3, 5) suggest that all PGMs are part of a single paragenesis.

Order of crystallization

The Cu-Fe sulfides and PGMs are synchronous and crystallized later than rock-forming minerals: plagioclase, clinopyroxene, orthopyroxene, ilmenite and titaniferous magnetite. The is shown by the inclusion of sulfides and PGMs in the minerals of the host rock.

The characteristic droplet-shape of both the PGMs and host sulfides suggest that they represent two immiscible melts: 1) a Cu-Fe sulfide melt and 2) a metal melt enriched in Pd, Cu, Pt and Au that separated from the Cu-Fe melt.

The residual sulfide-metal melt phase seems to have been enriched by fluid components (H_2O, CO_2 etc). That is suggested by the characteristic associations of PGE- and Au-bearing aggregates of Cu-Fe sulfides with H_2O- and CO_2-bearing minerals such as chamosite and calcite.

Summary

Thirty-three PGM-grains were recovered from sample 90-24 1062 (1.3 kg in weight) using the patented hydroseparator CNT-HS-11.

The dominant precious metal mineral is skaergaardite (Pd,Pt,Au)(Cu,Fe,Zn, 96.9 vol. %). In addition, at least 4 other PGMs (in total ~ 3.1 vol. %) were identified: (Cu,Pd,Pt) alloy (2.4 vol. %), keithconnite Pd_3(Te,Pb) (0.5 vol. %), vasilite $(Pd,Cu,Fe)_{16}S_7$ (0.1 vol. %) and zvyagintsevite Pd_3(Pb,Te).(?) (0.1 vol. %). The significant variation in concentrations of Pt reflects vary irregular distribution of minor elements (Pt and Au) in Pd-poor ores (<1 ppm).
The estimated bulk composition in the sample (ppb, assays of whole rock in brackets) is: Pd 800 (720), Au 24 (24), Pt 30 (110): Pd, Pt and Au are hosted in skaergaardite and partly in (Cu,Pd,Pt) alloy.

The sulfide droplets contain droplets of PGMs. The characteristic structure suggests the occurrence of two immiscible melts: 1) Cu-Fe sulfide melt and 2) metal melt enriched in Cu, Pd, Pt and Au. The latter is believed to have separated from sulfide melt.
One grain of baddeleyte (~50 µm) is found in the heavy mineral concentrate. It can be used for dating the ore horizon.

References

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Nielsen, T.F.D., Rasmussen, H., N.S. Rudashevsky, Kretser, Yu.L., Rudashevsky, V.N. 2003. PGE and sulfide phases of the precious metal mineralization of the Skaergaard intrusion. Part 2: sample 90-24, 1057.*Geol. Surv. Denmark & Greenland* report 2003/48; 20 pp.

Watts, Griffis & McOuat 1991: 1990 Skaergaard project, Platinova/Corona concession, East Greenland, 55 pp. with appendixes in volumes 2A, 2B, 3A and 3B (in archive of Danmarks og Grønlands Geologiske Undersøgelse, GRF no. 20848).

Tables

Table 1 Chemical composition and formuli of silicates and oxides of oxide-rich tholeiitic gabbro, sample 90-24 1062

Analysis	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Mineral	pl	pl	pl	cpx	cpx	opx	opx	ol	ilm	ilm	ilm	ilm	Ti-mt	Ti-mt	Ti-mt	Ti-mt
Analyses (weight %)																
SiO_2	57.00	56.70	56.50	51.90	50.90	50.80	51.30	33.60	nd	nd	nd	nd	nd	nd	nd	nd
TiO_2	nd	nd	nd	0.40	0.30	0.20	0.30	nd	52.60	51.90	50.40	50.80	13.20	12.60	16.40	14.80
Al_2O_3	26.50	26.60	27.30	0.90	1.00	0.30	0.40	nd	nd	nd	nd	nd	3.60	3.30	3.70	3.20
V_2O_3	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.30	0.20	1.70	1.70	1.20	1.90
Fe_2O_3	0.30	0.30	0.50	nd	nd	nd	nd	nd	2.30	2.70	5.00	4.90	37.70	39.00	32.00	35.60
FeO	nd	nd	nd	12.70	12.80	28.10	27.80	46.60	43.20	42.50	41.90	41.80	42.70	41.70	45.80	43.20
MnO	nd	nd	nd	0.20	0.30	0.60	0.70	0.60	0.60	0.50	0.40	0.40	0.20	0.20	0.30	0.30
MgO	nd	nd	nd	12.40	13.00	18.20	18.40	18.70	1.90	2.10	1.70	2.00	0.70	0.90	0.50	1.30
CaO	9.20	9.40	9.20	20.90	21.50	1.30	1.50	nd	nd	nd	nd	nd	nd	nd	nd	nd
Na_2O	6.20	6.50	6.60	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
K_2O	0.50	0.40	0.40	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Total	99.70	99.90	100.50	99.50	99.80	99.60	100.40	99.50	100.60	99.70	99.80	100.10	99.80	99.40	99.90	100.30
atomic proportions																
Si	*2.57*	*2.56*	*2.53*	*1.95*	*1.94*	*1.97*	*1.97*	*1.00*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*
Ti	*nd*	*nd*	*nd*	*0.01*	*0.01*	*0.01*	*0.01*	*nd*	*0.98*	*0.97*	*0.95*	*0.95*	*0.37*	*0.35*	*0.46*	*0.41*
Al	*1.41*	*1.41*	*1.44*	*0.04*	*0.04*	*0.01*	*0.02*	*nd*	*nd*	*nd*	*nd*	*nd*	*0.16*	*0.15*	*0.16*	*0.14*
V	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*0.01*	*0.00*	*0.05*	*0.05*	*0.03*	*0.05*
Fe3+	*0.01*	*0.01*	*0.02*	*nd*	*nd*	*nd*	*nd*	*nd*	*0.04*	*0.05*	*0.09*	*0.09*	*1.05*	*1.09*	*0.89*	*0.99*
Fe2+	*nd*	*nd*	*nd*	*0.40*	*0.41*	*0.91*	*0.89*	*1.16*	*0.89*	*0.89*	*0.88*	*0.87*	*1.33*	*1.30*	*1.42*	*1.33*
Mn	*nd*	*nd*	*nd*	*0.01*	*0.01*	*0.02*	*0.02*	*0.02*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*
Mg	*nd*	*nd*	*nd*	*0.77*	*0.74*	*1.05*	*1.05*	*0.83*	*0.07*	*0.08*	*0.06*	*0.07*	*0.04*	*0.05*	*0.03*	*0.07*
Ca	*0.44*	*0.45*	*0.44*	*0.84*	*0.88*	*0.05*	*0.06*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*
Na	*0.54*	*0.57*	*0.58*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*
K	*0.03*	*0.02*	*0.02*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*
O basis	*8*	*8*	*8*	*6*	*6*	*6*	*6*	*4*	*3*	*3*	*3*	*3*	*4*	*4*	*4*	*4*

Abbreviations: pl: plagioclase; cpx: clinopyroxene; opx: orthopyroxene; ilm: ilmenite; Ti-mt: titanomagnetite.

Table 2. **Chemical composition and formulas of sulphides in PGM-bearing globules of the heavy concentrates, sample 90-24 1062**

				Analyses, weight %						*Atomic proportions*					
An. #	**Grain**	**Association**	**Mineral**	**Cu**	**Fe**	**Ni**	**Co**	**S**	**Total**	***Cu***	***Fe***	***Ni***	***Co***	***S***	***Total***
1	125 gr1	sk+chc+bn+ct+chl	chc	78.5	1.6	nd	nd	20.3	100.4	*1.95*	*0.05*	*nd*	*nd*	*1.00*	*3.00*
2	125 gr2c	chc+pyr (exs)+chl	chc	79.2	0.4	nd	nd	19.9	99.5	*2.00*	*0.01*	*nd*	*nd*	*0.99*	*3.00*
3	125 gr2c	chc+bn+cp	bn	63.4	11.7	nd	nd	25.7	100.3	*5.00*	*1.05*	*nd*	*nd*	*3.95*	*10.00*
4	125 gr2e	chc+bn	chc	78.8	0.4	nd	nd	20.2	99.4	*1.98*	*0.01*	*nd*	*nd*	*1.01*	*3.00*
5	125 gr2e	chc+bn	bn	63.8	11.3	nd	nd	25.0	100.1	*5.06*	*1.02*	*nd*	*nd*	*3.92*	*10.00*
6	125 gr2f	bn+chc+pn+ilm	pn	3.2	14.7	27.6	21.7	32.7	99.9	*0.40*	*2.05*	*3.68*	*2.89*	*7.98*	*17.00*
7	125 gr2f	bn+chc+pn+ilm	bn	62.9	11.4	nd	nd	25.2	99.5	*5.00*	*1.04*	*nd*	*nd*	*3.96*	*10.00*
8	40 gr1a	bn+chc+pn+ilm	bn	63.1	11.7	nd	nd	25.8	100.6	*4.91*	*1.04*	*nd*	*nd*	*4.05*	*10.00*
9	40 gr1b	bn+chc	bn	62.2	11.3	nd	nd	25.1	98.6	*4.98*	*1.03*	*nd*	*nd*	*3.99*	*10.00*
10	40 gr1	sk+zv(?)+pn	pn	0.0	16.5	29.1	20.5	33.5	99.7	*0.00*	*2.31*	*3.87*	*2.70*	*8.12*	*17.00*
11	40 gr 10	sk+bn	bn	61.9	11.3	nd	nd	25.2	98.4	*4.96*	*1.03*	*nd*	*nd*	*4.01*	*10.00*
12	63 gr1a	bn+chl	bn	61.9	11.3	nd	nd	25.8	99.0	*4.91*	*1.02*	*nd*	*nd*	*4.06*	*10.00*
13	63 gr2	sk+bn	bn	63.3	11.3	nd	nd	25.0	99.6	*5.04*	*1.02*	*nd*	*nd*	*3.94*	*10.00*
14	63 gr2c	chc+chl	chc	76.2	1.9	nd	nd	20.5	99.1	*1.93*	*0.05*	*nd*	*nd*	*1.02*	*3.00*
15	63 gr3	(Cu,Pd,Pt)+bn+chc	bn	63.2	11.4	nd	nd	25.2	99.8	*5.01*	*1.03*	*nd*	*nd*	*3.96*	*10.00*
16	63 gr4	sk+bn+chc+chl	chc	78.4	1.1	nd	nd	20.1	99.6	*1.95*	*0.06*	*nd*	*nd*	*0.99*	*3.00*
17	40 gr18	sk+kth+chc	chc	78.3	1.1	nd	nd	20.1	99.5	*1.97*	*0.03*	*nd*	*nd*	*1.00*	*3.00*

Abbreviations: sk: skaergaardite; chc: chalcocine; bn: bornite; ct: calcite; chl: chlorite; pyr (ex): pyroxene exsolutions; cp: chalcopyrite; pn: Co-pentlandite; ilm: ilmenite; zv: zvyagintsevite; kth: keithconnite.

Table 3 Grain sizes of PGMs in heavy concentrates of sample 90-24 1062

N	Grain	Association	Type	Mineral	Area, μm^2	ECD, μm
1	125-1	sk-chc-bn-chl-ct	bms	sk		21.5
2	125-2	sk-chc-bn	bms	sk	327.0	20.4
3	40-10	sk-bn	bms	sk	371.0	21.7
4	40-11	(Cu,Pd)+chc	bsm	(Cu,Pd)	307.0	19.8
5	40-12	sk-bn	bms-L	sk	255.0	18.0
6	40-13	sk-bn	bms	sk	523.0	25.8
7	40-14	sk	L	sk	336.0	20.7
8	40-15	sk	L	sk	237.0	17.4
9	40-16	sk	L	sk	393.0	22.4
10	40-17	sk	L	sk	798.0	31.9
11	40-18	sk-kth-chc	bms-L	kth	75.0	9.8
12	40-18	sk-kth-chc	bms-L	sk	386.0	22.2
13	40-19	sk-vs-(Pd,Cu,Te,Pb)	LP	(Pd,Cu,Te,Pb)	3.0	2.0
14	40-19	sk-vs-(Pd,Cu,Te,Pb)	LP	vs	13.0	4.1
15	40-19	sk-vs-(Pd,Cu,Te,Pb)	LP	sk	245.0	17.7
16	40-1	sk-zv-pn	bms-L	zv	9.0	3.4
17	40-1	sk-zv-pn	bms-L	sk	405.0	22.7
18	40-20	sk-bn-chc	bms	sk	72.0	9.6
19	40-21	sk	L	sk	117.0	12.2
20	40-2	sk-bn-chc	bms	sk	24.0	5.5
21	40-3	sk-zv-bn	bms	zv	2.0	1.6
22	40-3	sk-zv-bn	bms	sk	395.0	22.4
23	40-4	sk-bn	bms-L	sk	286.0	19.1
24	40-5	sk	L	sk	185.0	15.4
25	40-6	sk-bn	bms	sk	879.0	33.5
26	40-7	sk	L	sk	704.0	29.9
27	40-8	sk-bn	bms-L	sk	850.0	32.9
28	40-9	sk	L	sk	151.0	13.9
29	63-1	sk-bn	bms	sk	924.0	34.3
30	63-2	sk-bn	bms	sk	1244.0	39.8
31	63-3	(Cu,Pd,Pt)-bn-chc	bms	(Cu,Pd,Pt)	27.0	5.9
32	63-4	sk-bn-chc-chl	bms	sk	61.0	8.8
33	63-5	sk-chl-bn	sag-L	sk	1502.0	43.7
34	80-1	sk-bn-chc	bms	sk	92.0	10.8
35	80-2	sk-bn	bms	sk	205.0	16.2
36	80-3	sk-chc-bn	bms	sk	38.0	7.0
37	80-4	sk-chc-bn	bms	sk	276.0	18.8
41	80-5	sk-chc-bn	bms	sk	882.0	33.5

Abbreviations: Sk: skaergaardite; chc: chalcocine; bn: bornite; chl: chlorite; ct:calcite;
kth: keithconnite; vs: vasilite; pn: Co-pentlandite; zv: zvyagintsevite

Table 4 PGMs in heavy concentrates from sample 90-24 1062

N	Mineral	General formula	Number of grains	Grain size, µm min	max	average	Vol. %
1	Skaergaardite	(Pd,Pt,Au)(Cu,Fe,Zn)	31	5	44	22	96.9
2	(Cu,Pd,Pt) alloy	(Cu,Pd,Pt)	2	6	20	13	2.4
3	Keithconnite	$Pd_3(Te,Pb)$	2	2	10	6	0.5
4	Vasilite	$(Pd,Cu,Fe)_{16}S_7$	1			4	0.1
5	Zvyagintsevite	$Pd_3(Pb,Te)$	2	1	3	2	0.1
						Total	100

Table 5

Table 5 is included in the text, see page 11

Table 6 **Chemical composition and formuli of different PGMs in the heavy concentrates from sample 90-24 1062**

An. #	1	2	3	4	5	6	7	8	9	10	11	12
Grain	125 gr1	125 gr2	40 gr1	40 gr2	40 gr3	40 gr4	40 gr5	40 gr6	40 gr7	40 gr8	40 gr9	40 gr10
Association	sk+chc+ bn+ct+chl	sk+chc+ bn+chl	sk+zv(?) +pn	sk+bn+chc	sk+zv(?)	sk+bn	sk	sk+bn	sk	sk+bn	sk+bn	sk+bn
Mineral	sk	sk	sk	sk	sk	sk	sk	sk	sk	sk	sk	sk
analyses, weight %												
Pd	61.4	60.7	60.1	55.7	59.3	61.9	64.0	59.3	60.1	62.9	58.6	57.7
Pt	0.0	0.0	0.0	6.8	0.0	0.0	0.0	0.0	0.0	0	1.0	1.0
Au	0.0	1.1	2.8	0.0	2.8	0.9	0.0	3.3	2.0	0.0	3.7	4.9
Cu	30.6	29.9	28.0	27.0	28.0	29.5	28.7	28.7	29.1	29.8	30.2	28.7
Fe	3.3	3.9	5.3	5.6	4.1	6.7	5.9	4.5	4.7	7.0	5.2	5.6
Zn	2.4	3.2	2.6	1.6	3.4	0.0	1.0	2.7	2.2	0.0	0.6	0.0
Sn	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Te	0.0	0.0	0.7	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.7	0.0
Pb	1.3	0.9	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Total	99.0	99.7	99.5	98.9	98.2	99.0	99.6	98.5	98.1	99.7	100.0	99.7
atomic proportions												
Pd	*1.00*	*0.98*	*0.98*	*0.93*	*0.97*	*0.99*	*1.02*	*0.97*	*0.98*	*1.00*	*0.95*	*0.93*
Pt	*0.00*	*0.00*	*0.00*	*0.06*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.01*	*0.01*
Au	*0.07*	*0.01*	*0.02*	*0.00*	*0.02*	*0.01*	*0.00*	*0.03*	*0.02*	*0.00*	*0.03*	*0.04*
Cu	*0.83*	*0.80*	*0.76*	*0.76*	*0.76*	*0.80*	*0.77*	*0.79*	*0.80*	*0.79*	*0.82*	*0.79*
Fe	*0.10*	*0.12*	*0.16*	*0.18*	*0.15*	*0.20*	*0.18*	*0.14*	*0.15*	*0.21*	*0.16*	*0.18*
Zn	*0.06*	*0.08*	*0.07*	*0.04*	*0.09*	*0.00*	*0.03*	*0.07*	*0.06*	*0.00*	*0.01*	*0.05*
Sn	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Te	*0.00*	*0.00*	*0.01*	*0.00*	*0.01*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.01*	*0.00*
Pb	*0.01*	*0.01*	*0.00*	*0.02*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
S	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*
Total	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*

Abbreviations: sk: skaergaardite; chc: chalcocine; bn:bornite; ct: calcite; chl: chlorite, zv: zvyagintsevite; pn: Co-pentlandite;
kth: keithconnite; Te: tellurium.

Table 6 continued

An. #	13	14	15	16	17	18	19	20	21	22	23
Grain	40 gr12	40 gr13	40 gr14	40 gr15	40 gr16	40 gr17	40 gr18	40 gr20	40 gr21	40 gr22	63 gr1
Association	sk+bn	sk+bn	sk	sk	sk	sk	sk+kth+chc	sk+bn+chc	sk+bn+chc	sk+bn+chc	sk+bn
Mineral	sk	sk	sk	sk	sk	sk	sk	sk	sk	sk	sk
analyses, weight %											
Pd	55.5	58.8	59.7	59.9	57.9	60.8	60.9	56.9	53.4	57.2	59.1
Pt	6.5	1.0	1.4	1.3	0.9	0.0	0.9	1.2	10.4	0.0	0.0
Au	2.4	3.7	2.8	2.3	3.9	1.7	1.1	5.0	0.0	5.9	3.0
Cu	28.2	28.6	28.9	27.1	29.6	29.1	28.5	31.3	29.4	29.8	29.0
Fe	6.2	4.3	5.3	7.2	5.2	4.7	4.2	3.4	5.9	5.9	5.0
Zn	0.6	2.6	0.0	1.7	1.0	2.5	2.7	0.0	1.0	0.3	2.1
Sn	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Te	0.0	0.8	0.8	0.0	0.7	0.7	1.1	0.9	0.0	0.0	1.5
Pb	0.0	0.0	1.1	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0
S	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Total	99.4	99.8	100.0	99.5	99.2	99.5	99.4	99.9	100.1	99.1	99.7
atomic proportions											
Pd	*0.92*	*0.96*	*0.98*	*0.97*	*0.95*	*0.98*	*0.99*	*0.94*	*0.88*	*0.94*	*0.96*
Pt	*0.06*	*0.01*	*0.01*	*0.01*	*0.01*	*0.00*	*0.01*	*0.01*	*0.09*	*0.00*	*0.00*
Au	*0.02*	*0.03*	*0.02*	*0.02*	*0.03*	*0.02*	*0.01*	*0.04*	*0.00*	*0.05*	*0.03*
Cu	*0.78*	*0.78*	*0.80*	*0.73*	*0.81*	*0.79*	*0.78*	*0.87*	*0.81*	*0.82*	*0.79*
Fe	*0.20*	*0.13*	*0.16*	*0.22*	*0.16*	*0.15*	*0.13*	*0.11*	*0.18*	*0.18*	*0.16*
Zn	*0.02*	*0.07*	*0.00*	*0.04*	*0.03*	*0.06*	*0.07*	*0.00*	*0.03*	*0.01*	*0.05*
Sn	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Te	*0.00*	*0.01*	*0.01*	*0.00*	*0.01*	*0.01*	*0.01*	*0.01*	*0.00*	*0.00*	*0.02*
Pb	*0.00*	*0.00*	*0.01*	*0.00*	*0.00*	*0.00*	*0.00*	*0.01*	*0.00*	*0.00*	*0.00*
S	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*
Total	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*

Table 6 continued

An. #	24	25	26	27	28	29	30	31	32	33	34
Grain	63 gr2	63 gr4	63 gr5	80 gr1	80 gr2	80 gr3	80 gr4	80 gr5		40 gr11	63 gr3
Association	sk+bn	sk+bn+ chc+chl	sk+bn+chl	sk+bn+chc	sk+bn	sk+bn+chc	sk+chc+bn	sk+chc+bn	average, n=31	(Pd,Cu)+ chc	(Pd,Cu)+ bn+chc
Mineral	sk	sk	sk	sk	sk	sk	sk	sk	sk	(Pd,Cu)	(Pd,Cu)
analyses, weight %											
Pd	62.8	58.9	60.7	57.8	55.5	58.5	53.9	59.5	59.01	51.0	49.4
Pt	0.0	3.1	0.0	5.6	8.0	4.8	8.8	0.0	2.02	5.1	6.0
Au	0.0	0.0	1.3	0.0	0.0	0.0	0.0	2.7	1.85	1.8	0.0
Cu	29.8	30.9	31.1	31.2	28.9	26.1	28.3	29.4	29.14	33.1	36.0
Fe	6.7	5.2	4.0	4.3	5.9	5.5	5.7	3.6	5.16	5.9	6.7
Zn	0.0	1.8	1.7	1.6	0.6	2.0	1.5	2.8	1.49	2.0	0.5
Sn	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0
Te	0.0	0.0	0.0	0.0	0.0	1.1	0.0	1.0	0.34	0.8	0.0
Pb	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.25	0.0	1.2
S	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Total	99.3	99.9	98.8	100.5	99.8	98.0	99.2	99.0	99.35	99.7	99.8
atomic proportions											
Pd	*1.00*	*0.94*	*0.98*	*0.93*	*0.92*	*0.98*	*0.91*	*0.97*	*0.96*	*0.41*	*0.39*
Pt	*0.00*	*0.03*	*0.00*	*0.05*	*0.07*	*0.04*	*0.08*	*0.00*	*0.02*	*0.02*	*0.03*
Au	*0.00*	*0.00*	*0.01*	*0.00*	*0.00*	*0.00*	*0.00*	*0.02*	*0.02*	*0.01*	*0.00*
Cu	*0.80*	*0.82*	*0.84*	*0.84*	*0.80*	*0.73*	*0.79*	*0.80*	*0.80*	*0.44*	*0.47*
Fe	*0.20*	*0.16*	*0.12*	*0.13*	*0.19*	*0.18*	*0.18*	*0.11*	*0.16*	*0.09*	*0.10*
Zn	*0.00*	*0.05*	*0.05*	*0.04*	*0.02*	*0.06*	*0.04*	*0.07*	*0.04*	*0.03*	*0.01*
Sn	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Te	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.01*	*0.00*	*0.01*	*0.00*	*0.01*	*0.00*
Pb	*0.00*	*0.00*	*0.00*	*0.00*	*0.01*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
S	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*
Total	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*1.00*	*1.00*

Table 6 continued

An. #	35	36	37	38
Grain	40 gr18	40 gr 19	40 gr1	40 gr3
Association	sk+ kth+chc	sk+vs+ (Pd,Cu,Te)	sk+zv(?)+ pn	sk+zv(?)
Mineral	kth	vs	zv(?)	zv(?)
analyses, weight %				
Pd	70.4	72.8	67.6	67.3
Pt	0.0	0.0	0.0	0.0
Au	0.0	0.0	1.3	1.4
Cu	1.3	13.0	5.4	5.1
Fe	0.0	1.1	1.7	1.1
Zn	0.0	0.0	0.4	0.6
Sn	0.0	0.0	0.0	0.0
Te	26.8	0.0	0.5	0.0
Pb	1.0	0.0	22.6	23.8
S	nd	12.8	nd	nd
Total	99.5	99.9	99.5	99.3
atomic proportions				
Pd	*2.95*	*12.05*		
Pt	*0.00*	*0.00*		
Au	*0.00*	*0.00*		
Cu	*0.09*	*3.61*		
Fe	*0.00*	*0.33*		
Zn	*0.00*	*0.00*		
Sn	*0.00*	*0.00*		
Te	*0.94*	*0.00*		
Pb	*0.02*	*0.00*		
S	*nd*	*7.01*		
Total	*4.00*	*23.00*		

Plates

Plate 1

Relationships of rock-forming minerals, Fe-Ti oxides and sulfides in the oxide-rich tholeitic gabbro of the sample 90-24 1062 (1-4); polished section, SEM-image (BIE). Abbreviations: **pl**: plagioclase, **pl II**: anorthite-rich reaction plagioclase, **ol**: olivine, **opx**: orthopyroxene, **cpx** clinopyroxene, **pyr (esc)**: pyroxene with exsolutions, **timt**: titaniferous magnetite, **ilm**: ilmenite, **bn**: bornite, and **ch**: chalcocine.

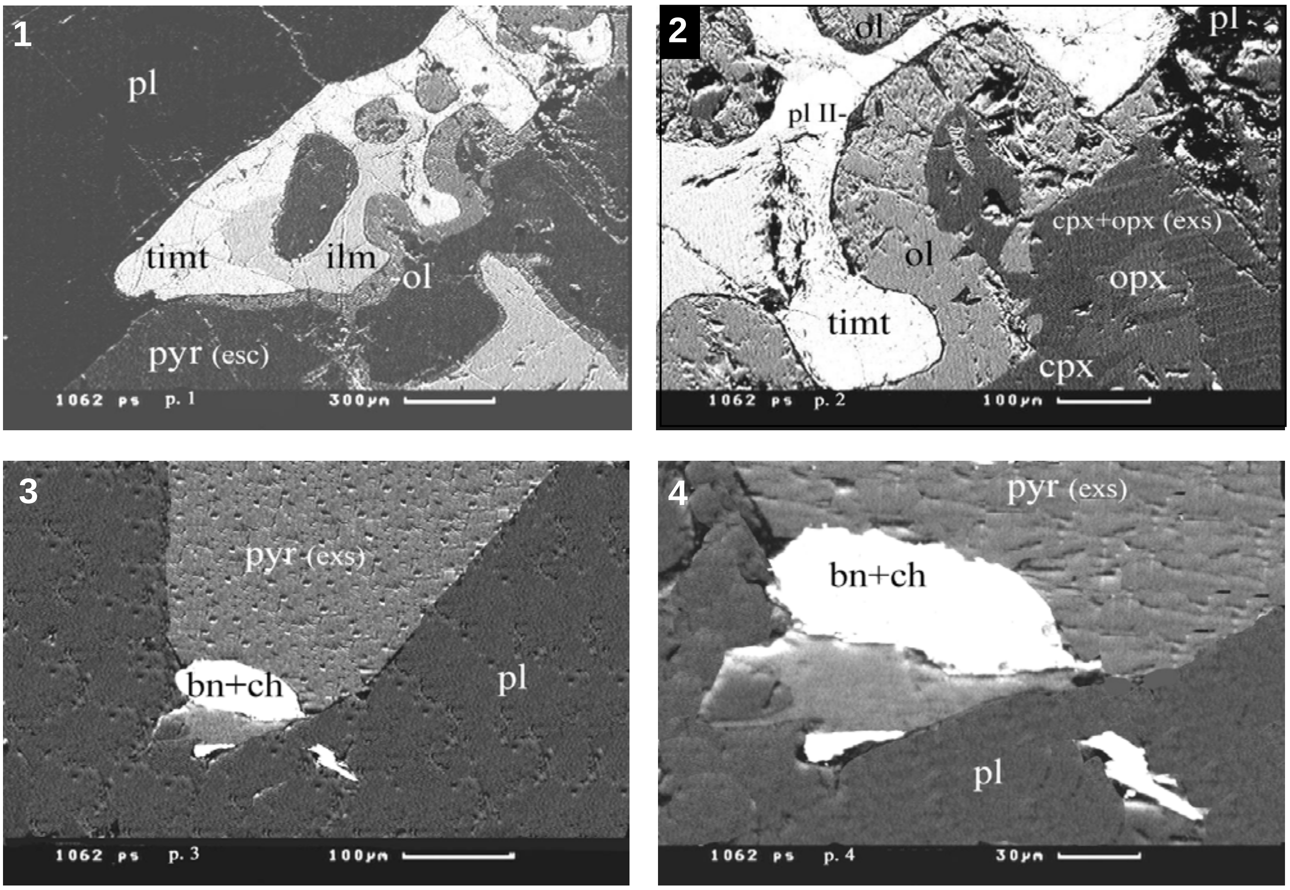

1
pl
timt
ilm
-ol
pyr (esc)
1062 ps p. 1
300μm
2
ol
pl
pl II-
cpx+opx (exs)
ol
opx
timt
cpx
1062 ps p. 2
100μm
3
pyr (exs)
bn+ch
pl
1062 ps p. 3
100μm
4
pyr (exs)
bn+ch
pl
1062 ps p. 4
30μm

Plate 2

Sulfide mineralization globules of oxide-rich tholeiitic gabbro sample 90-24 1062 (1-11), polished section of grains extracted in the heavy concentrate, SEM-image (BIE). Abbreviations: **ch**: chalcocine, **bn**: bornite, **cp**: chalcopyrite, **pn**: pentlandite, **cpx**: clinopyroxene, **ch**l: chlorite, and **ilm**: ilmenite.

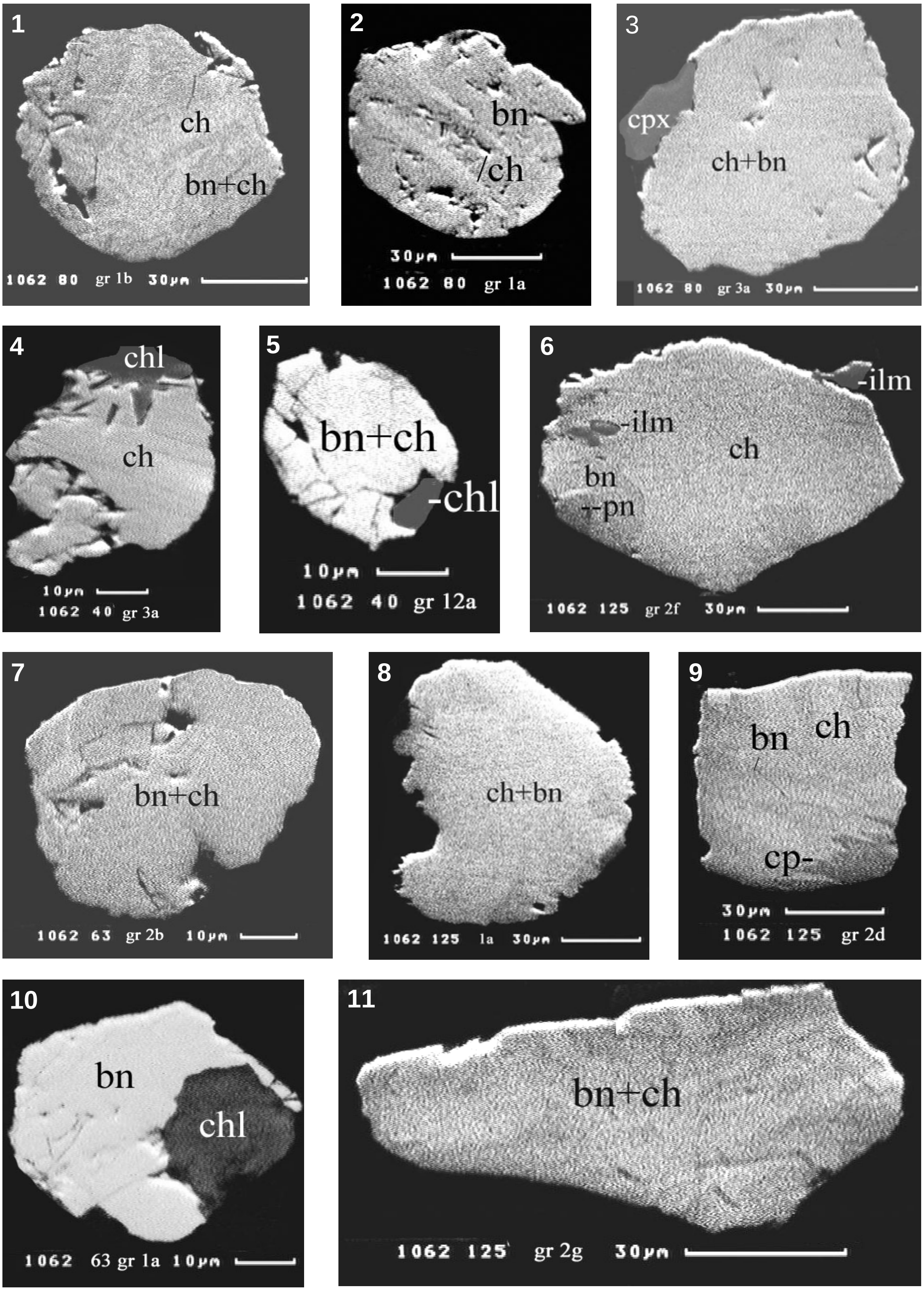
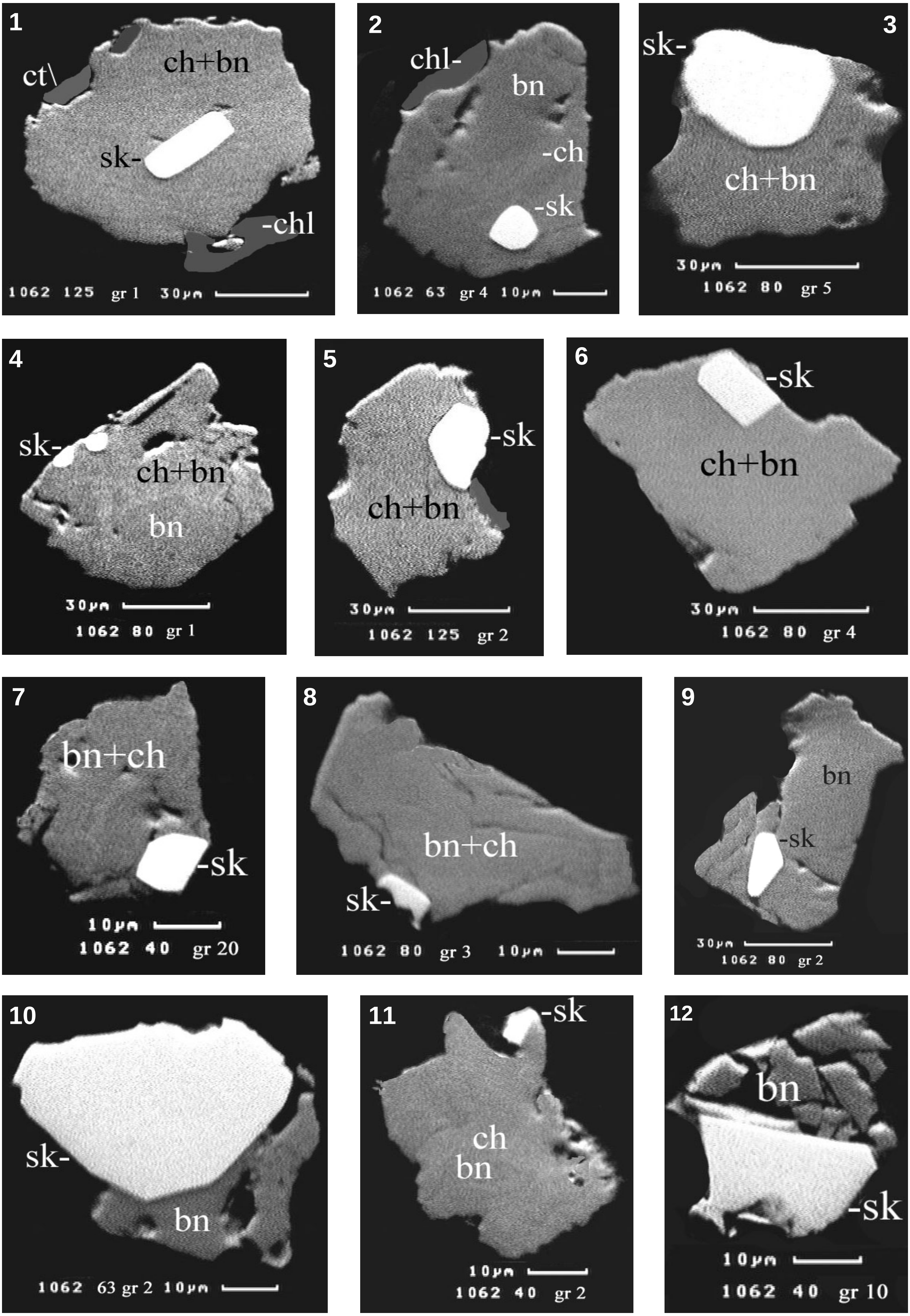

1
ch
bn+ch
1062 80 gr 1b 30μm
2
bn
/ch
30μm
1062 80 gr 1a
3
cpx
ch+bn
1062 80 gr 3a 30μm
4
chl
ch
10μm
1062 40 gr 3a
5
bn+ch
-chl
10μm
1062 40 gr 12a
6
-ilm
-ilm
ch
bn
--pn
1062 125 gr 2f 30μm
7
bn+ch
1062 63 gr 2b 10μm
8
ch+bn
1062 125 1a 30μm
9
bn
ch
cp-
30μm
1062 125 gr 2d
10
bn
chl
1062 63 gr 1a 10μm
11
bn+ch
1062 125 gr 2g 30μm

Plate 3

Sulfide globules with inclusions of skaergaardite (**bms**) and skaergaardite particles attached base metal sulfides (**bms-L**) or base metal sulfides together with gangue (**sag** and **sag-L**)- in heavy concentrates of the sample 90-24, 1062 (1-18); polished section, SEM-image (BIE). Abbreviations: **sk**: skaergaardite, **ch**: chalcocine, **bn**: bornite, and **chl**: chlorite.


1
ct\
ch+bn
sk-
-chl
1062 125 gr 1 30μm
2
chl-
bn
-ch
-sk
1062 63 gr 4 10μm
3
sk-
ch+bn
30μm
1062 80 gr 5
4
sk-
ch+bn
bn
30μm
1062 80 gr 1
5
-sk
ch+bn
30μm
1062 125 gr 2
6
-sk
ch+bn
30μm
1062 80 gr 4
7
bn+ch
-sk
10μm
1062 40 gr 20
8
bn+ch
sk-
1062 80 gr 3 10μm
9
bn
-sk
30μm
1062 80 gr 2
10
sk-
bn
1062 63 gr 2 10μm
11
-sk
ch
bn
10μm
1062 40 gr 2
12
bn
-sk
10μm
1062 40 gr 10

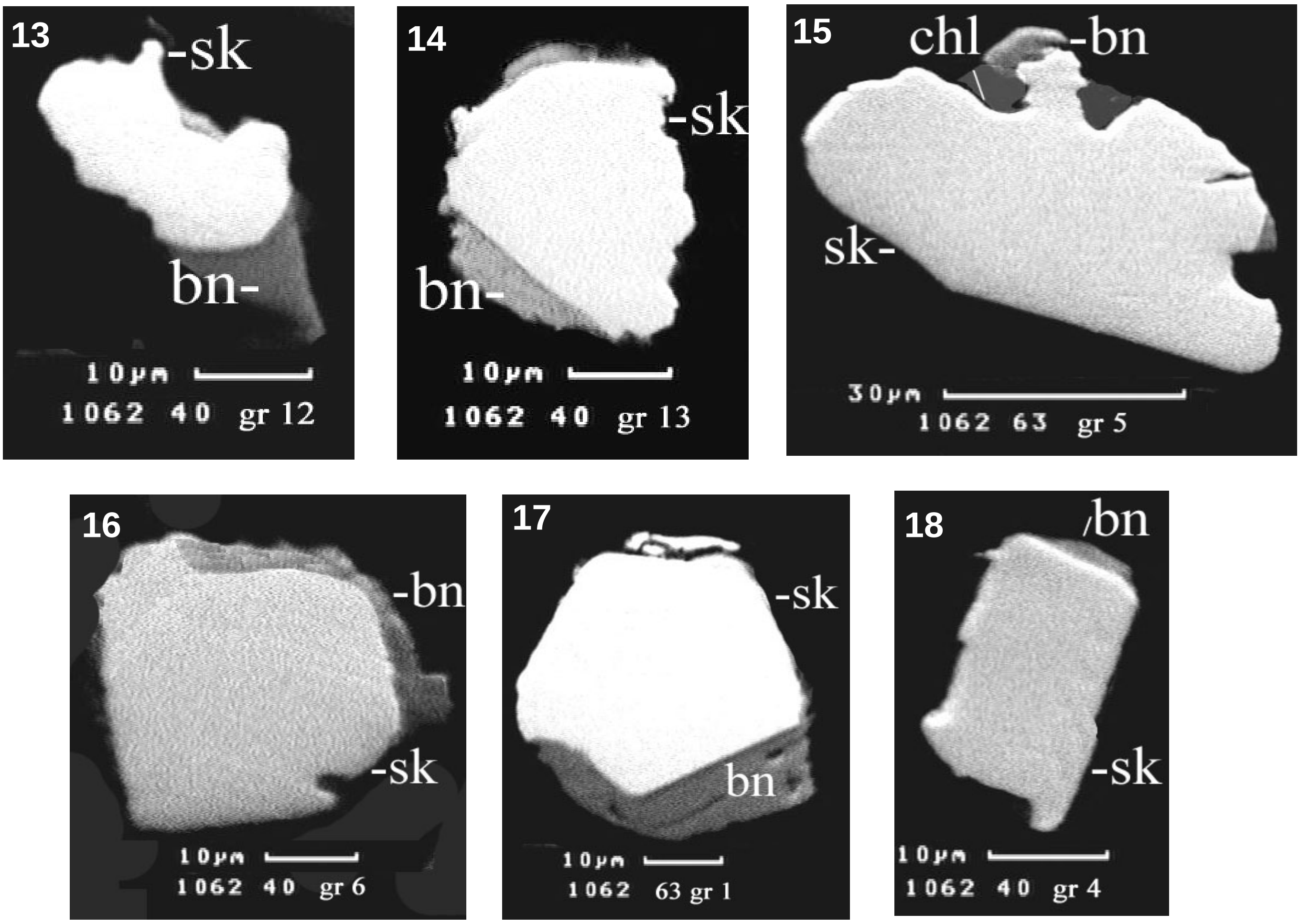

13
-sk
bn-
10µm
1062 40 gr 12
14
-sk
bn-
10µm
1062 40 gr 13
15
chl
-bn
sk-
30µm
1062 63 gr 5
16
-bn
-sk
10µm
1062 40 gr 6
17
-sk
bn
10µm
1062 63 gr 1
18
/bn
-sk
10µm
1062 40 gr 4

Plate 4

Totally liberated grains of skaergaardite (**L**) in heavy concentrates from sample 90-24 1062 (1-9); polished section, SEM-images (BIE). Abbreviations: **sk**: skaergaardite, and **bn**: bornite.

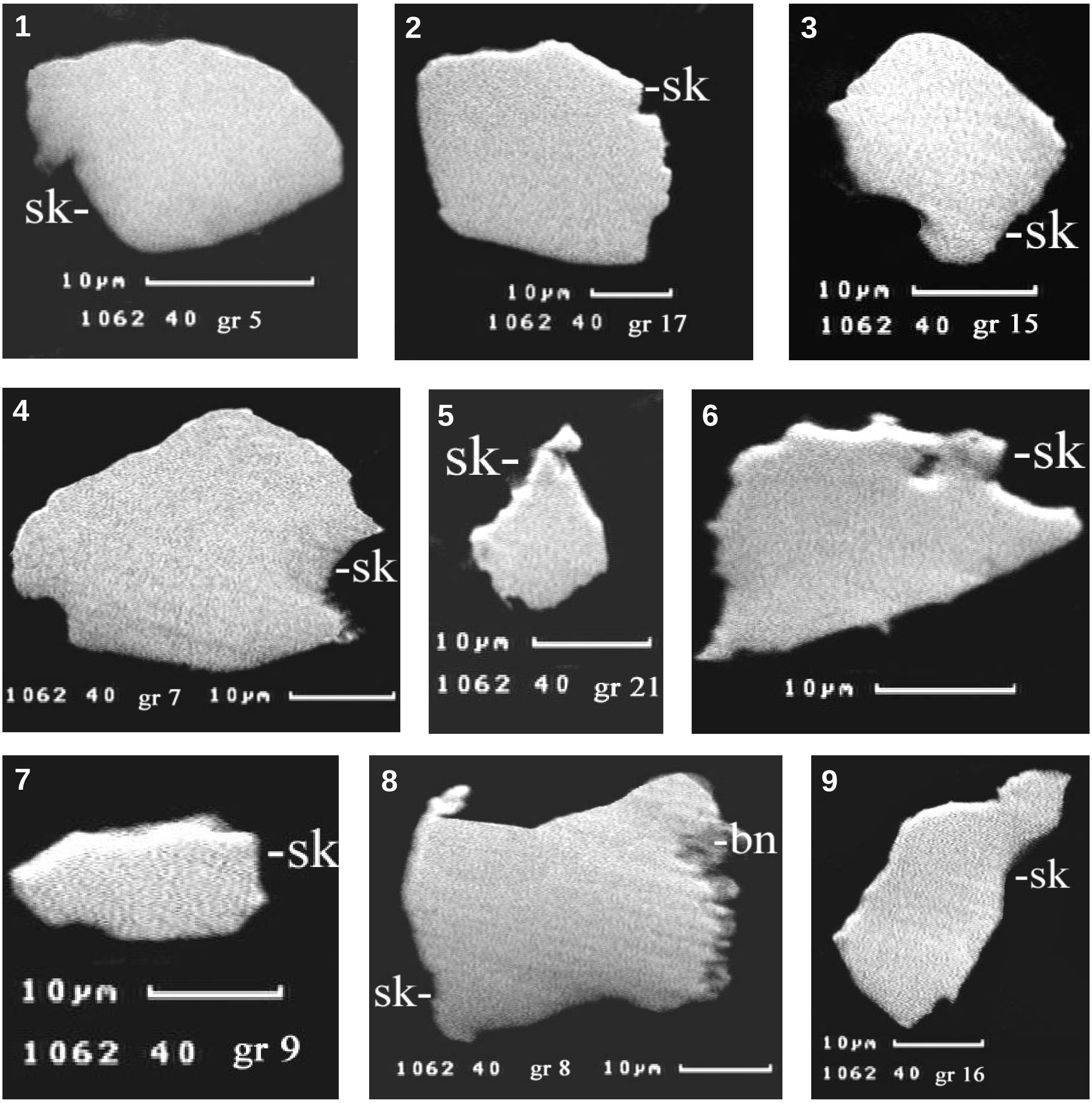
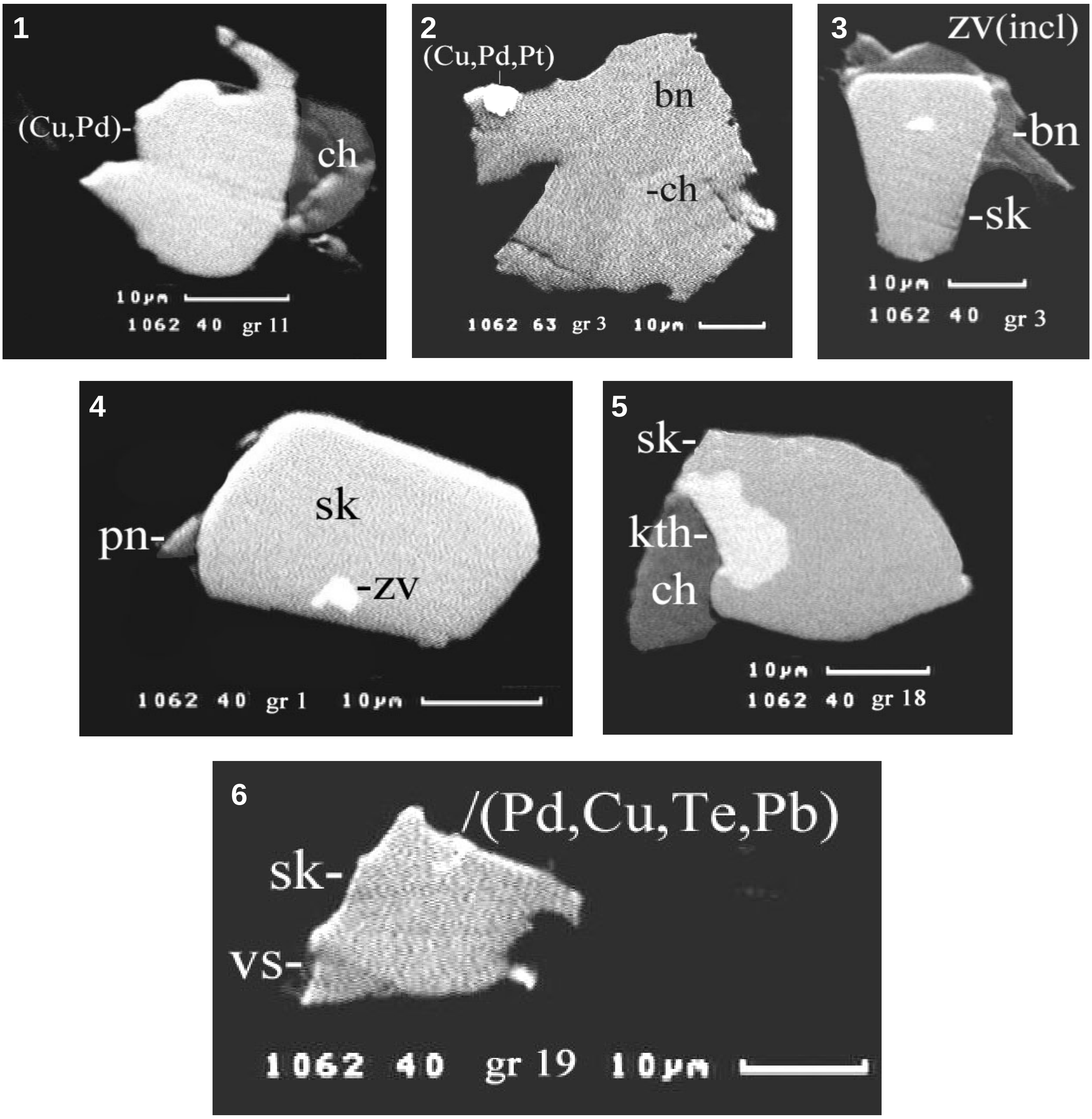

1
sk-
10μm
1062 40 gr 5
2
-sk
10μm
1062 40 gr 17
3
-sk
10μm
1062 40 gr 15
4
-sk
1062 40 gr 7 10μm
5
sk-
10μm
1062 40 gr 21
6
-sk
10μm
7
-sk
10μm
1062 40 gr 9
8
-bn
sk-
1062 40 gr 8 10μm
9
-sk
10μm
1062 40 gr 16

Plate 5

PGM grains containing (Cu,Pd,Pt) alloy (1, 2) zvyagintsevite (3, 4), keithconnite (5), vasilite (6) in heavy concentrates from sample 90-24 1062; polished section, SEM-image (BIE). Abbreviation: **(Cu,Pd)**: Cu-Pd alloy, **(Cu,Pd,Pt)** Cu-Pd-Pt alloy, **zv**: zviagintsevite, **kth**: keithconnite, **vs**: vasilite, **(Pd,Cu,Te,Pb)** alloy, possibly zviagintsevite variety, **ch**: chalcocine, **bn**: bornite, and **pn**: pentlandite.


1
(Cu,Pd)-
ch
10μm
1062 40 gr 11
2
(Cu,Pd,Pt)
bn
-ch
1062 63 gr 3 10μm
3
ZV(incl)
-bn
-sk
10μm
1062 40 gr 3
4
sk
pn-
-zv
1062 40 gr 1 10μm
5
sk-
kth-
ch
10μm
1062 40 gr 18
6
/(Pd,Cu,Te,Pb)
sk-
vs-
1062 40 gr 19 10μm