DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2012/97

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

Part 18: Sample 90-24 1056

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Abstract

The report presents the results of a mineralogical investigation of the sample 90-24 1056 from the Skaergaard intrusion Au-PGE mineralisation The sample represents the top of the Pd5 level in the mineralisation between 1056 and 1057 m in drill core 90-24. Assays give 2000 ppb Pd, 112 ppb Au, and 190 ppb Pt for this interval.

The 780g sample was crushed in small portions using a shatter box with small cavities (200 ml) for short periods (0.3-0.5 min) and sieved after each crushing session to remove the fine fraction (sieve - 125 µm). The residual coarse fraction >125 µm was crushed again until the entire sample had attained the desired maximum grain size.

After complete crushing the material was sieved into the following fractions: <40, 40-63, 63-80, and 80-125 µm. All fractions were then subjected to wet magnetic separation. Investigations showed that all magnetic fractions did not contain precious metal grains except for rare grains in intergrowth with titanomagnetite.

The non-magnetic parts of every grain size fraction from sample 90-24 1056 were processed through the computer controlled hydroseparator CNT-HS-11. Monolayer samples were prepared from the resulting heavy mineral concentrates, one for each grain size fraction. The polished sections and one made from a chip of the core were investigated under the scanning electron microprobe.

Contrary to most Middle zone gabbros from the Skaergaard intrusion sample 90-24 does not show the characteristic reaction relationship between cumulus and intercumulus phases, including rims of olivine and anorthite-rich plagioclase at the boundaries between accumulated grains of Fe-Ti-oxides and two-pyroxenes. The gabbro is “dry” and H_2O-bearing minerals are only locally present in very insignificant amounts and always in intergrowths with Cu-Fe-sulphides.

The HS heavy mineral concentrates contain numerous sulphide grains identified as sulphide droplets. They are composed of one or more of the Cu-sulphides bornite, chalcosine, chalcopyrite, sometimes of pentlandite and cobalt pentlandite. Some of these droplets and sulphide grains contain inclusions of PGMs and (Au,Cu,Pd) alloys. In the heavy mineral concentrate also a grain of zircon (~50 µm) was identified and may be used for geochronological studies.

For the present investigation 116 precious metal bearing grains were selected. The dominant precious metal mineral is skaergaardite (Pd,Pt,Au)(Cu,Fe,Zn) (92.7 vol. %) followed by (Au,Cu,Pd) alloys (2.7 %), vasilite $(Pd,Cu)_{17}S_6$ (1.3 %), vysotskite (Pd,Ni,Cu)S (1.3 %), kethconnite $Pd_3(Te,Sn,Pb)$ (1.4 %), and rare atokite $(Pd,Cu)_3Sn$, (Pd,Sn,Cu) alloy and zvyagintsevte $Pd_3(Pb,Te,Sn)$. The grain size of the precious metal minerals (ECD) varies between 2 and 74 µm with an average of 24 µm.

The average composition of skaergaardite (104 grains) is (wt. %): Pd 57.0, Pt 4.2, Au 2.5, Cu 28.3, Fe 5.0, Zn 1.6, Sn 0.2, Te 0.3, Pb 0.2, Total 99.3. giving the following formula:

$(Pd_{0.94}Pt_{0.04}Au_{0.02})_{1.00}(Cu_{0.79}Fe_{0.16}Zn_{0.04})_{0.99}$. The (Au,Cu,Pd) alloys are relatively poor in Au and rich in Pd –and close to unnamed mineral $AuPdCu_2$

The estimated bulk composition of the sample (assays of whole rock in brackets) is (ppb): Pd 2028 (2000), Au 132 (112), Pt 140 (190). Pt is contained in skaergaardite; Au is in skaergaardite (83 ppb) with some in (Au,Pd,Cu) alloys (49 ppb); Pd is in skaergaardite (1896 ppb), with minor other Pd PGMs and Au-minerals (132 ppb). The very similar estimates of the bulk composition demonstrates that the separation method has caught almost all the precious metal bearing grains in the sample.

All the observations and the inter-grain relations suggest that all precious metal minerals are part of a single paragenesis. The sulphide droplets contain rare droplets of PGMs and Au-minerals. This characteristic texture suggests the occurrence of two immiscible melts: 1) Cu-Fe sulphide melt and 2) metal melt enriched by Cu, Pd, Pt and Au which is separated from sulphide melt, in accordance with experimental investigations of the Cu-Pd-S system.

Intoduction

The report describes the mineralogy of sample 90-24 1056 from the top of Pd5 level in the "Platinova Reef" of the Skaergaard intrusion (Andersen et al., 1998; Nielsen et al, 2005). The report is based on concentrates of PGMs produced using monolayer thin section on heavy mineral concentrates obtained using Hydroseparator CNT-HS-11 and one polished section of a rock chip from the core. The monolayer samples were studied using electron microscopy and electron microprobe analysis (Camscan-4DV, Link AN-10 000). The report gives the grain characteristics, the parageneses and the compositional variation for the identified groups of minerals in the host rock, sulphides droplets, the PGMs and the alloys.

Sample 90-24 1056

Sample 90-24 1056 collects the interval between 1056 and 1057 m in BQ drill core # 90-24. The core was drilled with an azimuth of 0° and an inclination of –70 from a location at 504 meters a.s.I, on the western slope of Basistoppen. The core has previously been sampled for other purposes. The 780g sample collects 1/3 of the diameter of the preserved core. Sample 90-24 1056 collects the top of the Pd5 level in the mineralisation and assays show 2000 ppb Pd, 112 ppb Au, and 190 ppb Pt for this interval (Watts, Griffis & McOuat, 1991).

Analytical techniques

Analytical techniques are described in Nielsen et al. (2003). The heavy mineral concentrates, enriched in precious metal minerals using the patented, computer controlled Hydroseparator CNT-HS-11 and patented glass separation tube (GST) (Rudashevsky & Rudashevsky, 2006 and 2007). One polished section was prepared from chip of core. All the. remaining material was crushed to –125 µm.

After complete grinding, the sample was sieved under water (wet sieving) into the following fractions: <40 µm (405 g), 40-63 µm (150 g), 63-80 µm (59 g), 80-125µm (288 g) and >125 µm (78 g) and followed by wet magnetitc separation. The remaining non-magnetitc material of the fractions fractions <40 µm, 40-63 µm, 63-80µm, 80-125 µm were then processed through hydroseparator CNT-HS-11 and the resulting concentrates were mounted in several monolayer polished sections.

Results

Rock forming minerals and sulphide mineralogy

Silicates and oxides

The silicates and FeTi-oxides related to the sulphides and precious metal phases are: 1) *plagioclase*, An_{38-44} (Table 1, analyses 1-4); 2) monoclinic ferrous *pyroxene*, Mg# = 0.64-0.66 (Table 1, analyses 5-9), 3) orthorhombic ferrous *pyroxene*, Mg# = 0.53-0.56 (Table 1, analyses 10-14) and Fe-Ti oxides including 4) *ilmenite* (Table1, analyses 15-19), 5) *titanomagnetite* (Table 1, analyses 20-23). Monoclinic pyroxenes show typical exsolution textures with orthorhombic pyroxenes (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, #1-3). Some fine grains of Fe-Ti oxides (<20 μm) have the form of droplets (Plate 1, #5). They occur as inclusions in pyroxenes, as well as in plagioclase. The are regarded as melt inclusions (see Jakobsen et al., 2011 and references therein).

Pyroxenes which are in contact with Fe-Ti-oxides aggregates (Plate 1, #2, 3) and plagiclase (Plate 1, #4, 5) do mostly not show the characteristic exsolution texture and are composed of orthopyroxene, only.

One zircon grain (~50 μm, Fig. 1) was found in the heavy mineral concentrate. It can be used for follow-up geochronological investigations of the ore horizon.

The host gabbro of sample 90-24 1056 is a fairly “dry” rock. Minerals containing volatile elements are very rare (Plate 1, #2) in the studies thin section. The few volatile bearing minerals include chamosite and calcite related to the sulphide globules (Plate 2, #4, 6) or in paragenesis with Cu-sulphides and precious metal minerals (Plate 4, #6; Plate 6, #2; Plate 7, #1, 2).

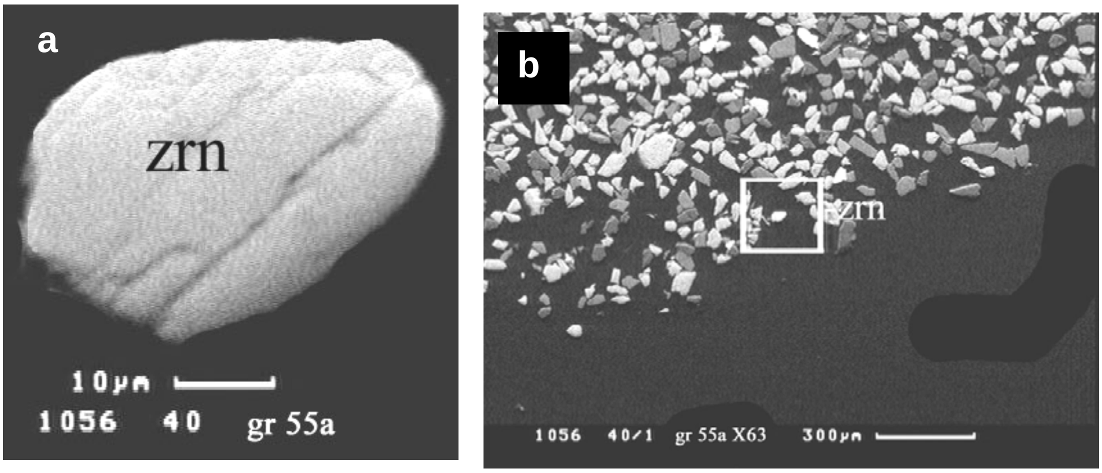


Fig. 1. Zircon grain (for age dating), extracted in the heavy concentrate of the sample 90-24, 1056; polished section, SEM-image (BIE).

Sulphides

Despite of the high concentration of precious metals (>2 ppm), the gabbro is relatively poor in sulphides. Only one chalcosine grain of irregular shape (aggregate < 50 μm) found in the thin section. It occurs as an inclusion in pyroxenes (Plate 1, #6).

The non-magnetic heavy mineral concentrates are ilmenite-rich products (> 90 %). In contrast to the observations in the thin section, the non-magnetic concentrates are enriched in grains of sulphides and precious metal minerals. The sulphides grains include numerous droplet-like microglobules (up to 0.1 mm in size) and irregular grains and of the Cu-Fe sulphides (see Plate 2).

The sulphide grains and aggregates are composed dominantly by bornite and chalcosine group minerals (see Plates 1, #6; Plate 2). The volume ratio varies significantly from grain to grain (see Plate 2). In the microglobules bornite and chalcosine group minerals form classic exsolution textures (see Plate 2).

Compositions of bornite (Table 2, analyses 1-5, 7, 9, 11, 14), chalcosine (Table 2, analyses 6, 8, 10, 16) and chalcopyrite (Table 2, analysis 15) are all near-stoikiometric. Pentlandite (Plate 3, #36; Table 2, analysis 12) and cobalt pentlandite (Plate 3, #4; Table 2, analysis 13) occurs in intergrowths with skaergaardite and contain 18.7-27.1 % Co.

PGMs and Au-minerals: recovery, grain size and relations to host rock

Recovery

No precious metal minerals were identified in the thin section of the core rock. By contrast, the heavy mineral concentrates have yielded >150 grains of PGM and Au-minerals. A representative selection of 116 grains of a wide size range (from –40 μm up to 80-125 μm) was selected for more detailed studies. At least 9 different precious metal minerals are recorded in the concentrates of sample 90-24 1056. They include:

1. *Skaergaardite* (Pd,Au,Pt)(Cu,Fe,Zn,Sn,Te,Pb) - 107 grains,
2. *(Au,Cu,Pd) alloys: tetra-auricupride* (Au,Pd)Cu and two unnamed $AuPdCu_2$ and
3. Au_3Cu mineral phases- 9 grains;
4. *Keithconnite* $Pd_3(Te,Sn,Pb)$ – 10 grains;
5. *Vasilite* $(Pd,Cu,Fe)_{17}S_7$- 4 grains;
6. *Vysotskite* (Pd,Ni,Cu)S – 2 grains;
7. *Atokite* $(Pd,Cu)_3Sn$ – 1 grain;
8. *Zvyagintsevite* $Pd_3(Pb,Te,Sn)$ – 1 grain.

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

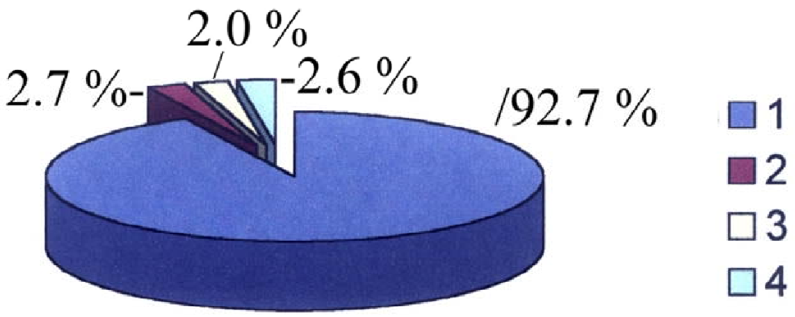


Fig. 2. Relative contents of PGE- and Au-minerals in sample 90-24 1056 (see Table 3). 1) skaergaardite; 2) (Au,Cu,Pd)-alloys; 3) Pd, Cu, Te, Sn and Pb-minerals (keithconnite, atokite, zvyagintsevite and Pd-Cu-Sn-alloys); 4) Pd sulphides (vasilite and vysotskite).

Grain size

The grain size of the grains was measured as the effective diameter (ECD) using the "imageJ" ® software. It varies from 2 to 74 μm with an average of 24 μm (Table 3, 4; Fig. 3). The histogram of precious metal mineral grains (Fig. 3) is facing the lognormal distribution for this statistical selection (n=116). According to this histogram, sizes of grains of precious metal minerals are distributed as follows:

Grain size, µm	Number of grains
0-10	4
10-20	50
20-30	36
30-40	13
40-50	7
50-60	2
60-70	2
70-80	2

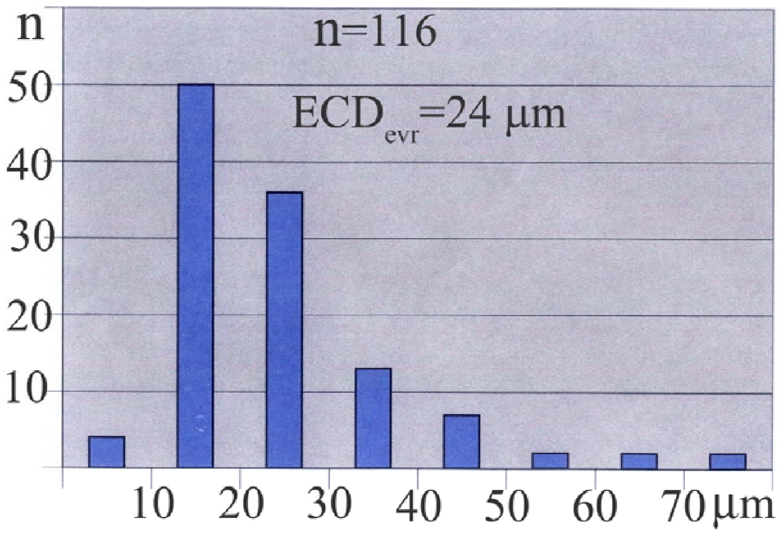


Fig 3. Histogram of the grain size distribution for the precious metal mineral grains (n=116) in the heavy mineral concentrates of the sample 90-24 1056.

The SEIs (scanning electron images) show that the majority of PGM grains are well preserved and have retained their primary shape and size (Plates 3-7). The grains have not been broken during the production of the concentrates. The largest proportion of precious metal mineral grains are in the –40 µm fraction.

Petrographic observations

The almost perfect separation of accessory minerals was achieved by gentle crushing of the studied sample. The method of disintegration allows preservation of the grains and the recovery of most of the information needed for the reconstruction of the genesis of the mineralisation in sample 90-24 1056. The concentrates provide full information for the reconstruction of the primary shapes and sizes of accessory minerals, the mineral paragenesises and the relationship to the host rock.

In the heavy mineral concentrates of the sample 90-24, 1056 precious metal mineral grains (n=116) occur in the following mineral associations (Fig. 4; Table 5):

Table 5. Mineral associations of precious metal mineral grains in sample 90-24 1056:

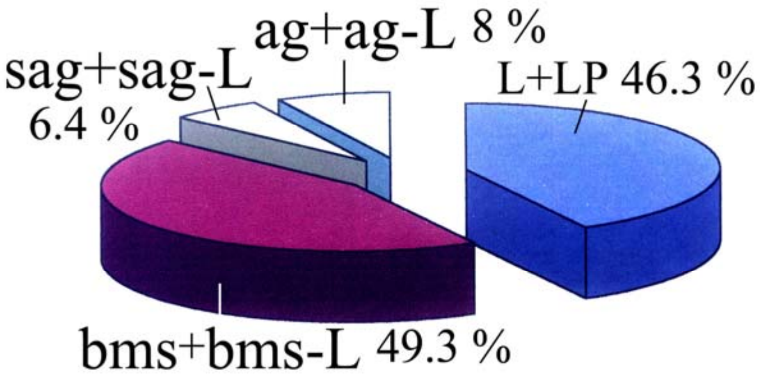
Association	PGMs, vol %, (n=107 grains)	(Au,Cu,Pd) alloys, vol. % (n=9 grains)	Presious metal mineral grains, sample total, vol. % (n=116 grains)
L	41.8	23.7	41.0
LP	4.5	11.0	4.7
bms	14.8	-	14.5
bms-L	24.5	37.0	24.9
sag	2.2	26,2	2.9
sag-L	4.2	-	4.1
ag	0.5	-	0.5
ag-L	7.5	2.2	7.4

L) completely liberated (free) particles; **LP**) two or more precious metal completely liberated (free) particles; **bms**) intergrowths with base metal sulphides (bornite, chalcosine, chalcopyrite, sometimes pentlandite, cobalt pentlandite); **bms-L**) liberated particles with <10 % attached base metal sulphides; **sag**) sulphide and gangue attached to precious metal minerals ; **sag-L**) sulphide and gangue attached to precious metal minerals, but < 10 %; **ag** – precious metal minerals attached to gangue (clinopyroxene, plagioclase, ilmenite, chamosite); **ag-L** – precious metal minerals attached to gangue, but <10 %.

Based on the SEIs, the precious metal minerals in the heavy concentrates divide into the following groups:

1. skaergaardite grains in intergrowths with base metal sulphides (**bms, bms-L**), and sulphides + gangue (**sag** and **sag-L**) - (Plate 3);
2. skaergaardite grains in intergrowths with gangue (**ag** and **ag-L**) - (Plate 4);
3. skaergaardite grains that are completely liberated (**L**) – (Plate 5).
4. grains of (Au,Cu,Pd) alloys with variable composition (Plate 6).
5. grains containing PGMs other than skaergaardite (Plate 7).

A



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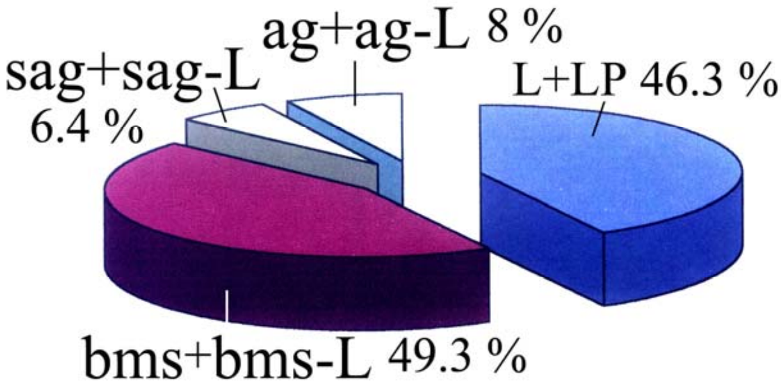

Fig. 4. PGM- and Au-minerals, grouped by associations (sample 90 24, 1056): a – PGMs (n=107), b - (Au,Cu,Pd) alloys (n=9); see Table 5.

L- completely liberated (free) particle; **LP** - two or more precious metal minerals completely liberated (free) particle; **bms** - base metal sulphides attached to precious metal minerals, **bms-L** – liberated particle with <10 % attached base metal sulphides; **sag** – sulphides and gangue attached to precious metal minerals; **sag-L** - sulphides and gangue attached to precious metal minerals, but <10 %;; **ag** - precious metal minerals attached to gangue; ag-L - precious metal minerals attached to gangue, but <10 %.

Description and composition of PGMs and Au- minerals

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

Description

Skaergaardite is the dominant Pd mineral in the heavy mineral concentrates of the sample (92.7 vol.%). It is found in the heavy mineral concentrates in the following forms:

1. liberated (free) grains: **L** (Plate 5);
2. intergrowths with base metal sulphides (bornite, chalcosine, chalcopyrite, pentlandite,cobalt pentlandite: **bms** (Plate 3, #1-7, 8-15, 17-20, 22-26; Plate 7, #5, 11, 12); **bms-L** (Plate 3, #27-40; Plate 7, #3, 14, 17);
3. intergrowths with sulphide and gangue (monoclinic pyroxenes, ilmenite): **sag** (Plate 3, #8, 21) and **sag-L** (Plate 3, #16);
4. intergrowths with gangue (ilmenite, plagioclase and chamosite): **ag** (Plate 4, #1-3; Plate 7, #13); **ag-L** (Plate 4, #4-6; Plate 6, #7);
5. intergrowths with other PGM and (Au,Cu,Pd) alloys - vasilite, keithkonnite, atokite, zvyagintsevite, (Pd,Sn,Cu) alloy, (Au,Cu,Pd) alloy, unnamed $AuPdCu_2$ (Plate 6, #3-7; Plate 7, #3, 5, 6, 11-17).

Besides occurring as liberated grains, skaergaardite is also found in clear and characteristic associations with base metal sulphides (see Plate 3). Skaergaardite-bearing sulphide grains can be either droplet-like (Plate 3, #1-4) or irregular shaped aggregates (Plate 3, #7-13 etc). Quite often, skaergaardite grains are localized at the margin of the sulphide globules (Plate 3, #1-4, 6, 7, 12 etc). Skaergaardite grains occur as:

1. isometric droplet-like grains with the rounded outlines (Plate 3, #3-5, 13, 27-32; Plate 5, #1-9; Plate 7, #12);
2. euhedral crystals or subeuhedral grains (Plate 3, #2, 6, 8-10, 18-22);
3. irregular grains (Plate 3, #15, 16, 25, 38-40; Plate 5, #27, 29-43 etc).

The grain size of skaergaardite varies between 2 and 74 μm with an average of 24.1 μm (Table 4).

Mineral chemistry

The composition of skaergaardite was constrained by 104 analyses from 104 grains (Table 6). The average composition of skaergaardite is (wt. %): Pd 57.0; Pt 4.2, Au 2.5, Cu 28.3, Fe 5.0, Zn 1.6, Sn 0.2, Te 0.3, Pb 0.2, Total 99.3. The composition corresponds to the formula:

$$(Pd_{0.94}Pt_{0.04}Au_{0.02})_{1.00}(Cu_{0.79}Fe_{0.16}Zn_{0.04})_{0.99}$$

Typical substitutions in skaergaardite are: Pt up to 19.2 % (Table 6, analysis 33), Au up to 23.8 % (Table 6, analysis 56), Fe up to 7.8 % (Table 6, analysis 100), Zn up to 5.7 % (Table6, analysis 50), Sn up to 4.0 % (Table 6, analysis 80), Te up to 3.0 % (Table 6, analysis 72), Pb up to 2.2 % (Table 6, analysis 5).

Pt and Au concentrations in the 104 analyses of skaergaardite distribute as follows (see also Fig. 5):

Interval, wt%	**Pt - number of analyses**	**Au - number of analyses**
0-0.9	50	44
0.9-2	7	31
2-4	8	16
4-6	10	4
6-8	1	1
8-10	5	1
10-12	10	-
12-14	6	1
14-16	5	1
16-18	1	-
18-20	1	2
20-22	-	2

It is to be mentioned that the chemical compositions of skaergaardite depends on the pragenesis in which it is found. For example, skaergaardite which contains inclusions of (Au,Cu,Pd) alloys, is richer in Au (Plate 6; #3, 4; Table 6, analyses 46, 59); skaergaardite, containing inclusions of Sn-minerals (atokite, Pd-Sn-Cu alloy) is richer in Sn (Plate 7, #16, 17; Table 6, analyses 29, 80), and skaergaardite containing inclusions of Pb-mineral (zvyagintsevite) is enriched in Pb (Plate 7, #15; Table 6, analysis 7).

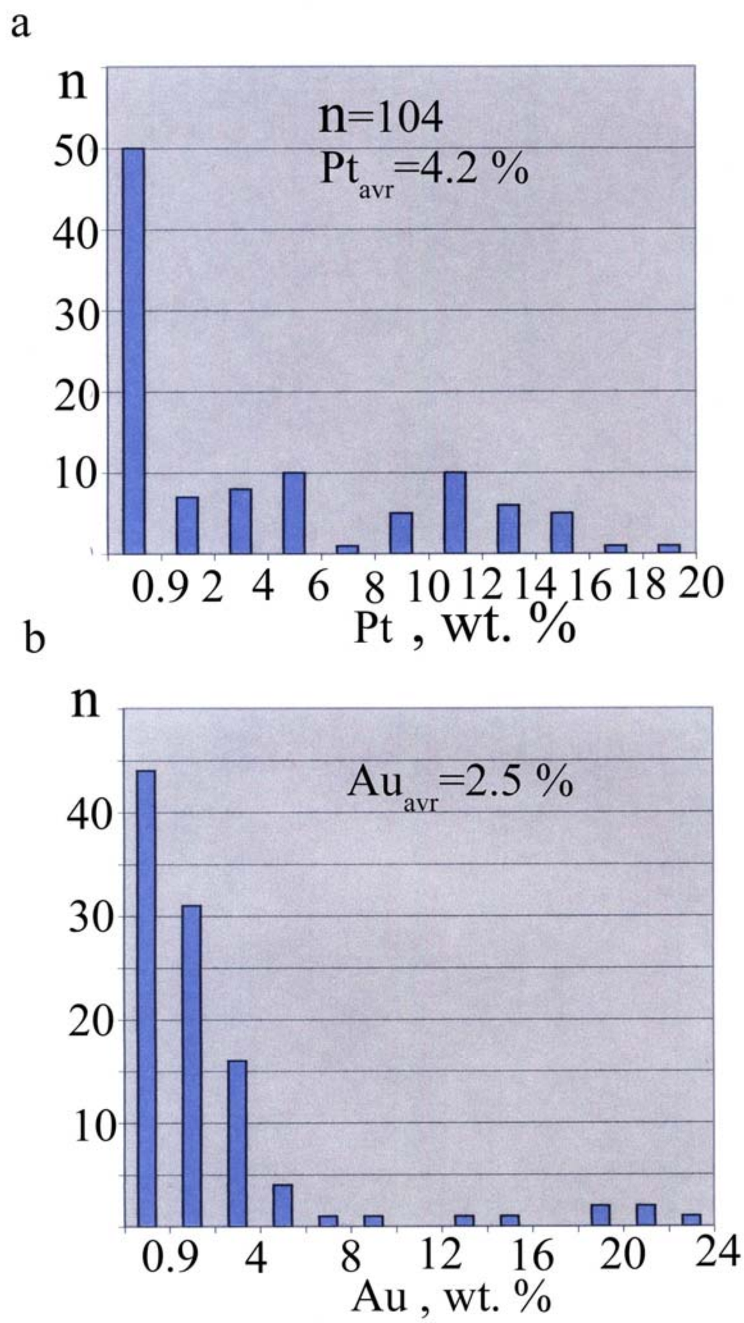

Fig. 5. Histograms of Pt and Au of skaergaardite in sample 90-24 1056), data in the Table 6.

(Au,Cu,Pd) alloys

Description

(Au,Cu,Pd) alloys represent the second 2.7 vol.% of the precious metal paragenesis in the heavy mineral concentrates of the sample 90-24 1056. The 9 grains that were observed occur in the following associations:

1. liberated (free) grains - (**LP**: Plate 6, #3-6);
2. intergrowths with base metal sulphides (chalcopyrite) - **bms-L**: Plate 6, #1;
3. intergrowth with base metal sulphides and gangue (chamosite and chalcosine) –
4. **sag**:: Plate 6,# 2;
5. intergrowth with gangue (ilmenite) – **ag-L:** Plate 6, #7;
6. intergrowths with PGMs: skaergaardite (Plate 6, #3-6) and keithconnite (Plate 6, #1);
7. intergrowths of different (Au,Cu,Pd) alloys: 1) tetra-auricupride and unnamed Au_3Cu (Plate 6, #1), 2) tetra-auricupride and (Au,Cu,Pd) alloy (Plate 6, #6).

Au-mineral grains may occur as:

1. isometric droplet-like grains with the rounded outlines (Plate 6, #1, 2, 4, 6);
2. irregular grains (Plate 6, #3, 6, 7).

The size of the Au-mineral grains is from 2 to 26 µm with an average of 14 µm (Table 4).

Mineral chemistry

The chemical compositions of Au-minerals is shown in Table 7 and includes: 1) tetra-auricupride (analyses 1 and 3); 2) (Au,Cu,Pd) alloy (analysis 2); 3) unnamed mineral phase Au_3Cu (analysis 4); 4) unnamed mineral phase $AuPdCu_2$ (analyses 5-9). The average composition of all the analysed (Au,Cu,Pd) alloys in the sample 90-24 1056 (Table 7, analysis 10) is (wt. %): Au 52.9 Pd 22.4 Pt 0.4 Cu 23.4 Fe 0.7 Te 0.4 Total 99.4.

The dominant (Au,Cu,Pd) alloy is close to $AuPdCu_2$, an unnamed mineral phase – poor in Au and rich in Pd.

Rare PGMs

Six other PGMs were found in the heavy mineral concentrate and constitute c. 4.6 vol. % of the precious metal paragenesis. They include vasilite, vysotskite, keithconnite, zvyagintsevite, atokite, and (Pd,Sn,Cu) and (Pd,Te,Sn,Pb) alloys (see Table 4).

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

Vasilite (Pd,Cu,Fe) was found of 4 precious metal mineral grains in association with the base metal sulphides bornite, chalcosine and chalcopyrite (Plate 7, #3-5), as well as with other PGMs including skaergaardite and keithconnite (Plate 7, #3, 5, 6). The vasilite containing grains are irregular in shape, their size varies between 8.4 and 21.8 µm, and the average size is 16 µm.

The chemical composition of vasilite corresponds to the stoikiometric formula $(Pd,Cu,Fe)_{16}S_7$ (Table 8, analyses 9-12).

Vysotskite (Pd,Ni,Cu)S

Vysotskite (Pd,Ni,Cu)S was found in two precious metal mineral grains and constitute 1.3 vol.% of the precious metal mineral paragenesis. Vysotskite occurs in association with the base metal sulphides bornite and pentlandte and shamosite (Plate 7, #1, 2),

The shape of vysotskite-containing grains is droplet-like (Plate 7, #1) or irregular (Plate 7, #2), and the sizes of the grains is between 15 and 29 μm, with an average of 22 μm. Chemical composition of vysotskite is shown in Table 8 (analyses 13, 14).

Keithconnite Pd_3(Te,Sn,Pb)

Keithconnite Pd_3(Te,Sn,Pb) was identified in 10 precious metal mineral grains and constitutes

1.4 vol. % of the precious metal mineral paragenesis. Keithconnite occurs in the following associations:

1. liberated (free) grains - (**L**: Plate 7, #7, 9, 10);
2. intergrowths with the base metal sulphides bornite and chalcopyrite); **bms:**: Plate 7, #11, 12; **bms-L**: Plate 6, #1; Plate 7, #14);
3. intergrowth with the gangue minerals ilmenite, clinopyroxene and plagioclase; **ag:** Plate 7, #13; **ag-L**: Plate 7, #8;
4. intergrowths with PGMs and (Au,Cu,Pd) alloys: skaergaardite (Plate 7, #6, 11-14) and vasilite (Plate 7, #6); tetra-auricupride and Au_3Cu (Plate 6, #1).

Small grains of keithconnite occur in the following shapes: 1) droplet-like (Plate 7, #11, 12,14), 2) euhedral crystals or partially euhedral grains (Plate 7, #7, 8, 1) and 3) irregular (Plate 6, #1; Plate 7, #6, 9, 13). The size of the keithconnite grains is between 2 and 20 μm, with an average of 9 μm. Chemical composition of kethconnite are found in Table 8, analyses 1-8.

Zvyagintsevite Pd_3(Pb,Te,Sn)

One small grain of zvyagintsevite Pd_3(Pb,Te,Sn) (~2 μm) was found as an inclusion in skaergaardite (Plate 7, #15).

Atokite $(Pd,Cu)_3Sn$

One grain of atokite $(Pd,Cu)_3Sn$ (19 μm) was found as an inclusion in skaergaardite (Plate 7, #16: Table 8, analysis 15).

(Pd,Cu,Sn) alloy

One grain of (Pd,Cu,Sn) alloy (10 μm) was found as an inclusion in skaergaardite in association with bornite (Plate 7, #17; Table 8; analysis 16).

Bulk composition of the sample 90-24 1056

The relative concentrations of Pd, Au and Pt in sample 90-24 1056 can be calculated from the total concentration of precious metal, the determined recovery, the modal proportions and the chemical compositions (Tables 4-8). The estimated bulk composition in the sample (assays of whole rock in brackets) is (ppb): Pd 2028 (2000), Au 132 (112), Pt 140 (190). Pt substitutes in skaergaardite; Au in skaergaardite (83 ppb) and to a lesser extend in (Au,Pd,Cu) alloys (49 ppb) and Pd in skaergaardite (1896 ppb) and to lesser extende in other Pd-PGMs and Au-minerals (132 ppb).

Discussion

The PGM- and Au-mineral paragenesis

The extensive data shows that the dominant PGM in the studied sample is skaergaardite. Skaergaardite shows a wide compositional range (Table 6). Its composition depends on the PGM and Au-mineral associations of the specific grain (Plates 3, 6, 7; Fig. 4; Table 5). The defined compositional groups of skaergaardite and the associated PGMs and Au-minerals are correlated as follows:

1. skaergaardite enriched by Au-(Te) coexists with tetra-auricupride, $AuPdCu_2$, Au_3Cu, (Au,Cu,Pd) alloy and keithconnite;
2. skaergaardite enriched by Pt;
3. skaergaardite enriched by Sn coexists with atokite and (Pd,Sn,Cu) alloy;
4. skaergaardite enriched in Pb coexists with zvyagintsevite and keithconnite.

Fig. 4 shows that beside the liberated grains (**L, LP**), the paragenesis with base metal sulphides (**bms, bms-L, sag, sag-L**) hosts both PGMs (see Fig. 4a) and (Au,Cu,Pd) alloys (see Fig 4b) parageneses. This conclusion is based on the observations of liberated grain intergrowths of (Au,Cu,Pd) alloys with skaergaardite (Plate 6, #3-5).

All the observations and the inter-grain relations (Plates3, 6, 7) suggest that all PGMs and Au-minerals are as a part of a single paragenesis. The characteristic droplet-like shape of many grains of the (Au,Cu,Pd) alloy is emphasized (see Plate 6, #1, 2, 4, 5).

Order of crystallization

The Cu-Fe sulphides and PGMs are contemporaneous and crystallized later than the bulk of the rock-forming minerals plagioclase, clinopyroxene, orthopyroxene, ilmenite and titanomagnetite.

The characteristic droplet shape of both - PGMs and host sulphides suggests that the sulphide droplets and enclosed PGM droplets represent two immiscible melts: 1) a Cu-Fe sulphide melt and 2) a metal melt enriched in Pd, Cu, Pt and Au Au that separated from the sulphide melt. This is In agreement with the experimental investigations of the Cu-Pd-S system (Karup-Møller and Mackovicky,1999).

The residual sulphide-metal melt phase seems to be 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 sulphides with H_2O- and CO_2-bearing minerals (chamosite, calcite etc).

Summary

1. A selection of 116 grains of precious metal minerals in the heavy mineral concentrates from the sample 90-24 1056 (0.78 kg) was inverstigated using HS-hydroseparation technology.

2. The dominant precious metal mineral is skaergaardite (Pd,Pt,Au)(Cu,Fe,Zn) – 92.7 vol. %. In addition, at least 9 other precious metal minerals were identified (~ 7.3 vol. % all together). They include: 1) gold minerals (2.7 vol. %): tetra-auricupride AuCu, unnamed $AuPdCu_2$, unnamed Au_3Cu and Au-Cu-Pd alloy); 2) vasilite $(Pd,Cu,Fe)_{16}S_7$ (1.3 vol. %); 3) vysotskite (Pd,Ni,Cu)S (1.3 vol. %); 4) keithconnite $Pd_3(Te,Sn,Pb)$ (1.4 vol. %); 5) minor atokite $(Pd,Cu)_3Sn$ (Pd,Sn,Cu) alloy and 6) minor zvyagintsevite $Pd_3(Pb,Te,Sn)$.

3. The estimated bulk composition in the sample (assays of whole rock in brackets) is: (ppb) Pd 2028 (2000), Au 132 (112), Pt 140 (190): Pt is in skaergaardite; Au is substituted into skaergaardite (83 ppb) less so in (Au,Pd,Cu) alloys (49 ppb); Pd in skaergaardite (1896 ppb) and less so in other Pd PGMs and Au-minerals (132 ppb).

4. Skaergaardite shows a wide compositional range. Its composition depends on the PGM and Au-mineral paragenesis of the specific grain: a) skaergaardite enriched in Au-(Te) coexists with tetra-auricupride, $AuPdCu_2$, Au_3Cu, (Au,Cu,Pd) alloy and keithconnite; b) skaergaardite enriched by Sn coexists with atokite and (Pd,Sn,Cu) alloy; and c) skaergaardite enriched by Pb coexists with zvyagintsevite and keithconnite.

5. The base metal sulphides paragenesis coexists with both PGMs and (Au,Cu,Pd) alloys. Intergrowths of skaergaardite with (Au,Cu,Pd) alloys.are very characteristic.

6. All observations and the inter-grain relations suggest that all PGMs and Auminerals are part of a single paragenesis.

7. The sulphide droplets contain droplets of PGMs and Au-minerals. The characteristic structure suggests the occurrence of two immiscible melts: 1) a Cu-Fe sulphide melt and 2) a metal melt enriched in Cu, Pd, Pt and Au that separated from the suphide melt.

8. The (Au,Cu,Pd) alloys are in composition generally relatively poor in Au and rich in Pd and close to the unnamed mineral phase $AuPdCu_2$.

9. In the heavy mineral concentrates one grain of zircon (~50 μm) was found. It can be used for geochronological studies of the ore horizon.

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TABLES

Table 1. Composition of silicates and FeTi-oxides in sample 90-24 1056

Mineral	Plagioclase				orthopyrox CPX					Clinopyroxene					Ilmenite					Titanomagnetite			
Analysis	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
wt%																							
SiO2	56.3	56.9	56.9	56.6	52.1	52	51.8	51.8	51.5	51.2	50.8	49	50.1	51.1	-	-	-	-	-	-	-	-	-
TiO2	-	-	-	-	0.5	0.4	0.3	0.2	0.5	0.2	0.2		0.2	0.3	51	50.6	49.2	49.8	49.6	15.8	12.4	13.9	13
Al2O3	27.2	27	27	27	1.1	1.2	1	0.9	1.2	0.2	0.5	2.5	1.9	0.5	-	-	-	-	-	3.2	4.1	3.3	3.2
V2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.5	0.5	1.3	1.8	1.2	1.2
Fe2O3	0.3	0.4	0.4	0.3	-	-	-	-	-	-	-	-	-	-	3.9	4.9	6.2	6.7	6.8	33.9	38.4	36.8	38.7
FeO	-	-	-	-	12.6	12.2	12.7	12.9	13	25.8	27.3	27	27.5	28	42.9	41.9	40.6	39.2	39.8	44.4	42	43.9	43.6
MnO	-	-	-	-	0.2	0.3	0.2	0.4	0.3	0.5	0.6	0.6	0.6	0.5	0.5	0.4	0.6	0.6	0.5	0.3	0.4	0.3	0.2
MgO	-	-	-	-	13	13	14	13.6	12.9	19	18.6	17.5	17.5	18.5	1.3	1.8	1.8	2.7	2.3	1	0.5	0.7	-
CaO	9.3	8.6	8.6	8.1	20.6	20.5	20.5	20.7	20.1	2.4	1.4	2.7	2	1	-	-	-	-	-	-	-	-	-
Na2O	6.3	6.3	6.7	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
K2O	0.4	0.4	0.2	0.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	99.8	99.6	99.8	99.4	100.1	99.7	100.5	100.5	99.6	99.3	99.5	99.3	99.8	100	99.6	99.5	99.1	99.4	99.5	99.9	99.7	100.1	99.9
Atomic proportions																							
SiO2	2.54	2.57	2.56	2.56	1.97	1.97	1.94	1.95	1.96	1.97	1.96	1.91	1.93	1.96	-	-	-	-	-	-	-	-	-
TiO2	-	-	-	-	0.01	0.01	0.01	0.01	0.01	0.01	0.01		0.01	0.01	0.96	0.95	0.93	0.93	0.93	0.44	0.35	0.4	0.36
Al2O3	1.45	1.43	1.43	1.44	0.05	0.05	0.05	0.04	0.06	0.01	0.02	0.11	0.08	0.02	-	-	-	-	-	0.14	0.18	0.14	0.14
V2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02	0.01	0.01	0.04	0.06	0.04	0.05
Fe2O3	0.01	0.01	0.01	0.01	-	-	-	-	-	-	-	-	-	-	0.07	0.09	0.12	0.13	0.13	0.94	1.07	1.02	1.08
FeO	-	-	-	-	0.4	0.39	0.4	0.41	0.41	0.83	0.88	0.88	0.89	0.9	0.9	0.88	0.86	0.82	0.83	1.37	1.3	1.36	1.36
MnO	-	-	-	-	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
MgO	-	-	-	-	0.73	0.73	0.79	0.77	0.73	1.09	1.07	1.01	1.01	1.06	0.05	0.07	0.07	0.11	0.09	0.05	0.03	0.04	-
CaO	0.45	0.42	0.41	0.39	0.83	0.83	0.83	0.84	0.82	0.1	0.06	0.11	0.08	0.04	-	-	-	-	-	-	-	-	-
Na2O	0.55	0.55	0.58	0.61	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
K2O	0.03	0.02	0.01	0.02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
O-basis	8	8	8	8	6	6	6	6	6	6	6	6	6	6	3	3	3	3	3	4	4	4	4
An%	0.45	0.433	0.414	0.39	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	0.646	0.652	0.664	0.653	0.64	0.568	0.549	0.534	0.532	0.541	-	-	-	-	-	-	-	-	-

Table 2. Compositions of base metal sulphides in PGM-bearing globules in the heavy mineral concentrates of sample 90-24 1056

				Analysis (wt%)						*proportions*					
An	**Grain**	**Association**	**Mineral**	**Cu**	**Fe**	**Ni**	**Co**	**S**	**Total**	***Cu***	***Fe***	***Ni***	***Co***	***S***	***Total***
1	40 gr41	sk+bn	bn	62,4	11,2	nd	nd	26,1	99,7	*4,91*	*1,00*	*nd*	*nd*	*4,09*	*10,00*
2	80 gr1e	bn+ch	bn	63,1	11,1	nd	nd	24,9	99,1	*5,05*	*1,01*	*nd*	*nd*	*3,94*	*10,00*
3	125 gr1a	bn+ch	bn	61,7	11,2	nd	nd	25,6	98,5	*4,92*	*1,02*	*nd*	*nd*	*4,06*	*10,00*
4	125 gr1b	bn	bn	61,7	11,4	nd	nd	25,7	98,8	*4,91*	*1,04*	*nd*	*nd*	*4,06*	*10,00*
5	125 gr1c	bn+ch+chl	bn	63,2	10,2	nd	nd	25,4	98,8	*5,01*	*1,01*	*nd*	*nd*	*3,98*	*10,00*
6	125 gr1c	bn+ch+chl	ch	79,0	0,9	nd	nd	19,7	99,6	*1,99*	*0,03*	*nd*	*nd*	*0,98*	*3,00*
7	125 gr2b	bn+ch	bn	62,2	11,6	nd	nd	25,1	98,9	*4,97*	*1,06*	*nd*	*nd*	*3,98*	*10,00*
8	125 gr2b	bn+ch	ch	77,0	1,5	nd	nd	19,9	98,4	*1,96*	*0,04*	*nd*	*nd*	*1,00*	*3,00*
9	125 gr2c	bn+ch+ct	bn	63,0	10,9	nd	nd	25,1	99,0	*0,79*	*0,21*	*nd*	*nd*	*3,97*	*10,00*
10	125 gr2c	bn+ch+ct	ch	79,5	0,0	nd	nd	20,5	100,0	*1,98*	*0,00*	*nd*	*nd*	*1,02*	*3,00*
11	125 gr3	vys+bn+pn+chl	bn	61,8	11,5	nd	nd	25,4	98,7	*4,93*	*1,04*	*nd*	*nd*	*4,03*	*10,00*
12	125 gr3	vys+bn+pn+chl	pn	2,5	13,1	32,8	18,7	32,3	99,4	*0,32*	*1,84*	*4,40*	*2,50*	*7,94*	*17,00*
13	125 gr6	sk+bn+copn	copn	1,3	12,7	26,0	27,1	32,7	99,8	*0,16*	*1,79*	*3,49*	*3,59*	*8,00*	*17,00*
14	125 gr6	sk+bn+copn	bn	63,1	11,5	nd	nd	25,1	99,7	*5,01*	*1,04*	*0,00*	*0,00*	*3,95*	*10,00*
15	63 gr2	sk+cp	cp	34,7	30,2	nd	nd	34,2	99,1	*1,01*	*1,00*	*0,00*	*0,00*	*1,99*	*4,00*
16	63 gr10	$AuPdCu_2$+ch	ch	78,4	1,1	nd	nd	20,1	99,6	*1,95*	*0,06*	*0,00*	*0,00*	*0,99*	*3,00*

Abbreviations: sk: skaergaardite; vys: vysotskite; AuPdCu2: unnamed mineral; bn: bornite; ch: chalcosine: cp: chalcopyrite; pn: pentlandite; copn: cobalt pentlandite; chl: chlorite and ct: calcite;

Table 3. Size of precious metal mineral grains in sample 90-24 1056

N	Grain	Association	Type	Mineral	Area, μm^2	ECD, μm
1	125-1	sk-bn-ch	bms	sk	914	34,1
2	125-2	sk-ilm	ag-L	sk	2855	60,3
3	125-3	vys-bn--pn-chl	bms	vys	180	15,1
4	125-4	sk	L	sk	1296	40,6
5	125-5	vys-bn-chl	sag	vys	654	28,9
6	125-6	sk-bn-copn	bms	sk	1509	43,8
7	40-10	sk	L	sk	269	18,5
8	40-11	sk-ch-bn-ilm	bms	sk	183	15,3
9	40-12	sk	L	sk	642	28,6
10	40-13	sk	L	sk	359	21,4
11	40-14	sk	L	sk	127	12,7
12	40-15	sk	L	sk	622	28,2
13	40-16	sk-cp-bn	bms	sk	170	14,7
14	40-17	sk-bn-ch	bms	sk	86	10,5
15	40-18	sk-kth-bn	bms-L	sk	899	33,8
16	40-18	sk-kth-bn	bms-L	kth	4	2,3
17	40-19	sk-pn	bms-L	sk	316	20,1
18	40-1	sk-ilm	ag	sk	218	16,7
19	40-20	sk-bn	bms-L	sk	378	21,9
20	40-21	sk-bn	bms-L	sk	155	14,1
21	40-22	(Au,Cu,Pd)	L	(Au,Cu,Pd)	345	21,0
22	40-23	kth	L	kth	132	13,0
23	40-24	sk	L	sk	199	15,9
24	40-25	sk	L	sk	102	11,4
25	40-26	sk-cp-cpx	sag-L	sk	2688	58,5
26	40-27	AuCu-Au_3Cu-kth-cp	bms-L	AuCu	537	26,2
27	40-27	AuCu-Au_3Cu-kth-cp	bms-L	Au_3Cu	120	12,4
28	40-27	AuCu-Au_3Cu-kth-cp	bms-L	kth	170	14,7
29	40-28	sk-vs-kth	LP	sk	268	18,5
30	40-28	sk-vs-kth	LP	vs	56	8,4
31	40-28	sk-vs-kth	LP	kth	112	11,9
32	40-29	sk-bn-ch	bms-L	sk	491	25,0
33	40-2	sk	L	sk	307	19,8
34	40-30	sk	L	sk	248	17,8
35	40-31	sk	L	sk	728	30,5
36	40-32	sk-at	LP	sk	558	26,7
37	40-32	sk-at	LP	at	279	18,9
38	40-33	sk	L	sk	322	20,3
39	40-34	sk-ch	bms-L	sk	511	25,5
40	40-35	sk	L	sk	390	22,3
41	40-36	sk-chl	ag-L	sk	296	19,4
42	40-37	sk-(Au,Cu,Pd)-ilm	ag-L	sk	65	9,1
43	40-37	sk-(Au,Cu,Pd)-ilm	ag-L	(Au,Cu,Pd)	39	7,0
44	40-38	sk	L	sk	200	16,0
45	40-39	sk-bn	bms	sk	178	15,1
46	40-3	sk-bn	bms	sk	239	17,4
47	40-40	sk-bn-cp	bms	sk	178	15,1
48	40-41	sk-bn	bms	sk	610	27,9
49	40-42	sk	L	sk	653	28,8
50	40-43	sk	L	sk	281	18,9
51	40-44	kth	L	kth	97	11,1
52	40-45	sk-kth-pl	ag-L	sk	134	13,1
53	40-45	sk-kth-pl	ag-L	kth	20	5,0
54	40-46	kth	L	kth	47	7,7

Table 3 continued

N	Grain	Association	Type	Mineral	Area, μm^2	ECD, μm
55	40-47	sk-kth-bn	bms	sk	129	12,8
56	40-47	sk-kth-bn	bms	kth	11	3,7
57	40-48	sk	L	sk	176	15,0
58	40-49	sk	L	sk	1264	40,1
59	40-4	sk	L	sk	898	33,8
60	40-50	sk-bn	bms	sk	153	14,0
61	40-51	sk-bn	bms	sk	73	9,6
62	40-52	sk-$AuPdCu_2$	LP	sk	110	11,8
63	40-52	sk-$AuPdCu_2$	LP	$AuPdCu_2$	121	12,4
64	40-53	$AuPdCu_2$	L	$AuPdCu_2$	76	9,8
65	40-54	sk	L	sk	185	15,4
66	40-55	sk	L	sk	1622	45,5
67	40-56	kth-ilm-cpx	ag-L	kth	308	19,8
68	40-57	sk-bn	bms-L	sk	401	22,6
69	40-58	sk-bn-ilm	sag	sk	781	31,5
70	40-59	sk	L	sk	44	7,5
71	40-59	sk	L	sk	164	14,5
72	40-5	sk-ilm	ag-L	sk	457	24,1
73	40-60	sk-bn	bms-L	sk	212	16,4
74	40-61	sk	L	sk	223	16,9
75	40-62	sk	L	sk	196	15,8
76	40-63	sk-bn-ch	bms	sk	91	10,8
77	40-64	sk-bn-ch	bms	sk	174	14,9
78	40-65	sk	L	sk	490	25,0
79	40-66	sk-$AuPdCu_2$	LP	sk	200	16,0
80	40-66	sk-$AuPdCu_2$	LP	$AuPdCu_2$	81	10,2
81	40-67	vs-sk-cp	LP	vs	230	17,1
82	40-67	vs-sk-cp	LP	sk	243	17,6
83	40-68	sk-ilm	ag	sk	104	11,5
84	40-69	sk	L	sk	228	17,0
85	40-6	sk-bn	bms	sk	493	25,1
86	40-70	sk	L	sk	499	25,2
87	40-71	sk	L	sk	289	19,2
88	40-72	sk	L	sk	300	19,5
89	40-73	sk-bn	bms	sk	170	14,7
90	40-74	vs-sk-cp	bms	vs	233	17,2
91	40-74	vs-sk-cp	bms	sk	50	8,0
92	40-75	sk-bn	bms	sk	176	15,0
93	40-76	sk	L	sk	248	17,8
94	40-77	sk-bn-ch	bms-L	sk	649	28,8
95	40-78	sk-bn	bms-L	sk	336	20,7
96	40-79	sk-bn-ch	bms	sk	224	16,9
97	40-7	sk-zv	LP	sk	456	24,1
98	40-7	sk-zv	LP	zv	2	1,6
99	40-80	sk	L	sk	478	24,7
100	40-81	sk	L	sk	262	18,3
101	40-82	sk-bn	bms-L	sk	390	22,3
102	40-83	sk	L	sk	676	29,3
103	40-84	sk-ilm	ag-L	sk	733	30,6
104	40-85	sk	L	sk	835	32,6
105	40-86	sk	L	sk	848	32,9
106	40-87	sk-bn	bms-L	sk	792	31,8
107	40-88	sk-(Pd,Sn,Cu)-bn	bms-L	(Pd,Sn,Cu)	83	10,3
108	40-88	sk-(Pd,Sn,Cu)-bn	bms-L	sk	289	19,2

Table 3 continued

N	Grain	Association	Type	Mineral	Area, μm²	ECD, μm
109	40-89	sk-bn	bms-L	sk	341	20,8
110	40-9	sk	L	sk	342	20,9
111	40-90	sk	L	sk	305	19,7
112	40-91	sk	L	sk	160	14,3
113	63-10	$AuPdCu_2$-ch-chl	sag	$AuPdCu_2$	465	24,3
114	63-11	sk-bn	bms	sk	321	20,2
115	63-12	sk-bn	bms	sk	674	29,3
116	63-1	vs-bn-ch	bms	vs	373	21,8
117	63-2	sk-cp	bms	sk	303	19,6
118	63-3	sk	L	sk	455	24,1
119	63-5	sk-kth-bn	bms	sk	146	13,6
120	63-5	sk-kth-bn	bms	kth	2	1,6
121	63-6	sk	L	sk	207	16,2
122	63-7	sk	L	sk	364	21,5
123	63-9	sk-$AuPdCu_2$	LP	sk	389	22,3
124	63-9	sk-$AuPdCu_2$	LP	$AuPdCu_2$	4	2,3
125	80-1	sk	L	sk	1295	40,6
126	80-2	sk-bn-ch	bms-L	sk	1523	44,0
127	80-3	sk	L	sk	1058	36,7
128	80-4	sk-ch-bn	bms-L	sk	3898	70,5
129	80-5	sk-ch-bn	bms-L	sk	4299	74,0
130	80-6	sk	L	sk	3607	67,8
131	80-7	sk-bn-ch	bms	sk	793	31,8
132	80-8	sk	L	sk	1875	48,9
133	80-9	sk-bn-ch	bms	sk	743	30,8

Abbreviations

sk: skaergaardite; zv: zvyagintsevite; kth: keithconnite; vs: vasilite; atk: atokite; (AuPdCu2): unnamed mineral; (Pd,Sn,Cu): alloy; (AuCu) alloy; Au3Cu: unnamed mineral; (Au,Cu,Pd): alloy; bn: bornite; ch: chalcosine; cp: chalcopyrite; pn: pentlandite; copn: cobalt pentlandite; pl: plagioclase; cpx: clinopyroxene; ilm: ilmenite; chl: chlorite

Table 4. Precious metal minerals the heavy mineral concentrates of sample 90-24 1056

N	Mineral	General formula	Number of grains	Grain size, μm			Vol. %
				min	max	average	
							92.7
1	Skaergaardite	(Pd,Pt,Au)(Cu,Fe,Zn,Sn,Te,Pb)	107	2	74	24.1	2.7
2	(Au,Cu,Pd) alloys	(Au,Cu,Pd), (Au,Pd)Cu, $AuPdCu_2$ and $(Au,Pd)_3Cu$	9	2.3	26.2	13.9	1.4
3	Keithconnite	$Pd_3(Te,Pb,Sn)$	10	2	19.8	9.1	1.3
4	Vasilite	$(Pd,Cu,Fe)_{16}S_7$	4	8.4	21.8	16.1	1.3
5	Vysotskite	(Pd,Ni,Cu)S	2	15.1	28.9	20	0.4
6	Atokite	$(Pd,Cu)_3Sn$	1			18.9	0.2
7	(Pd,Sn,Cu) alloy	(Pd,Sn,Cu)	1			10.2	
8	Zvyagintsevite	$Pd_3(Pb,Te,Sn)$	In 1			2	100

Table 5. Mineral associations in grains of precious metal minerals in sample 90-24 1056

Association	PGMs, vol %, (n=107 grains)	(Au,Cu,Pd) alloys, vol. % (n=9 grains)	Presious metal mineral grains, sample total, vol. % (n=116 grains)
L	41.8	23.7	41
LP	4.5	11	4.7
bms	14.8	-	14.5
bms-L	24.5	37	24.9
sag	2.2	26,2	2.9
sag-L	4.2	-	4.1
ag	0.5	-	0.5
ag-L	7.5	2.2	7.4

L - completely liberated (free) particles; **LP** – two or more precious metal completely liberated (free) particles; bms - intergrowths with base metal sulphides (bornite, chalcosine, chalcopyrite, sometimes pentlandite, cobalt pentlandite); bms-L - liberated particles with <10 % attached base metal sulphides; sag - sulphide and gangue attached to precious metal minerals; sag-L - sulphide and gangue attached to precious metal minerals, but < 10 %; ag – precious metal minerals attached to gangue (clinopyroxene, plagioclase, ilmenite, chamosite); ag-L – precious metal minerals attached to gangue, but <10 %.

Table 6. Compositions of skaergaardite in PGM-grains of the heavy mineral concentrates of sample 90-24 1056

			Analysis (wt%)										*Proportions*									
An	Grain	Association	Pd	Pt	Au	Cu	Fe	Zn	Sn	Te	Pb	Total	*Pd*	*Pt*	*Au*	*Cu*	*Fe*	*Zn*	*Sn*	*Te*	*Pb*	*Total*
1	40 gr1	sk+ilm	57.5	0.0	7.6	28.1	2.9	4.0	0.0	0.0	0.0	100.1	*0.95*	*0.00*	*0.07*	*0.78*	*0.09*	*0.11*	*0.00*	*0.00*	*0.00*	*2.00*
2	40 gr2	sk	61.5	0.0	1.5	29.5	3.7	2.9	0.0	0.8	0.0	99.9	*0.99*	*0.00*	*0.01*	*0.80*	*0.11*	*0.08*	*0.00*	*0.01*	*0.00*	*2.00*
3	40 gr3	sk+bn	60.3	0.0	2.0	28.5	5.5	2.9	0.0	0.8	0.0	100.0	*0.97*	*0.00*	*0.02*	*0.76*	*0.17*	*0.07*	*0.00*	*0.01*	*0.00*	*2.00*
4	40 gr4	sk	58.6	1.1	4.0	27.2	4.3	3.3	0.0	1.2	0.0	99.7	*0.96*	*0.01*	*0.04*	*0.75*	*0.14*	*0.09*	*0.00*	*0.02*	*0.00*	*2.00*
5	40 gr5	sk+ilm	50.5	7.3	5.8	29.2	2.0	2.2	0.4	0.0	2.2	99.6	*0.88*	*0.07*	*0.05*	*0.85*	*0.07*	*0.06*	*0.01*	*0.00*	*0.02*	*2.00*
6	40 gr6	sk+bn	54.3	0.0	9.9	29.7	2.4	2.8	0.0	0.5	0.0	99.6	*0.91*	*0.00*	*0.09*	*0.84*	*0.08*	*0.08*	*0.00*	*0.01*	*0.00*	*2.00*
7	40 gr7	sk+zv(?)	61.6	0.0	0.0	29.1	6.3	1.1	0.0	0.0	1.6	99.7	*1.00*	*0.00*	*0.00*	*0.76*	*0.19*	*0.03*	*0.00*	*0.00*	*0.01*	*2.00*
8	40 gr8	sk	61.2	0.0	2.2	27.1	4.7	3.6	0.0	0.0	0.0	98.8	*1.00*	*0.00*	*0.02*	*0.74*	*0.15*	*0.09*	*0.00*	*0.00*	*0.00*	*2.00*
9	40 gr9	sk+bn+ch	61.6	0.0	0.9	28.6	4.4	3.7	0.0	0.0	0.0	99.2	*0.99*	*0.00*	*0.01*	*0.77*	*0.13*	*0.10*	*0.00*	*0.00*	*0.00*	*2.00*
10	40 gr10	sk	58.5	4.8	0.0	28.6	5.9	1.2	0.0	0.0	0.0	99.0	*0.96*	*0.04*	*0.00*	*0.78*	*0.18*	*0.03*	*0.00*	*0.00*	*0.00*	*2.00*
11	40 gr11	sk+ch+bn+ilm	49.3	14.3	1.2	27.4	6.0	0.7	0.0	0.7	0.0	99.6	*0.84*	*0.13*	*0.01*	*0.79*	*0.20*	*0.02*	*0.00*	*0.01*	*0.00*	*2.00*
12	40 gr12	sk	63.7	0.0	0.0	30.3	5.7	0.0	0.0	0.0	0.0	99.7	*1.02*	*0.00*	*0.00*	*0.81*	*0.17*	*0.00*	*0.00*	*0.00*	*0.00*	*2.00*
13	40 gr13	sk	53.8	10.6	0.0	27.6	5.6	1.1	0.0	0.0	0.0	98.7	*0.91*	*0.10*	*0.00*	*0.78*	*0.18*	*0.03*	*0.00*	*0.00*	*0.00*	*2.00*
14	40 gr14	sk	62.9	0.0	0.0	28.7	6.5	1.8	0.0	0.0	0.0	99.9	*1.00*	*0.00*	*0.00*	*0.76*	*0.20*	*0.04*	*0.00*	*0.00*	*0.00*	*2.00*
15	40 gr15	sk	61.8	0.0	0.9	27.9	4.8	3.0	0.4	0.0	1.1	99.9	*1.00*	*0.00*	*0.01*	*0.76*	*0.15*	*0.08*	*0.01*	*0.00*	*0.01*	*2.00*
16	40 gr16	sk+bn+cp	58.9	5.2	1.3	25.9	6.8	1.7	0.0	0.0	0.0	99.8	*0.97*	*0.05*	*0.01*	*0.71*	*0.21*	*0.05*	*0.00*	*0.00*	*0.00*	*2.00*
17	40 gr17	sk+bn+ch	61.3	0.0	0.0	28.6	4.6	3.5	0.6	0.0	0.9	99.5	*0.98*	*0.00*	*0.00*	*0.77*	*0.14*	*0.09*	*0.01*	*0.00*	*0.01*	*2.00*
18	40 gr18	sk+kth+bn	60.9	0.0	1.3	28.6	5.8	2.6	0.0	0.6	0.0	99.8	*0.97*	*0.00*	*0.01*	*0.76*	*0.18*	*0.07*	*0.00*	*0.01*	*0.00*	*2.00*
19	40 gr19	sk+pn	58.2	5.2	1.1	28.2	4.8	1.7	0.0	0.0	0.0	99.7	*0.96*	*0.05*	*0.01*	*0.78*	*0.15*	*0.05*	*0.00*	*0.00*	*0.00*	*2.00*
20	40 gr20	sk+bn	62.7	0.0	0.0	28.2	5.6	2.2	0.0	0.0	0.0	98.7	*1.01*	*0.00*	*0.00*	*0.76*	*0.17*	*0.06*	*0.00*	*0.00*	*0.00*	*2.00*
21	40 gr21	sk+bn	53.0	11.9	1.2	25.9	6.5	0.8	0.0	0.0	0.0	99.3	*0.90*	*0.11*	*0.01*	*0.74*	*0.21*	*0.02*	*0.00*	*0.00*	*0.00*	*2.00*
22	40 gr24	sk	57.4	9.0	0.0	26.3	5.1	1.4	0.0	0.0	0.0	99.3	*0.97*	*0.08*	*0.00*	*0.74*	*0.16*	*0.04*	*0.00*	*0.00*	*0.00*	*2.00*
23	40 gr25	sk	52.7	12.4	2.2	24.0	5.5	0.9	0.0	1.3	0.0	99.0	*0.93*	*0.12*	*0.02*	*0.71*	*0.18*	*0.02*	*0.00*	*0.02*	*0.00*	*2.00*
24	40 gr25	sk+cp+cpx	62.4	0.9	0.0	28.3	6.9	0.3	0.0	0.0	0.0	98.8	*1.01*	*0.01*	*0.00*	*0.76*	*0.21*	*0.01*	*0.00*	*0.00*	*0.00*	*2.00*
25	40 gr28	sk+kth+vs+ilm	49.8	11.2	3.6	27.2	3.2	2.0	0.7	0.5	1.2	99.4	*0.87*	*0.11*	*0.03*	*0.80*	*0.11*	*0.06*	*0.01*	*0.01*	*0.01*	*2.00*
26	40 gr29	sk+bn+ch	61.9	0.0	0.9	29.6	4.8	2.3	0.0	0.0	0.0	99.5	*0.99*	*0.00*	*0.01*	*0.79*	*0.15*	*0.06*	*0.00*	*0.00*	*0.00*	*2.00*
27	40 gr30	sk	61.9	1.6	0.0	28.3	5.0	2.4	0.0	0.0	0.0	99.2	*1.00*	*0.01*	*0.00*	*0.77*	*0.16*	*0.06*	*0.00*	*0.00*	*0.00*	*2.00*
28	40 gr31	sk	61.8	0.9	2.1	28.1	5.1	1.3	0.0	0.5	0.0	99.8	*1.00*	*0.01*	*0.02*	*0.77*	*0.16*	*0.04*	*0.00*	*0.01*	*0.00*	*2.00*
29	40 gr32	sk+atk	57.7	1.2	4.3	28.1	3.9	1.3	2.8	0.0	0.0	99.3	*0.96*	*0.01*	*0.04*	*0.79*	*0.12*	*0.04*	*0.04*	*0.00*	*0.00*	*2.00*
30	40 gr33	sk	54.9	9.0	0.0	27.6	6.0	0.9	0.0	0.0	0.0	98.4	*0.92*	*0.08*	*0.00*	*0.78*	*0.19*	*0.03*	*0.00*	*0.00*	*0.00*	*2.00*
31	40 gr34	sk	63.0	0.0	1.2	29.0	5.9	0.0	0.0	0.0	0.0	99.1	*1.02*	*0.00*	*0.01*	*0.79*	*0.18*	*0.00*	*0.00*	*0.00*	*0.00*	*2.00*
32	40 gr35	sk	51.2	14.0	0.0	26.2	5.4	1.6	0.0	0.0	0.0	98.4	*0.88*	*0.13*	*0.00*	*0.76*	*0.18*	*0.05*	*0.00*	*0.00*	*0.00*	*2.00*
33	40 gr36	sk	45.5	19.2	1.1	26.7	5.6	0.8	0.0	0.0	0.0	98.9	*0.80*	*0.18*	*0.01*	*0.79*	*0.19*	*0.02*	*0.00*	*0.00*	*0.00*	*2.00*
34	40 gr38	sk	60.2	1.0	2.4	29.3	5.6	0.5	0.0	0.5	0.0	99.5	*0.98*	*0.01*	*0.02*	*0.80*	*0.17*	*0.01*	*0.00*	*0.01*	*0.00*	*2.00*

Abbreviations: sk: skaergaardite; zv: zvyagintsevite; kth: keithconnite; vs: vasilite; atk: atokite; ($AuPdCu_2$): unnamed mineral; (Pd,Sn,Cu): alloy; bn: bornite; ch: chalcosine; cp: chalcopyrite; pn: pentlandite; pl: plagioclase; cpx: clinopyroxene; ilm: ilmenite

Table 6 continued

An	Grain	Association	Analysis (wt%) Pd	Pt	Au	Cu	Fe	Zn	Sn	Te	Pb	Total	*Proportions* *Pd*	*Pt*	*Au*	*Cu*	*Fe*	*Zn*	*Sn*	*Te*	*Pb*	*Total*
35	40 gr39	sk+bn	53.2	10.4	1.7	26.9	6.6	0.7	0.0	0.0	0.0	99.5	*0.90*	*0.10*	*0.02*	*0.75*	*0.21*	*0.02*	*0.00*	*0.00*	*0.00*	*2.00*
36	40 gr40	sk+bn+cp	61.4	0.0	1.5	28.2	3.8	4.9	0.0	0.0	0.0	99.8	*0.98*	*0.00*	*0.01*	*0.76*	*0.12*	*0.13*	*0.00*	*0.00*	*0.00*	*2.00*
37	40 gr41	sk+bn	59.6	0.0	3.4	28.7	3.6	3.4	0.0	0.5	0.0	99.2	*0.98*	*0.00*	*0.03*	*0.78*	*0.11*	*0.09*	*0.00*	*0.01*	*0.00*	*2.00*
38	40 gr42	sk	53.0	11.8	1.1	26.4	6.3	1.3	0.0	0.0	0.0	99.9	*0.89*	*0.11*	*0.01*	*0.75*	*0.20*	*0.04*	*0.00*	*0.00*	*0.00*	*2.00*
39	40 gr43	sk	58.3	5.8	0.0	28.2	3.9	2.0	0.5	0.0	0.0	98.7	*0.98*	*0.05*	*0.00*	*0.79*	*0.12*	*0.05*	*0.01*	*0.00*	*0.00*	*2.00*
40	40 gr45	sk+kth+pl	50.3	1.4	12.1	30.5	2.9	0.5	0.0	1.3	0.0	99.0	*0.87*	*0.01*	*0.11*	*0.88*	*0.10*	*0.01*	*0.00*	*0.02*	*0.00*	*2.00*
41	40 gr47	sk+kth+bn	48.0	17.0	0.0	26.4	7.4	0.6	0.0	0.0	0.0	99.4	*0.82*	*0.16*	*0.00*	*0.76*	*0.24*	*0.02*	*0.00*	*0.00*	*0.00*	*2.00*
42	40 gr48	sk	50.1	11.6	4.0	25.4	6.5	1.0	0.0	0.0	0.0	99.2	*0.87*	*0.11*	*0.04*	*0.74*	*0.21*	*0.03*	*0.00*	*0.01*	*0.00*	*2.00*
43	40 gr49	sk	59.8	0.0	3.4	28.0	3.6	3.8	0.0	0.7	0.0	99.3	*0.99*	*0.00*	*0.03*	*0.78*	*0.11*	*0.08*	*0.00*	*0.01*	*0.00*	*2.00*
44	40 gr50	sk+bn	61.4	0.0	1.0	28.1	5.0	2.9	0.0	0.0	0.0	98.4	*0.99*	*0.00*	*0.01*	*0.76*	*0.16*	*0.08*	*0.00*	*0.00*	*0.00*	*2.00*
45	40 gr51	sk+bn	51.5	11.4	0.0	27.4	6.8	1.2	0.6	0.0	0.0	98.9	*0.86*	*0.10*	*0.00*	*0.77*	*0.22*	*0.03*	*0.01*	*0.00*	*0.00*	*2.00*
46	40 gr52	sk+AuPdCu$_2$	43.1	2.9	19.5	31.1	1.9	0.4	0.0	1.1	0.0	100.0	*0.77*	*0.03*	*0.19*	*0.93*	*0.06*	*0.01*	*0.00*	*0.02*	*0.00*	*2.00*
47	40 gr54	sk	53.4	11.2	0.0	28.0	5.9	0.5	0.0	0.0	0.9	99.9	*0.90*	*0.10*	*0.00*	*0.79*	*0.19*	*0.01*	*0.00*	*0.00*	*0.01*	*2.00*
48	40 gr55	sk	63.2	0.0	0.0	29.6	6.0	0.7	0.0	0.0	0.0	99.5	*1.01*	*0.00*	*0.00*	*0.79*	*0.18*	*0.02*	*0.00*	*0.00*	*0.00*	*2.00*
49	40 gr57	sk+bn	52.7	10.6	0.8	27.0	6.4	0.9	0.0	0.5	0.9	99.8	*0.88*	*0.10*	*0.01*	*0.77*	*0.20*	*0.03*	*0.00*	*0.01*	*0.01*	*2.00*
50	40 gr58	sk+bn+ilm	59.6	0.0	3.4	27.7	2.9	5.7	0.0	0.0	0.0	99.3	*0.97*	*0.00*	*0.03*	*0.76*	*0.09*	*0.15*	*0.00*	*0.00*	*0.00*	*2.00*
51	40 gr59	sk	56.6	5.4	1.9	29.2	6.0	0.6	0.0	0.0	0.0	99.7	*0.93*	*0.05*	*0.02*	*0.80*	*0.19*	*0.02*	*0.00*	*0.00*	*0.00*	*2.00*
52	40 gr60	sk+bn	54.0	8.9	0.0	29.9	5.3	1.1	0.0	0.9	0.0	100.1	*0.89*	*0.07*	*0.00*	*0.83*	*0.16*	*0.03*	*0.00*	*0.01*	*0.00*	*2.00*
53	40 gr61	sk	60.2	0.0	3.4	29.0	3.2	3.2	0.0	0.8	0.0	99.8	*0.98*	*0.00*	*0.03*	*0.79*	*0.10*	*0.08*	*0.00*	*0.01*	*0.00*	*2.00*
54	40 gr62	sk	50.1	14.1	0.0	27.5	5.9	0.6	0.0	0.9	0.0	99.1	*0.86*	*0.13*	*0.00*	*0.79*	*0.19*	*0.02*	*0.00*	*0.01*	*0.00*	*2.00*
55	40 gr63	sk+bn+ch	53.3	9.4	0.0	29.1	4.1	2.0	0.0	0.0	1.0	98.9	*0.90*	*0.09*	*0.00*	*0.82*	*0.13*	*0.05*	*0.00*	*0.00*	*0.01*	*2.00*
56	40 gr64	sk+bn+ch	38.0	4.3	23.8	30.9	1.6	0.0	0.0	1.0	0.0	99.6	*0.70*	*0.04*	*0.24*	*0.95*	*0.06*	*0.00*	*0.00*	*0.02*	*0.00*	*2.00*
57	40 gr65	sk	58.7	2.8	2.8	26.8	5.3	2.7	0.0	0.0	0.0	99.1	*0.97*	*0.03*	*0.03*	*0.74*	*0.17*	*0.07*	*0.00*	*0.00*	*0.00*	*2.00*
58	40 gr67	sk+vs+cp	43.7	3.1	20.2	28.1	1.2	1.3	0.0	0.0	1.0	98.6	*0.81*	*0.03*	*0.20*	*0.87*	*0.04*	*0.04*	*0.00*	*0.00*	*0.01*	*2.00*
59	40 gr66	sk+AuPdCu$_2$	45.0	3.6	19.4	28.6	1.1	1.6	0.0	0.0	0.0	99.3	*0.82*	*0.04*	*0.18*	*0.87*	*0.04*	*0.05*	*0.00*	*0.00*	*0.00*	*2.00*
60	40 gr68	sk+ilm	53.6	9.9	0.9	26.6	7.4	0.8	0.0	0.0	0.0	99.2	*0.90*	*0.09*	*0.01*	*0.75*	*0.24*	*0.02*	*0.00*	*0.00*	*0.00*	*2.00*
61	40 gr69	sk	53.8	10.1	1.0	25.7	7.5	1.0	0.0	0.0	0.0	99.1	*0.91*	*0.09*	*0.01*	*0.72*	*0.24*	*0.03*	*0.00*	*0.00*	*0.00*	*2.00*
62	40 gr70	sk	51.2	13.5	1.2	26.6	4.9	1.2	0.9	0.5	0.0	100.0	*0.88*	*0.13*	*0.01*	*0.77*	*0.16*	*0.03*	*0.01*	*0.01*	*0.00*	*2.00*
63	40 gr71	sk	50.8	13.6	1.4	26.0	6.4	1.3	0.0	0.0	0.0	99.5	*0.87*	*0.13*	*0.01*	*0.74*	*0.21*	*0.03*	*0.00*	*0.00*	*0.00*	*2.00*
64	40 gr72	sk	62.2	0.0	0.0	29.9	5.6	0.6	0.0	0.0	0.0	98.8	*1.00*	*0.00*	*0.00*	*0.82*	*0.17*	*0.01*	*0.00*	*0.00*	*0.00*	*2.00*
65	40 gr73	sk+bn	58.6	2.8	1.9	27.7	4.2	1.4	0.0	1.0	1.9	99.5	*0.98*	*0.03*	*0.02*	*0.77*	*0.13*	*0.04*	*0.00*	*0.01*	*0.02*	*2.00*
66	40 gr74	sk+vs+cp	46.6	5.3	15.5	29.5	1.0	1.2	0.0	0.0	0.0	99.1	*0.84*	*0.05*	*0.15*	*0.90*	*0.03*	*0.03*	*0.00*	*0.00*	*0.00*	*2.00*
67	40 gr75	sk+bn	53.1	12.8	0.0	26.1	6.1	0.9	0.5	0.0	0.0	99.5	*0.91*	*0.12*	*0.00*	*0.74*	*0.20*	*0.03*	*0.01*	*0.00*	*0.00*	*2.00*
68	40 gr76	sk	54.3	5.5	4.6	27.9	3.4	1.6	0.0	0.5	2.1	99.9	*0.93*	*0.05*	*0.04*	*0.80*	*0.11*	*0.04*	*0.00*	*0.01*	*0.02*	*2.00*
69	40 gr77	sk+bn+ch	57.6	4.8	1.4	29.3	5.2	0.0	0.0	1.1	0.0	99.4	*0.95*	*0.04*	*0.01*	*0.81*	*0.16*	*0.00*	*0.00*	*0.02*	*0.00*	*2.00*
70	40 gr78	sk	59.7	0.0	1.9	30.9	4.5	0.6	0.0	1.7	0.0	99.3	*0.97*	*0.00*	*0.02*	*0.84*	*0.14*	*0.01*	*0.00*	*0.02*	*0.00*	*2.00*
71	40 gr79	sk+bn+ch	48.9	15.8	0.0	26.5	6.7	0.8	0.0	0.0	0.0	98.7	*0.84*	*0.15*	*0.00*	*0.77*	*0.22*	*0.02*	*0.00*	*0.00*	*0.00*	*2.00*
72	40 gr80	sk	55.5	2.8	3.9	30.5	3.4	0.6	0.0	3.0	0.0	99.7	*0.92*	*0.03*	*0.03*	*0.85*	*0.11*	*0.02*	*0.00*	*0.04*	*0.00*	*2.00*

Table 6 continued

An	Grain	Association	Analysis (wt%) Pd	Pt	Au	Cu	Fe	Zn	Sn	Te	Pb	Total	*Proportions* *Pd*	*Pt*	*Au*	*Cu*	*Fe*	*Zn*	*Sn*	*Te*	*Pb*	*Total*
73	40 gr81	sk	60.3	0.0	1.5	29.0	5.2	2.9	0.0	0.7	0.0	99.6	*0.96*	*0.00*	*0.01*	*0.78*	*0.16*	*0.08*	*0.00*	*0.01*	*0.00*	*2.00*
74	40 gr82	sk+bn	61.7	0.0	1.1	29.5	6.4	0.4	0.0	0.0	0.0	99.1	*0.99*	*0.00*	*0.01*	*0.80*	*0.19*	*0.01*	*0.00*	*0.00*	*0.00*	*2.00*
75	40 gr83	sk	61.6	0.0	0.0	28.2	3.9	1.6	2.9	0.0	0.0	98.2	*1.01*	*0.00*	*0.00*	*0.78*	*0.12*	*0.04*	*0.04*	*0.00*	*0.00*	*2.00*
76	40 gr84	sk+ilm	42.4	0.0	22.0	31.7	1.0	1.7	0.0	0.7	0.0	99.5	*0.75*	*0.00*	*0.21*	*0.94*	*0.03*	*0.05*	*0.00*	*0.01*	*0.00*	*2.00*
77	40 gr85	sk	61.8	0.0	0.0	29.1	5.8	1.9	0.0	0.0	0.8	99.4	*0.99*	*0.00*	*0.00*	*0.78*	*0.18*	*0.05*	*0.00*	*0.00*	*0.01*	*2.00*
78	40 gr86	sk	62.3	0.0	0.0	27.9	6.3	2.9	0.0	0.0	0.0	99.4	*0.99*	*0.00*	*0.00*	*0.74*	*0.19*	*0.08*	*0.00*	*0.00*	*0.00*	*2.00*
79	40 gr87	sk+bn	61.3	0.0	0.0	30.1	4.4	2.3	0.0	0.0	0.0	98.1	*0.99*	*0.00*	*0.00*	*0.81*	*0.14*	*0.06*	*0.00*	*0.00*	*0.00*	*2.00*
80	40 gr88	sk+(Pd,Sn,Cu)+bn	61.2	0.0	0.0	28.3	3.7	1.1	4.0	0.0	0.0	98.3	*1.01*	*0.00*	*0.00*	*0.78*	*0.12*	*0.03*	*0.06*	*0.00*	*0.00*	*2.00*
81	40 gr89	sk+bn	61.2	0.0	1.7	29.0	3.9	2.9	0.0	0.7	0.0	99.4	*0.99*	*0.00*	*0.02*	*0.79*	*0.12*	*0.08*	*0.00*	*0.01*	*0.00*	*2.00*
82	40 gr90	sk	59.8	0.0	2.9	28.7	4.8	2.3	0.0	0.7	0.0	99.2	*0.98*	*0.00*	*0.03*	*0.78*	*0.15*	*0.06*	*0.00*	*0.01*	*0.00*	*2.00*
83	40 gr91	sk	59.1	5.6	1.4	25.5	6.3	2.0	0.0	0.0	0.0	99.9	*0.98*	*0.05*	*0.01*	*0.71*	*0.20*	*0.05*	*0.00*	*0.01*	*0.00*	*2.00*
84	80 gr1	sk	62.5	0.0	0.0	29.3	6.6	0.0	0.0	0.0	0.0	98.4	*1.01*	*0.00*	*0.00*	*0.79*	*0.20*	*0.00*	*0.00*	*0.00*	*0.00*	*2.00*
85	80 gr2	sk+bn+ch	63.7	0.0	0.0	28.6	5.6	1.8	0.0	0.0	0.0	99.7	*1.02*	*0.00*	*0.00*	*0.76*	*0.17*	*0.05*	*0.00*	*0.00*	*0.00*	*2.00*
86	80 gr3	sk	59.9	0.0	0.0	29.7	3.5	1.3	1.7	0.9	1.7	98.7	*0.98*	*0.00*	*0.00*	*0.82*	*0.11*	*0.04*	*0.03*	*0.01*	*0.01*	*2.00*
87	80 gr4	sk+bn+ch	61.8	0.0	0.0	31.1	6.2	0.5	0.0	0.0	0.0	99.6	*0.98*	*0.00*	*0.00*	*0.82*	*0.19*	*0.01*	*0.00*	*0.00*	*0.00*	*2.00*
88	80 gr5	sk+bn+ch	61.4	0.0	0.0	28.9	6.4	1.3	0.5	0.5	0.0	99.0	*0.98*	*0.00*	*0.00*	*0.77*	*0.19*	*0.03*	*0.01*	*0.01*	*0.00*	*2.00*
89	80 gr6	sk	63.0	0.0	0.0	27.9	6.8	0.7	0.0	0.0	0.9	99.3	*1.01*	*0.00*	*0.00*	*0.75*	*0.21*	*0.02*	*0.00*	*0.00*	*0.10*	*2.00*
90	80 gr7	sk+bn+ch	59.6	0.0	3.1	28.8	4.6	2.7	0.0	1.0	0.0	99.8	*0.97*	*0.00*	*0.03*	*0.78*	*0.14*	*0.07*	*0.00*	*0.01*	*0.00*	*2.00*
91	80 gr8	sk	62.2	0.0	0.0	28.7	5.5	1.6	1.1	0.0	0.0	99.1	*1.00*	*0.00*	*0.00*	*0.77*	*0.17*	*0.04*	*0.02*	*0.00*	*0.00*	*2.00*
92	80 gr9	sk+bn+ch	59.2	3.2	0.0	29.9	4.8	1.2	0.0	0.0	1.3	99.6	*0.97*	*0.03*	*0.00*	*0.81*	*0.15*	*0.03*	*0.00*	*0.00*	*0.01*	*2.00*
93	125 gr1	sk+bn+ch	58.2	0.0	4.7	30.3	3.2	2.1	0.0	1.3	0.0	99.8	*0.95*	*0.00*	*0.04*	*0.83*	*0.10*	*0.06*	*0.00*	*0.02*	*0.00*	*2.00*
94	125 gr2	sk+ilm	61.9	0.0	0.0	28.4	5.6	2.4	0.7	0.0	0.0	99.0	*0.99*	*0.00*	*0.00*	*0.76*	*0.17*	*0.06*	*0.01*	*0.00*	*0.00*	*2.00*
95	125 gr4	sk	63.3	0.0	0.0	27.3	5.9	2.6	0.0	0.0	0.0	99.1	*1.02*	*0.00*	*0.00*	*0.73*	*0.18*	*0.07*	*0.00*	*0.00*	*0.00*	*2.00*
96	125 gr6	sk+bn+copn	62.7	0.0	0.0	29.1	5.6	1.9	0.0	0.0	0.0	99.3	*1.00*	*0.00*	*0.00*	*0.78*	*0.17*	*0.05*	*0.00*	*0.00*	*0.00*	*2.00*
97	63 gr2	sk+cp	58.9	3.5	1.0	28.6	4.7	1.5	0.0	1.1	0.0	99.3	*0.97*	*0.01*	*0.03*	*0.79*	*0.15*	*0.04*	*0.00*	*0.02*	*0.00*	*2.00*
98	63 gr3	sk	63.6	0.0	0.0	28.4	6.5	0.5	0.0	0.0	0.0	99.0	*1.02*	*0.00*	*0.00*	*0.77*	*0.20*	*0.01*	*0.00*	*0.00*	*0.00*	*2.00*
99	63 gr5	sk+kth+bn	49.7	14.3	0.0	27.1	5.9	0.9	0.0	0.0	1.5	99.4	*0.85*	*0.13*	*0.00*	*0.78*	*0.19*	*0.03*	*0.00*	*0.00*	*0.01*	*2.00*
100	63 gr6	sk	61.9	0.0	0.0	28.9	7.8	0.6	0.0	0.0	0.0	99.2	*0.98*	*0.00*	*0.00*	*0.77*	*0.24*	*0.02*	*0.00*	*0.00*	*0.00*	*2.00*
101	63 gr7	sk	51.5	13.7	0.0	26.5	6.5	0.8	0.0	0.0	0.0	99.0	*0.88*	*0.13*	*0.00*	*0.76*	*0.21*	*0.02*	*0.00*	*0.00*	*0.00*	*2.00*
102	63 gr8	sk	63.3	0.0	0.0	28.2	6.7	0.3	0.0	0.0	0.0	98.5	*1.03*	*0.00*	*0.00*	*0.76*	*0.20*	*0.01*	*0.00*	*0.00*	*0.00*	*2.00*
103	63 gr11	sk+bn	47.6	15.3	2.5	26.3	6.0	0.8	0.0	0.0	1.0	99.5	*0.83*	*0.15*	*0.02*	*0.77*	*0.20*	*0.02*	*0.00*	*0.00*	*0.01*	*2.00*
104	63 gr12	sk+bn	61.1	0.0	1.9	29.6	3.7	2.9	0.0	0.8	0.0	100.0	*0.98*	*0.00*	*0.02*	*0.80*	*0.11*	*0.08*	*0.00*	*0.01*	*0.00*	*2.00*

Table 7. **Compositions of the Au-minerals tetra-auricupride, unnamed AuPdCu2, Au3Cu alloy, and (Au,Cu,Pd) in the grains of precious metal mineral in the heavy concentrates of sample 90-24 1056**

				Analysis (wt%)							***proportions***						
An	**Grain**	**Association**	**Mineral**	**Au**	**Pd**	**Pt**	**Cu**	**Fe**	**Te**	**Total**	***Au***	***Pd***	***Pt***	***Cu***	***Fe***	***Te***	***Total***
1	40 gr 22	AuCu+(Au,Cu,Pd)	AuCu	58,9	16,8	0,0	23,2	0,6	0,0	99,5	*0,72*	*0,38*	*0,00*	*0,88*	*0,03*	*0,00*	*2,00*
2	40 gr 22	AuCu+(Au,Cu,Pd)	(Au,Cu,Pd)	66,3	16,4	0,0	15,4	0,6	0,0	98,7	*0,45*	*0,21*	*0,00*	*0,33*	*0,01*	*0,00*	*1,00*
3	40 gr27	kth+AuCu+Au_3Cu+cp	AuCu	52,3	21,7	0,0	25,4	0,7	0,0	100,1	*0,60*	*0,46*	*0,00*	*0,91*	*0,03*	*0,00*	*2,00*
4	40 gr27	kth+AuCu+Au_3Cu+cp	Au3Cu	64,9	22,6	0,0	11,9	0,0	0,0	99,4	*1,81*	*1,17*	*0,00*	*1,03*	*0,00*	*0,00*	*4,00*
5	40 gr52	sk+$AuPdCu_2$	$AuPdCu_2$	41,4	26,4	0,0	28,9	0,8	1,7	99,2	*0,89*	*1,06*	*0,00*	*1,93*	*0,06*	*0,06*	*4,00*
6	40 gr53	$AuPdCu_2$	$AuPdCu_2$	45,1	24,4	0,0	28,6	0,9	0,8	99,8	*0,98*	*0,98*	*0,00*	*1,93*	*0,07*	*0,03*	*4,00*
7	40 gr67	sk+$AuPdCu_2$	$AuPdCu_2$	47,2	25,1	0,0	26,0	1,2	0,0	99,5	*1,06*	*1,04*	*0,00*	*1,81*	*0,10*	*0,00*	*4,00*
8	63 gr 9	sk+$AuPdCu_2$	$AuPdCu_2$	45,0	25,6	0,0	26,7	0,8	1,0	99,1	*1,00*	*1,06*	*0,00*	*1,85*	*0,06*	*0,03*	*4,00*
9	63 gr10	$AuPdCu_2$+ch	$AuPdCu_2$	47,5	22,9	3,2	24,5	0,4	0,0	98,5	*1,11*	*1,00*	*0,08*	*1,78*	*0,03*	*0,00*	*4,00*
10	-	-	average	52,1	22,4	0,4	23,4	0,7	0,4	99,4	-	-	-	-	-	-	-

Abbreviations: AuCu: auricupride-like alloy; (Au,Cu,Pd): alloy; kth: keithconnite; ch: chalcosine; cp: chalcopyrite; sk: skaergaardite; $AuPdCu_2$: unnamed mineral.

Table 8. Composition of keithconnite (1-7), vasilite (2-12), vysotskite (13, 14), atokite (15), (Pd,Te,Sn,Pb) alloy (8) and (Pd,Sn,Cu) alloy (16) in the heavy mineral concentrates of sample 90-24 1056

mineral	keithconnite							(Pd,Te,Sn,Pb)	vasilite			
Grain	40 gr18	40 gr23	40 gr27	40 gr28	40 gr44	40 gr45	40 gr56	40 gr46	40 gr28	40 gr63	40 gr74	63 gr1
Association	sk+kth+bn	kth?	kth+AuCu +Au3Cu +cp	sk+kth +vs+ilm	kth	sk+kth +pl	kth+ilm +cpx	(Pd,Te,Sn,Pb)	sk+kth +vs+ilm	sk+vs +cp	sk+vs +cp	vs+bn +chl
Analysis	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
wt%												
Pd	68.2	70.6	71.1	68.8	69.9	67.8	68.5	77.1	72.4	74.2	72.4	71.8
Pt	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.7	0.0	0.0	0.0
Au	0.0	0.0	1.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cu	2.7	1.5	0.5	0.5	0.0	1.3	0.0	0.5	11.7	12.0	14.3	13.6
Fe	1.10	0.80	0.00	0.00	1.00	0.60	0.70	0.50	0.60	0.00	0.70	0.50
Ni	-	-	-	-	-	-	-	-	-	-	-	-
Te	24.8	14.6	14.6	25.3	27.2	28.9	27.6	6.1	0.0	0.0	0.0	0.0
Sn	2.0	3.4	6.0	2.3	1.1	0.0	3.0	5.6	0.0	0.0	0.0	0.0
Pb	3.0	8.0	6.0	0.0	0.0	0.9	0.0	9.0	0.0	0.0	0.0	0.0
S	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.6	12.5	12.6	12.4
Total	99.5	98.9	99.2	99.8	99.2	99.5	99.8	98.8	99.0	98.7	100.0	98.3
Atomic proportions												
Pd	2.81	3.00	3.06	2.91	2.92	2.83	2.87	0.82	12.25	12.57	11.93	12.08
Pt	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00
Au	0.00	0.00	0.02	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cu	0.19	0.11	0.03	0.04	0.00	0.09	0.00	0.01	3.32	3.41	3.95	3.83
Fe	0.09	0.07	0.00	0.00	0.08	0.05	0.06	0.01	0.19	0.00	0.22	0.16
Ni	-	-	-	-	-	-	-	-	-	-	-	-
Te	0.85	0.52	0.52	0.89	0.95	1.01	0.96	0.05	0.00	0.00	0.00	0.00
Sn	0.02	0.13	0.23	0.09	0.04	0.00	0.11	0.05	0.00	0.00	0.00	0.00
Pb	0.04	0.17	0.13	0.00	0.00	0.02	0.00	0.05	0.00	0.00	0.00	0.00
S	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.08	7.02	6.90	6.92
Total	4.00	4.00	4.00	4.00	4.00	4.00	4.00	1.00	23.00	23.00	23.00	23.00

Abbreviations: sk: skaergaardite; kth: keithconnite; bn: bornite, AuCu: alloy; Au_3Cu: unnamed mineral,; cp: cahalcopyrite; vs: vasilite; ilm: ilmenite; pl: plagioclase; cpx: clinopyroxene; (Pd,Te,Sn,Pb): alloy; chl: chlorite; vys: vysotskite; pn: pentlandite; atk: atokite; (Pd,Sn,Cu): alloy

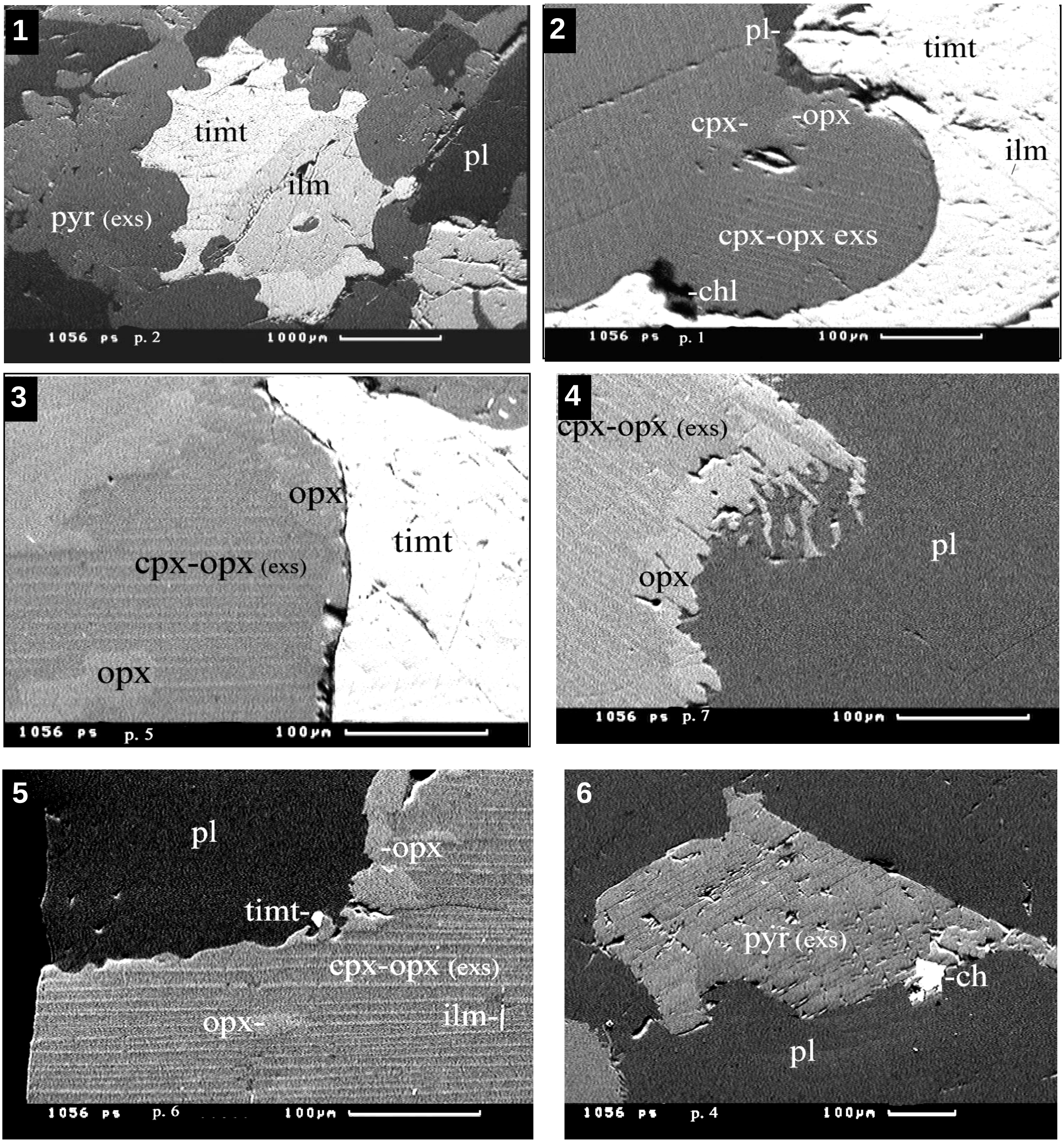
Table 8 continued

Mineral	vasilite				vysotskite		atokite	(Pd,Sn,Cu)
Grain	40 gr28	40 gr63	40 gr74	63 gr1	125 gr3	125 gr5	40 gr32	40 gr88
Association	sk+kth +vs+ilm	sk+vs +cp	sk+vs +cp	vs+bn +chl	vys+bn +pn+chl	vys+bn +chl	sk+atk atk	(Pd,Sn,Cu) +sk+bn
Analysis	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
wt%								
Pd	72.4	74.2	72.4	71.8	74.7	69.3	71.4	66.4
Pt	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Au	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cu	11.7	12.0	14.3	13.6	1.6	0.6	1.8	9.6
Fe	0.60	0.00	0.70	0.50	0.60	0.00	0.00	0.00
Ni	-	-	-	-	0.40	5.70	nd	nd
Te	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
Sn	0.0	0.0	0.0	0.0	0.0	0.0	25.3	21.7
Pb	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S	12.6	12.5	12.6	12.4	22.7	23.9	0.0	0.0
Total	99.0	98.7	100.0	98.3	100.0	99.5	98.5	98.3
Atomic proportions								
Pd	12.25	12.57	11.93	12.08	0.97	0.87	2.94	0.65
Pt	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Au	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cu	3.32	3.41	3.95	3.83	0.03	0.01	0.13	0.16
Fe	0.19	0.00	0.22	0.16	0.01	0.00	0.00	0.00
Ni	-	-	-	-	0.01	0.13	nd	nd
Te	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Sn	0.00	0.00	0.00	0.00	0.00	0.00	0.93	0.19
Pb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S	7.08	7.02	6.90	6.92	0.97	0.99	0.00	0.00
Total	23.00	23.00	23.00	23.00	2.00	2.00	4.00	1.00

Abbreviations: sk: skaergaardite; kth: keithconnite; bn: bornite, AuCu: alloy; Au_3Cu: unnamed mineral,; cp: cahalcopyrite; vs: vasilite; ilm: ilmenite; pl: plagioclase; cpx: clinopyroxene; (Pd,Te,Sn,Pb): alloy; chl: chlorite; vys: vysotskite; pn: pentlandite; atk: atokite; (Pd,Sn,Cu): alloy

PLATES

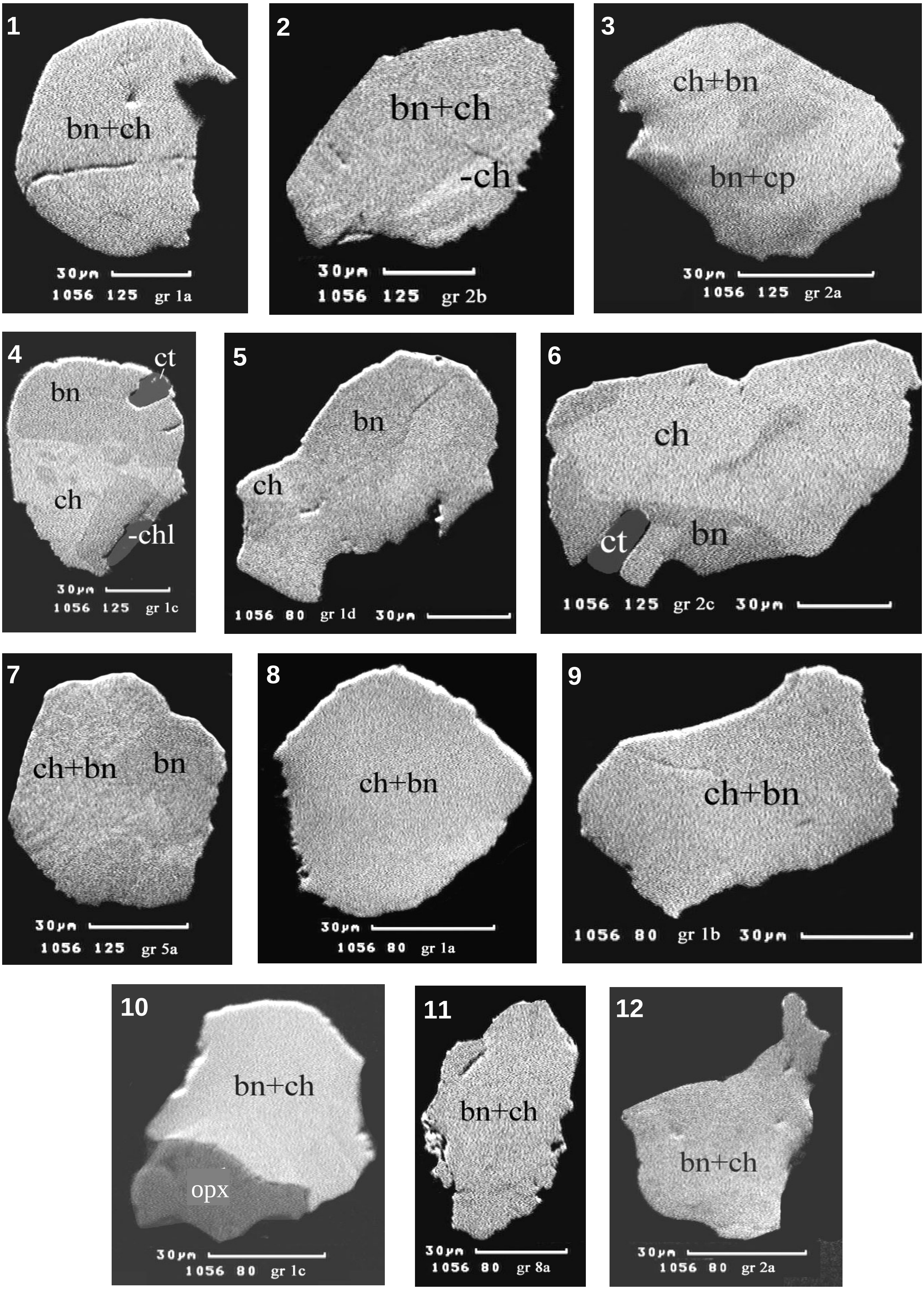
Plate 1

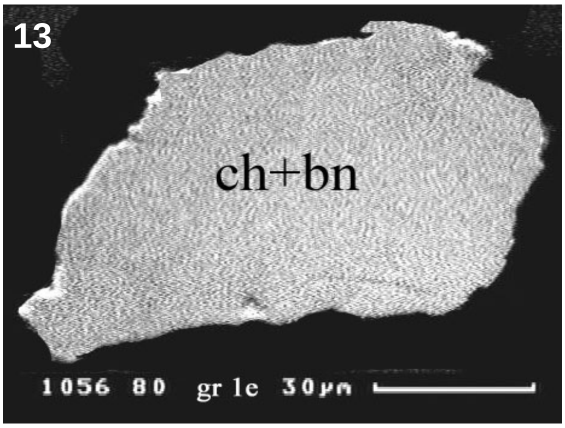


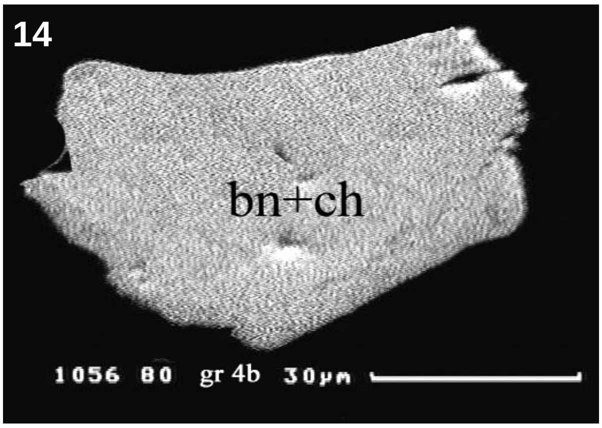
Relationsips of rock-forming minerals, Fe-Ti oxides and sulphides in sample 90-24 1056; polished section, SEM-image (BIE). Abbreviations: Pl: plagioclase, pyr (exs): pyroxene exsolution grains; ilm: ilmenite; timt: totanomagnetite; chl: chlorite; ch: chalcosine

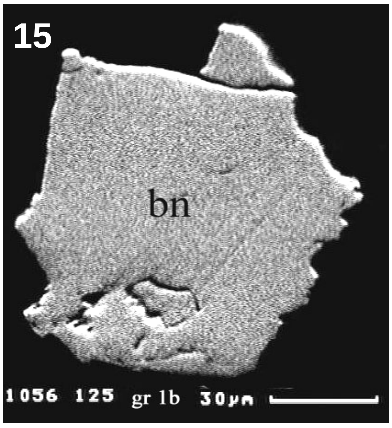
Plate 2

Sulphide globules in the heavy mineral concentrates of sample 90-24 1056 polished section; SEM-image (BIE). Abbreviations:bn: bornite; ch: chalcosine; cp: chalcopyrite; opx: orthopyroxene and ct: calcite.


1
bn+ch
30μm
1056 125 gr 1a
2
bn+ch
-ch
30μm
1056 125 gr 2b
3
ch+bn
bn+cp
30μm
1056 125 gr 2a
4
ct
bn
ch
-chl
30μm
1056 125 gr 1c
5
bn
ch
1056 80 gr 1d 30μm
6
ch
ct
bn
1056 125 gr 2c 30μm
7
ch+bn
bn
30μm
1056 125 gr 5a
8
ch+bn
30μm
1056 80 gr 1a
9
ch+bn
1056 80 gr 1b 30μm
10
bn+ch
opx
30μm
1056 80 gr 1c
11
bn+ch
30μm
1056 80 gr 8a
12
bn+ch
30μm
1056 80 gr 2a


13
ch+bn
1056 80 gr 1e 30μm


14
bn+ch
1056 80 gr 4b 30μm


15
bn
1056 125 gr 1b 30μm

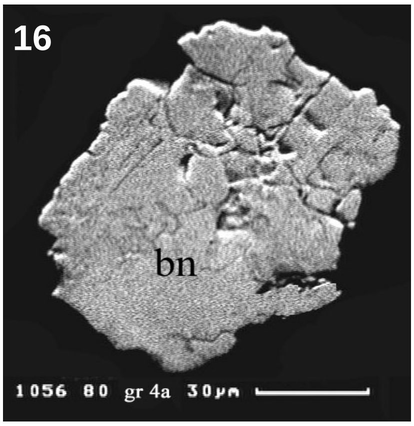
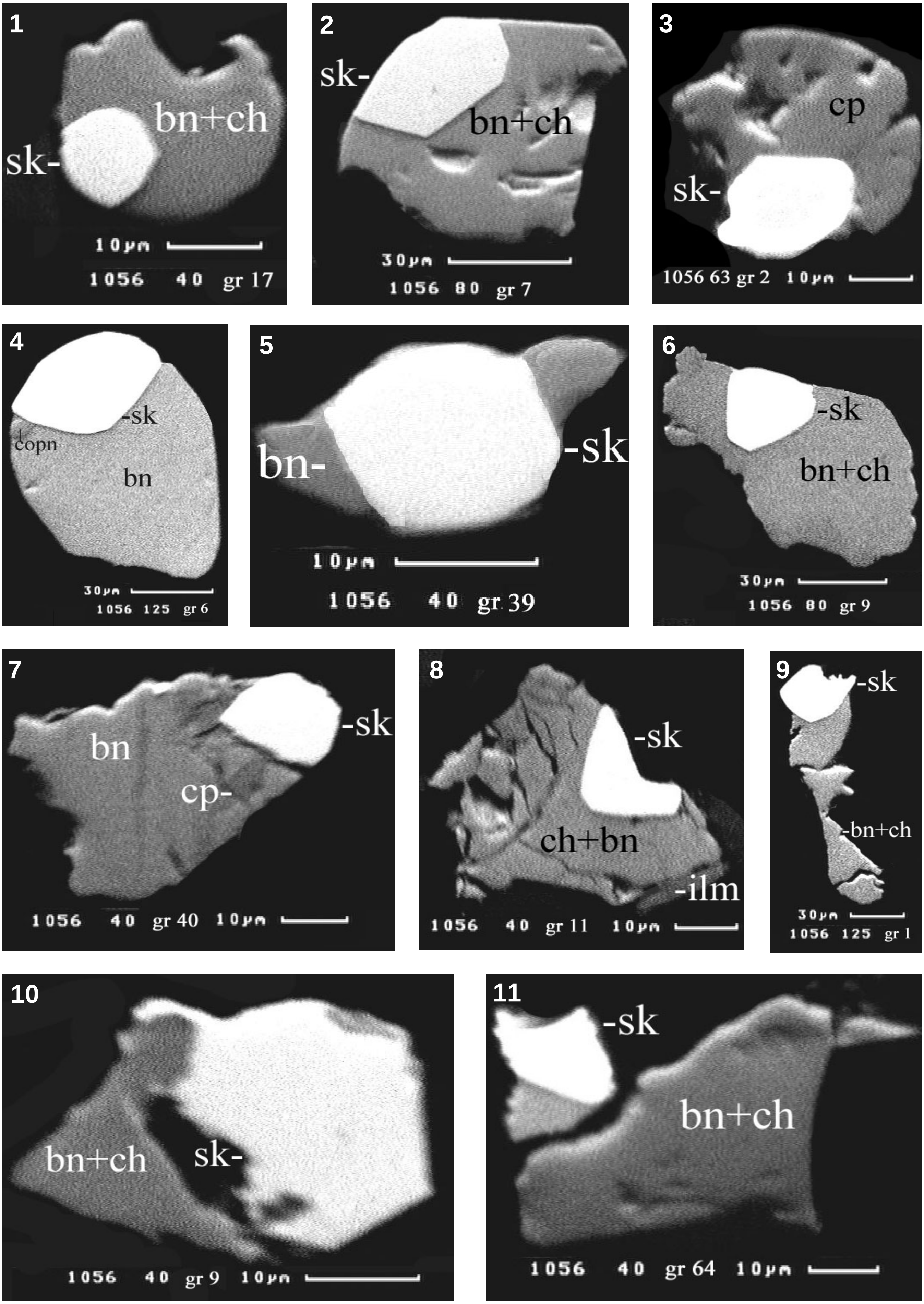
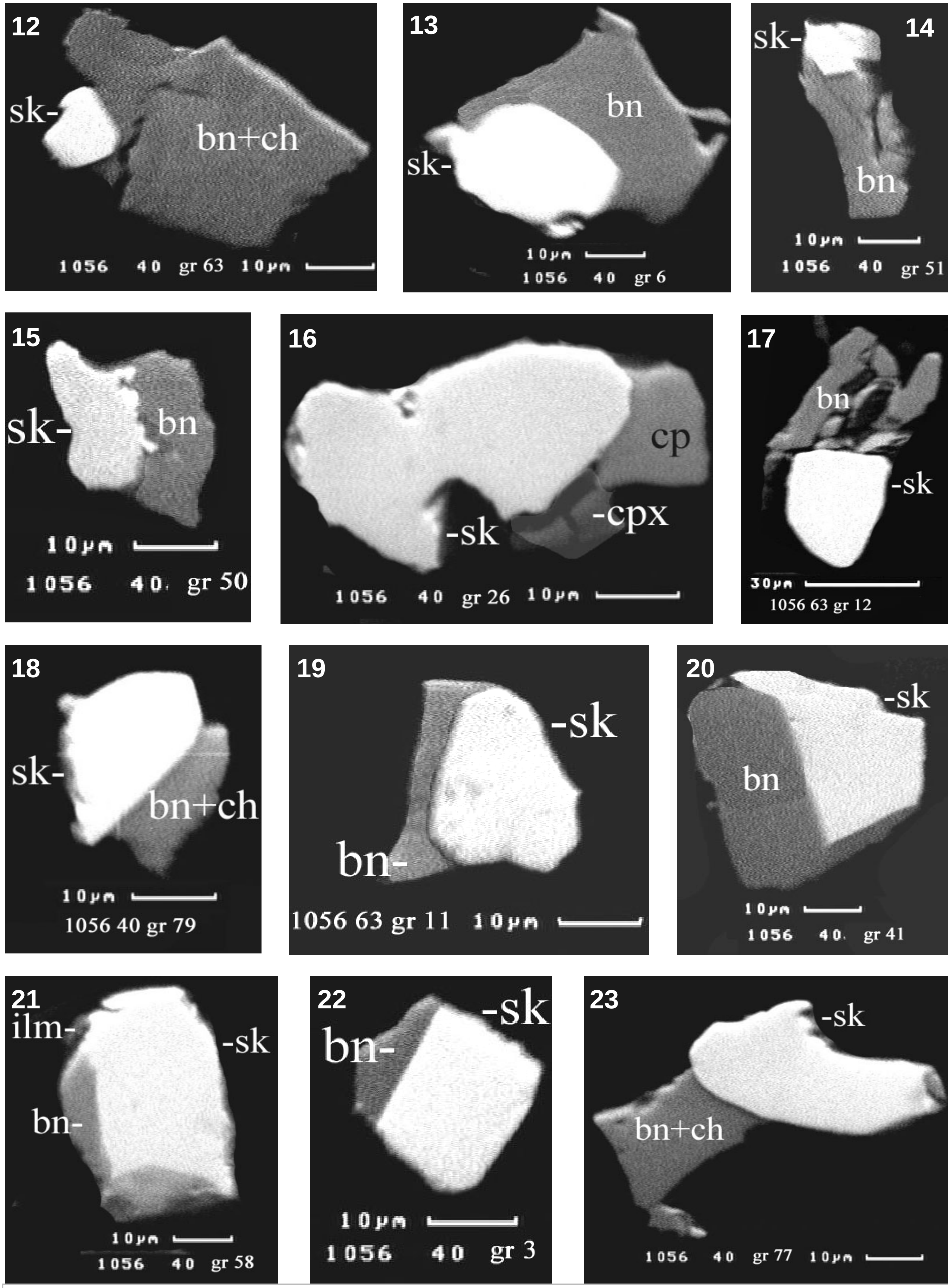
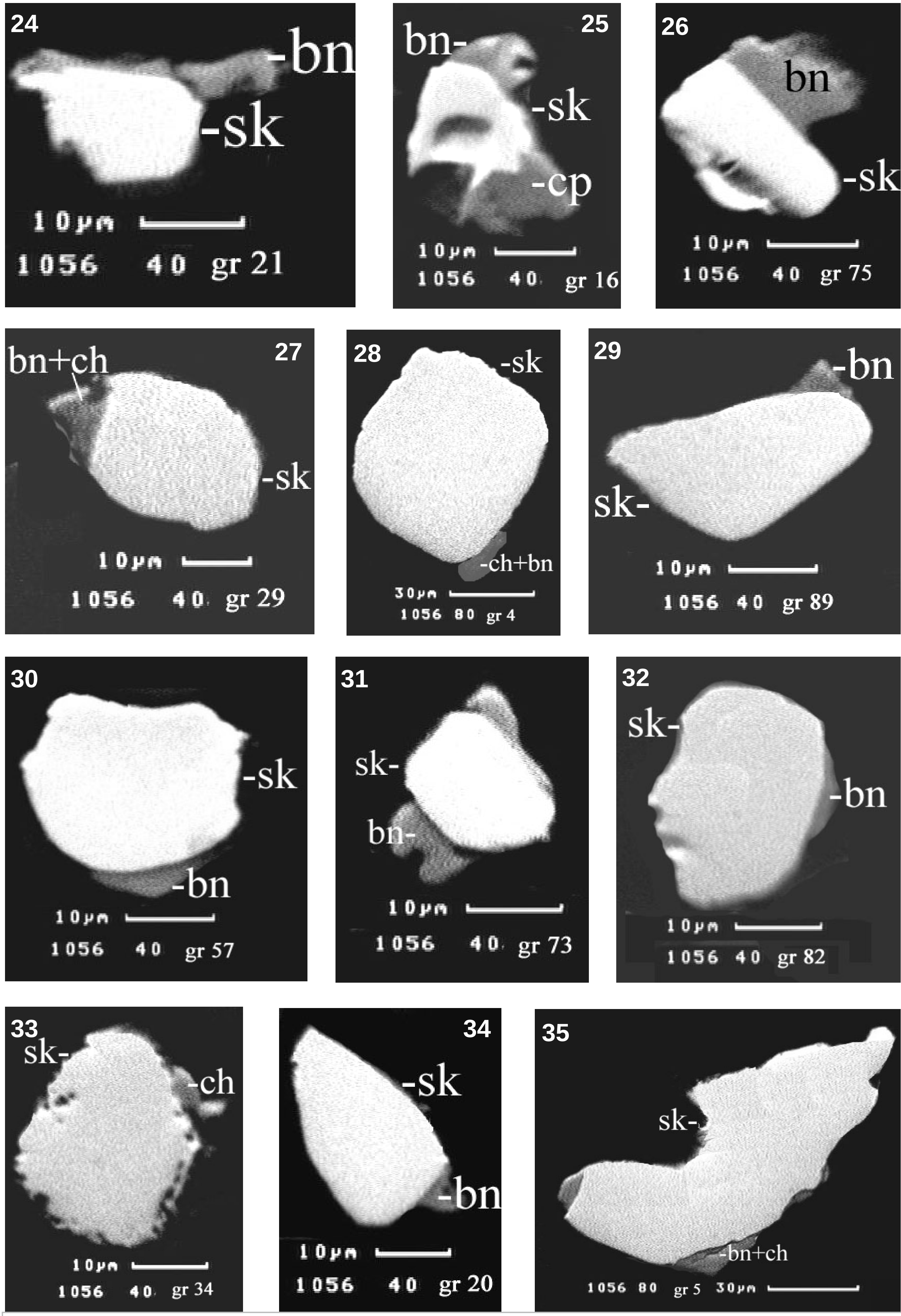

16
bn
1056 80 gr 4a 30μm

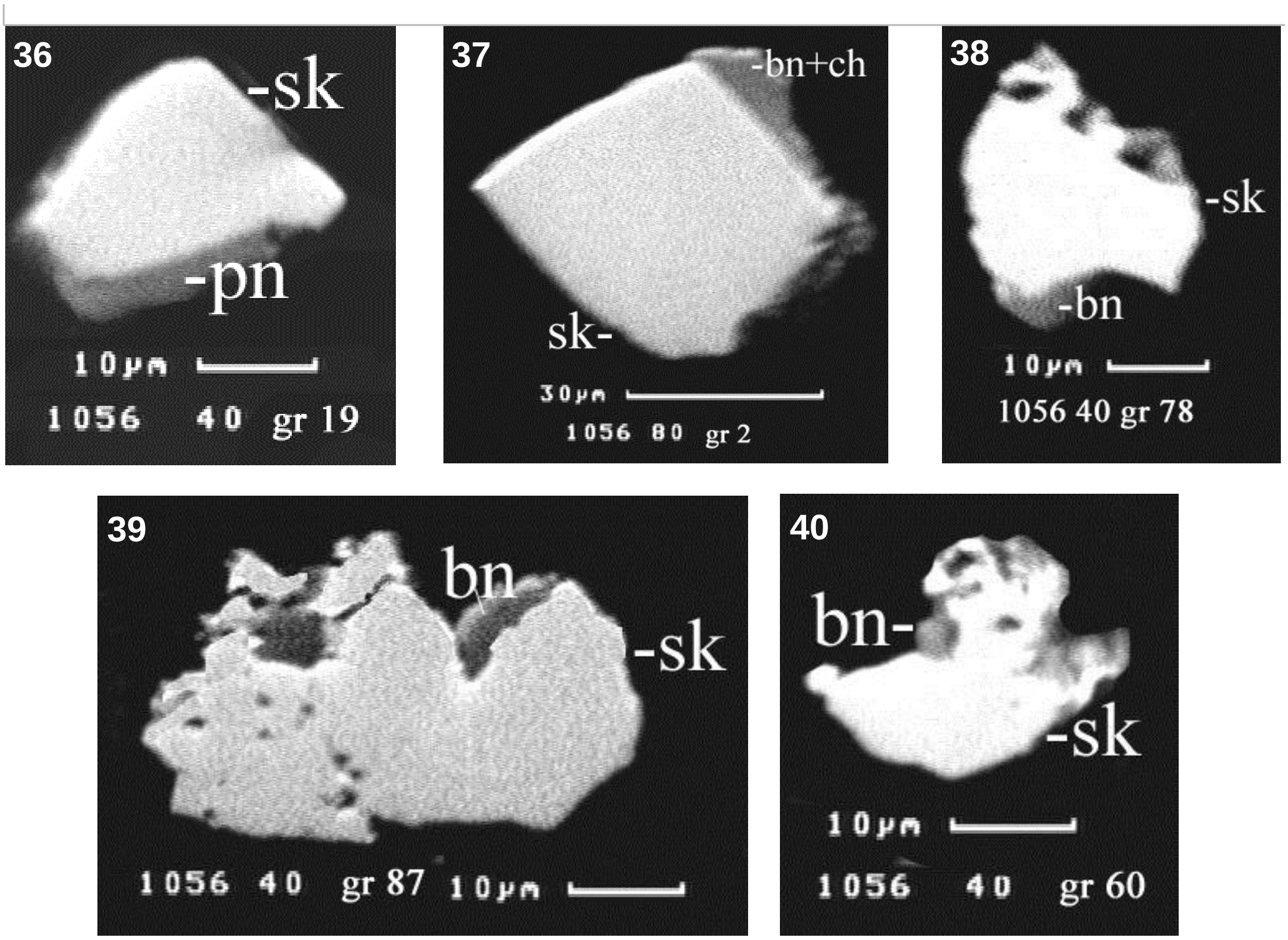
Plate 3

Sulphide globules with inclusions of skaergaardite (**bsm**) and skaergaardite particles attached to base metal sulphides (**bsm-L**) or base metal sulphides together with gangue (**sag** and **sag-L**) in the heavy mineral concentrates of sample 90-24 1056; polished section, SEM-image (BIE). Abbreviations: sk: skaergaardite; bn: bornite; ch: chalcosine; cp: chalcopyrite; copn: cobalt pentlandite; cpx: clinopyroxene and ilm ilmenite.


1
sk-
bn+ch
10µm
1056 40 gr 17
2
sk-
bn+ch
30µm
1056 80 gr 7
3
cp
sk-
1056 63 gr 2 10µm
4
-sk
copn
bn
30µm
1056 125 gr 6
5
bn-
-sk
10µm
1056 40 gr 39
6
-sk
bn+ch
30µm
1056 80 gr 9
7
bn
cp-
-sk
1056 40 gr 40 10µm
8
-sk
ch+bn
-ilm
1056 40 gr 11 10µm
9
-sk
-bn+ch
30µm
1056 125 gr 1
10
bn+ch
sk-
1056 40 gr 9 10µm
11
-sk
bn+ch
1056 40 gr 64 10µm


12
sk-
bn+ch
1056 40 gr 63 10μm
13
bn
sk-
10μm
1056 40 gr 6
14
sk-
bn
10μm
1056 40 gr 51
15
sk-
bn
10μm
1056 40. gr 50
16
cp
-sk
-cpx
1056 40 gr 26 10μm
17
bn
-sk
30μm
1056 63 gr 12
18
sk-
bn+ch
10μm
1056 40 gr 79
19
-sk
bn-
1056 63 gr 11 10μm
20
-sk
bn
10μm
1056 40. gr 41
21
ilm-
-sk
bn-
10μm
1056 40 gr 58
22
-sk
bn-
10μm
1056 40 gr 3
23
-sk
bn+ch
1056 40 gr 77 10μm


24
-bn
-sk
10µm
1056 40 gr 21
25
bn-
-sk
-cp
10µm
1056 40 gr 16
26
bn
-sk
10µm
1056 40 gr 75
27
bn+ch
-sk
10µm
1056 40 gr 29
28
-sk
-ch+bn
30µm
1056 80 gr 4
29
-bn
sk-
10µm
1056 40 gr 89
30
-sk
-bn
10µm
1056 40 gr 57
31
sk-
bn-
10µm
1056 40 gr 73
32
sk-
-bn
10µm
1056 40 gr 82
33
sk-
-ch
10µm
1056 40 gr 34
34
-sk
-bn
10µm
1056 40 gr 20
35
sk-
-bn+ch
1056 80 gr 5 30µm


36
-sk
-pn
10μm
1056 40 gr 19
37
-bn+ch
sk-
30μm
1056 80 gr 2
38
-sk
-bn
10μm
1056 40 gr 78
39
bn
-sk
1056 40 gr 87 10μm
40
bn-
-sk
10μm
1056 40 gr 60

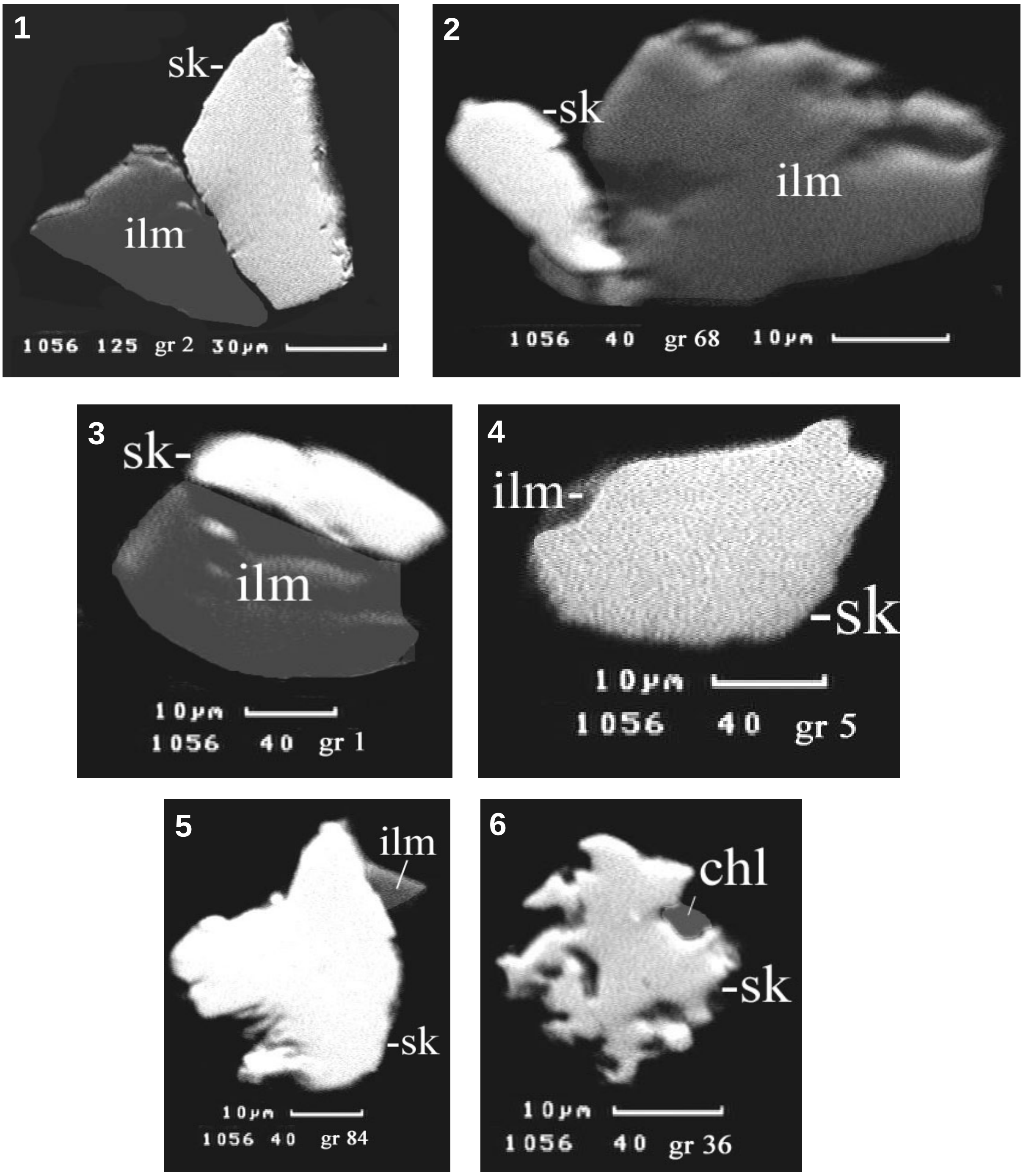
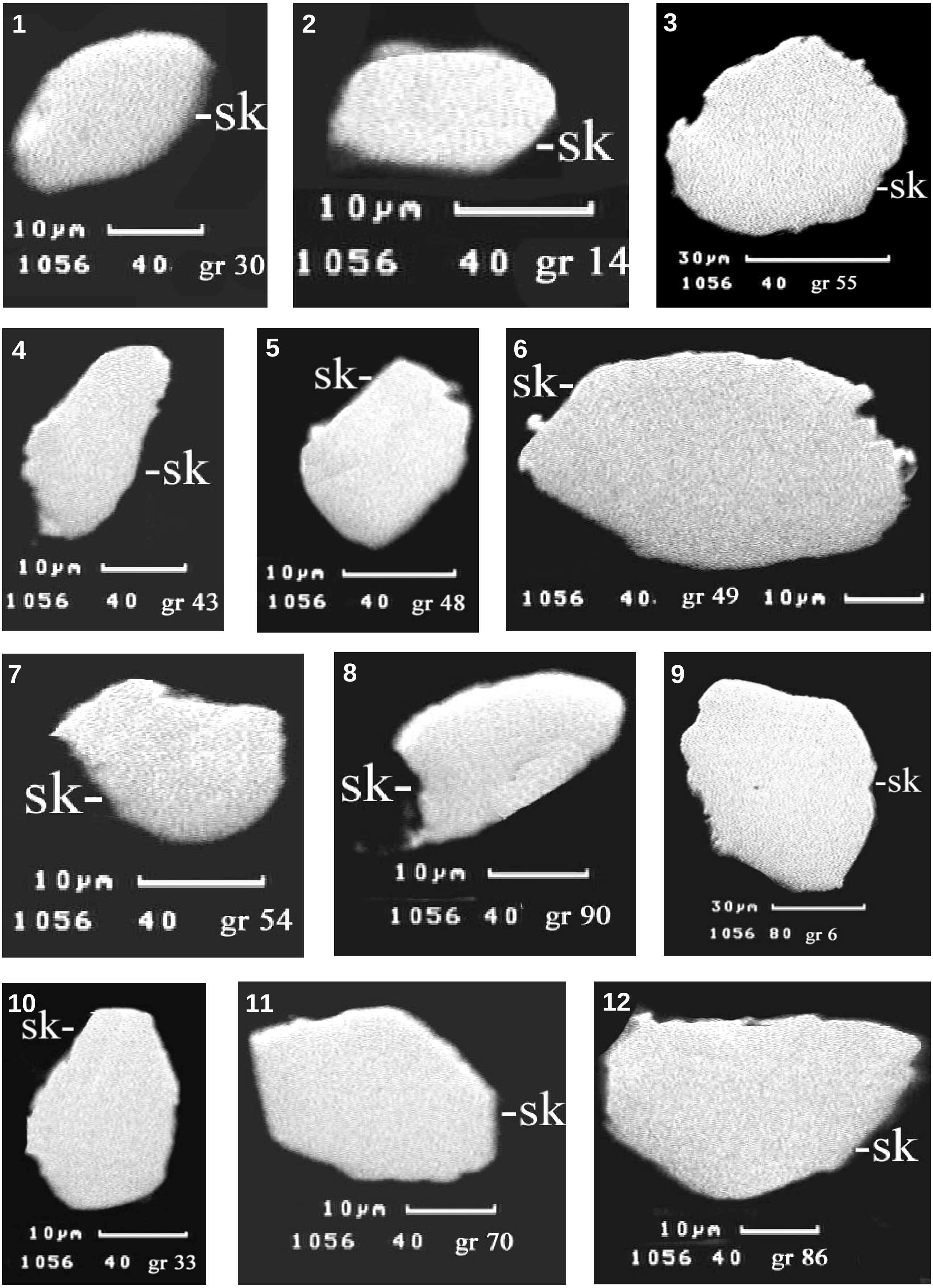


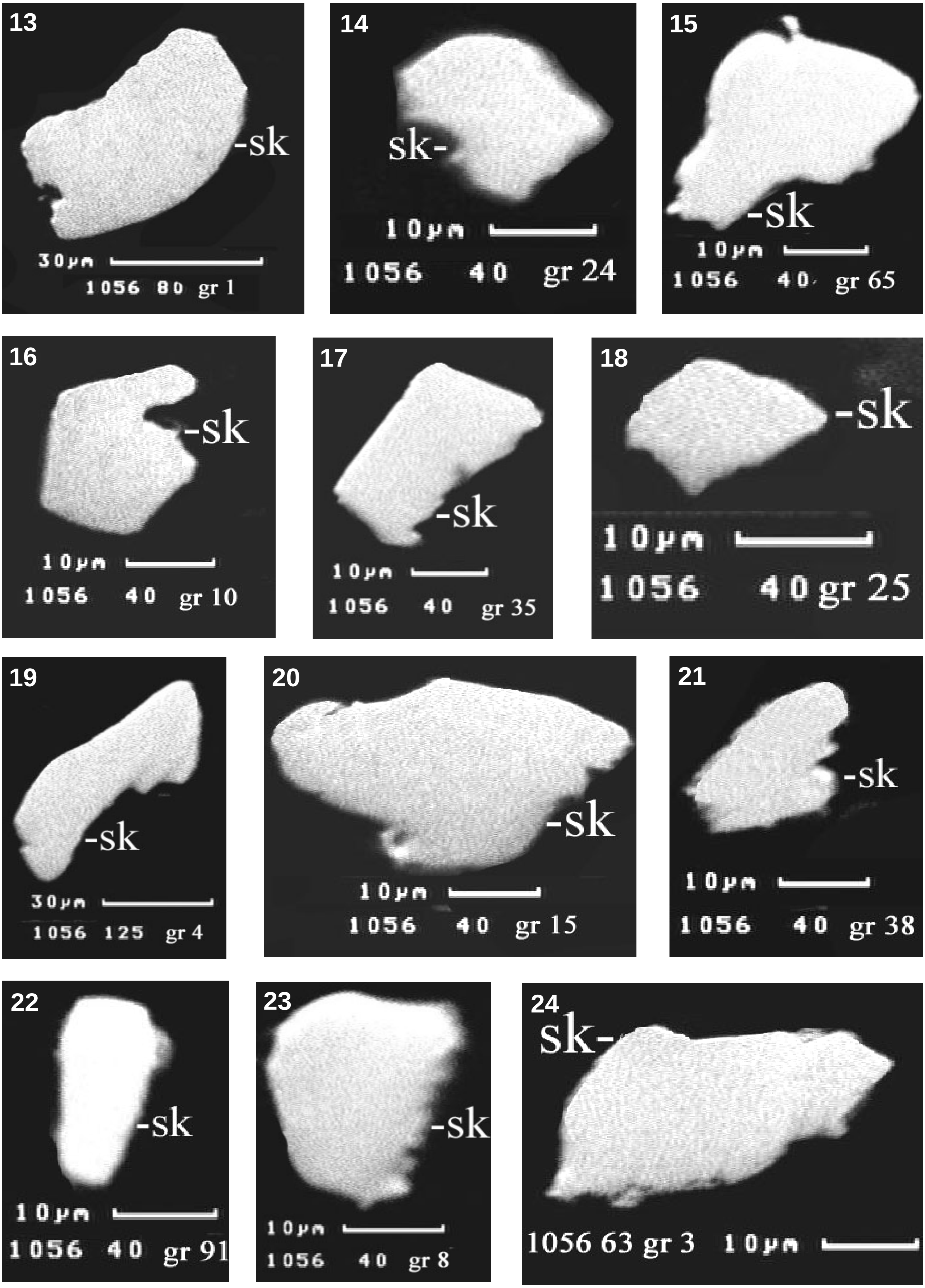
Plate 4

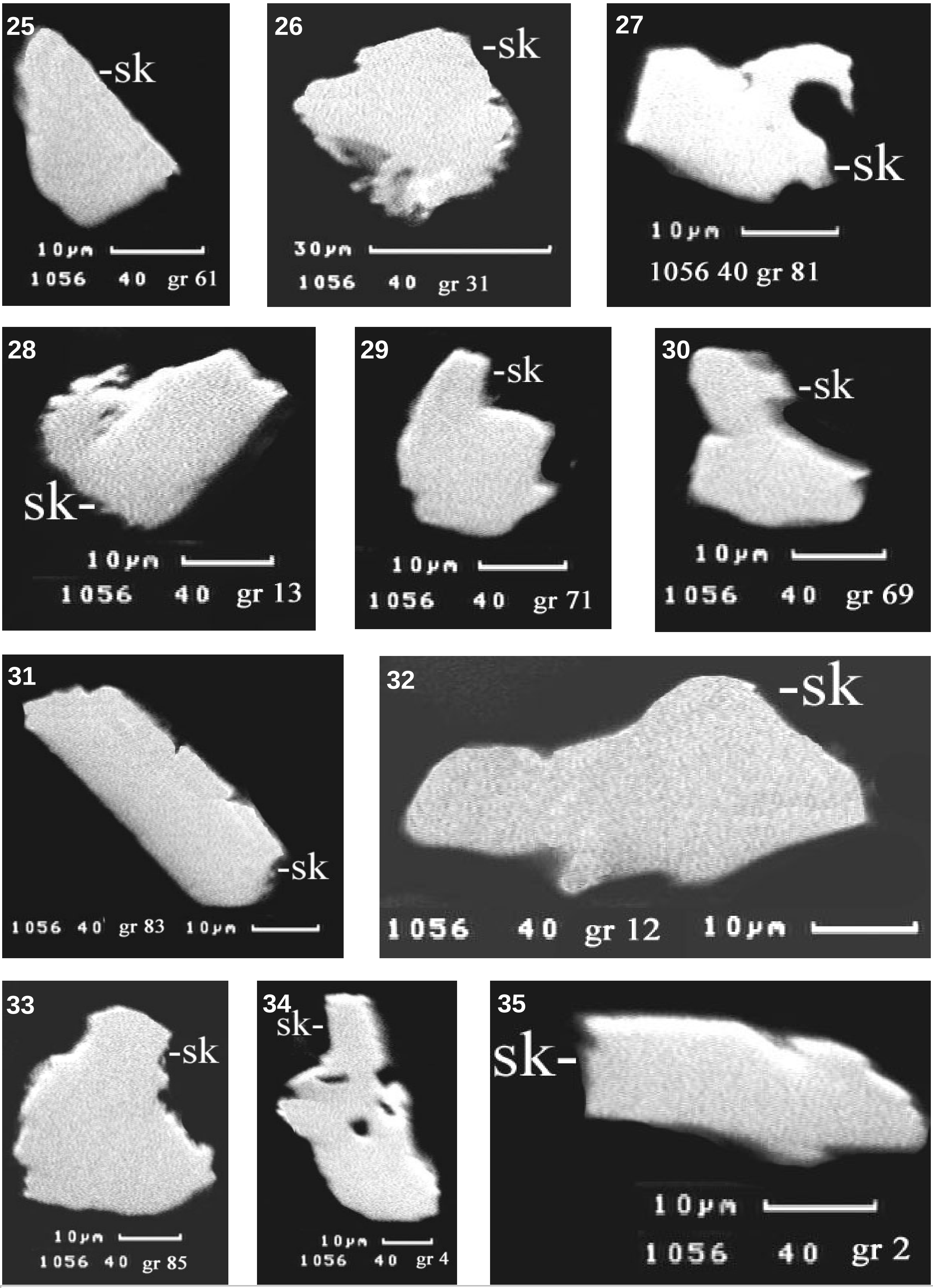
Grains of skaergaardite attached to gangue (**ag** and **ag-L**) in the heavy mineral concentrates of sample 90-24 1056 polished section, SEM-image (BIE). Abbreviations: sk: skaergaardite; ilm: ilmenite and chl: chlorite.

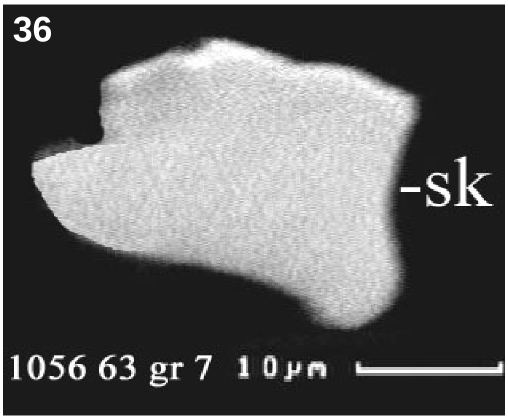
Plate 5

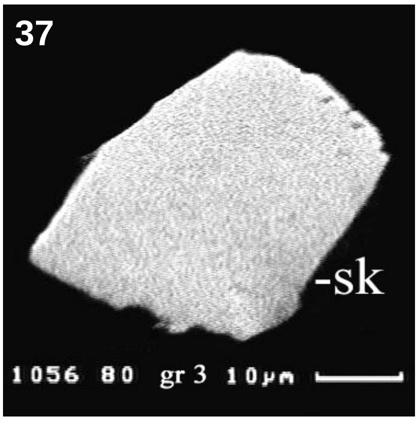
Totally liberated grains of skaergaardite (sk) in the heavy mineral concentrates of sample 90-24 1056; polished section, SEM-images (BIE).

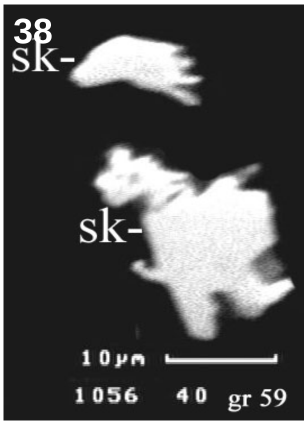

1
-sk
10μm
1056 40 gr 30
2
-sk
10μm
1056 40 gr 14
3
-sk
30μm
1056 40 gr 55
4
-sk
10μm
1056 40 gr 43
5
sk-
10μm
1056 40 gr 48
6
sk-
1056 40 gr 49 10μm
7
sk-
10μm
1056 40 gr 54
8
sk-
10μm
1056 40 gr 90
9
-sk
30μm
1056 80 gr 6
10
sk-
10μm
1056 40 gr 33
11
-sk
10μm
1056 40 gr 70
12
-sk
10μm
1056 40 gr 86

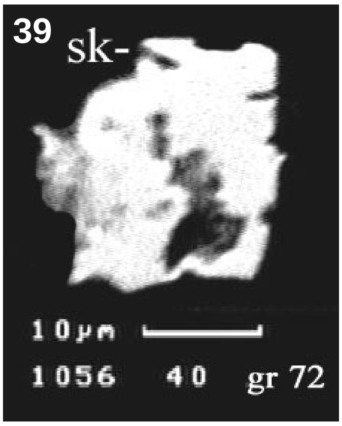

13
-sk
30µm
1056 80 gr 1
14
sk-
10µm
1056 40 gr 24
15
-sk
10µm
1056 40 gr 65
16
-sk
10µm
1056 40 gr 10
17
-sk
10µm
1056 40 gr 35
18
-sk
10µm
1056 40 gr 25
19
-sk
30µm
1056 125 gr 4
20
-sk
10µm
1056 40 gr 15
21
-sk
10µm
1056 40 gr 38
22
-sk
10µm
1056 40 gr 91
23
-sk
10µm
1056 40 gr 8
24
sk-
1056 63 gr 3
10µm

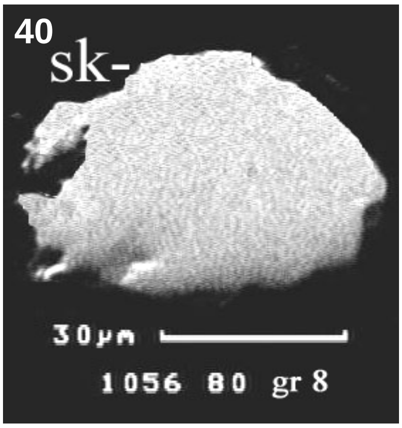

25
-sk
10μm
1056 40 gr 61
26
-sk
30μm
1056 40 gr 31
27
-sk
10μm
1056 40 gr 81
28
sk-
10μm
1056 40 gr 13
29
-sk
10μm
1056 40 gr 71
30
-sk
10μm
1056 40 gr 69
31
-sk
1056 40 gr 83 10μm
32
-sk
1056 40 gr 12 10μm
33
-sk
10μm
1056 40 gr 85
34
sk-
10μm
1056 40 gr 4
35
sk-
10μm
1056 40 gr 2

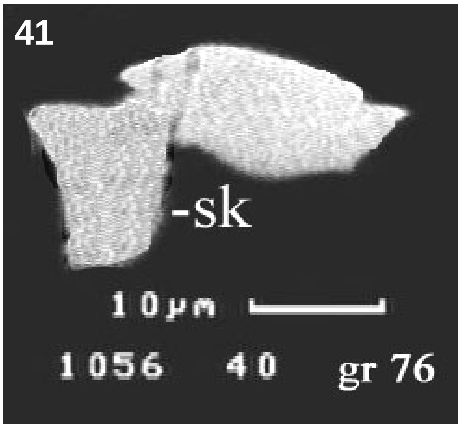

36
-sk
1056 63 gr 7 10μm

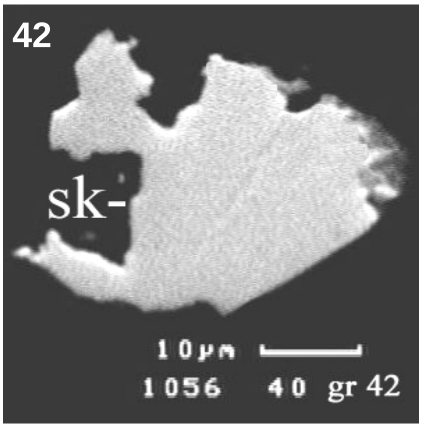

37
-sk
1056 80 gr 3 10μm

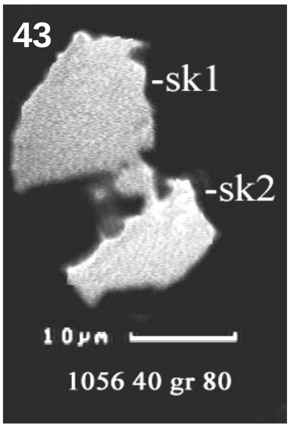

38
sk-
sk-
10μm
1056 40 gr 59


39
sk-
10μm
1056 40 gr 72


40
sk-
30μm
1056 80 gr 8


41
-sk
10μm
1056 40 gr 76


42
sk-
10μm
1056 40 gr 42


43
-sk1
-sk2
10μm
1056 40 gr 80

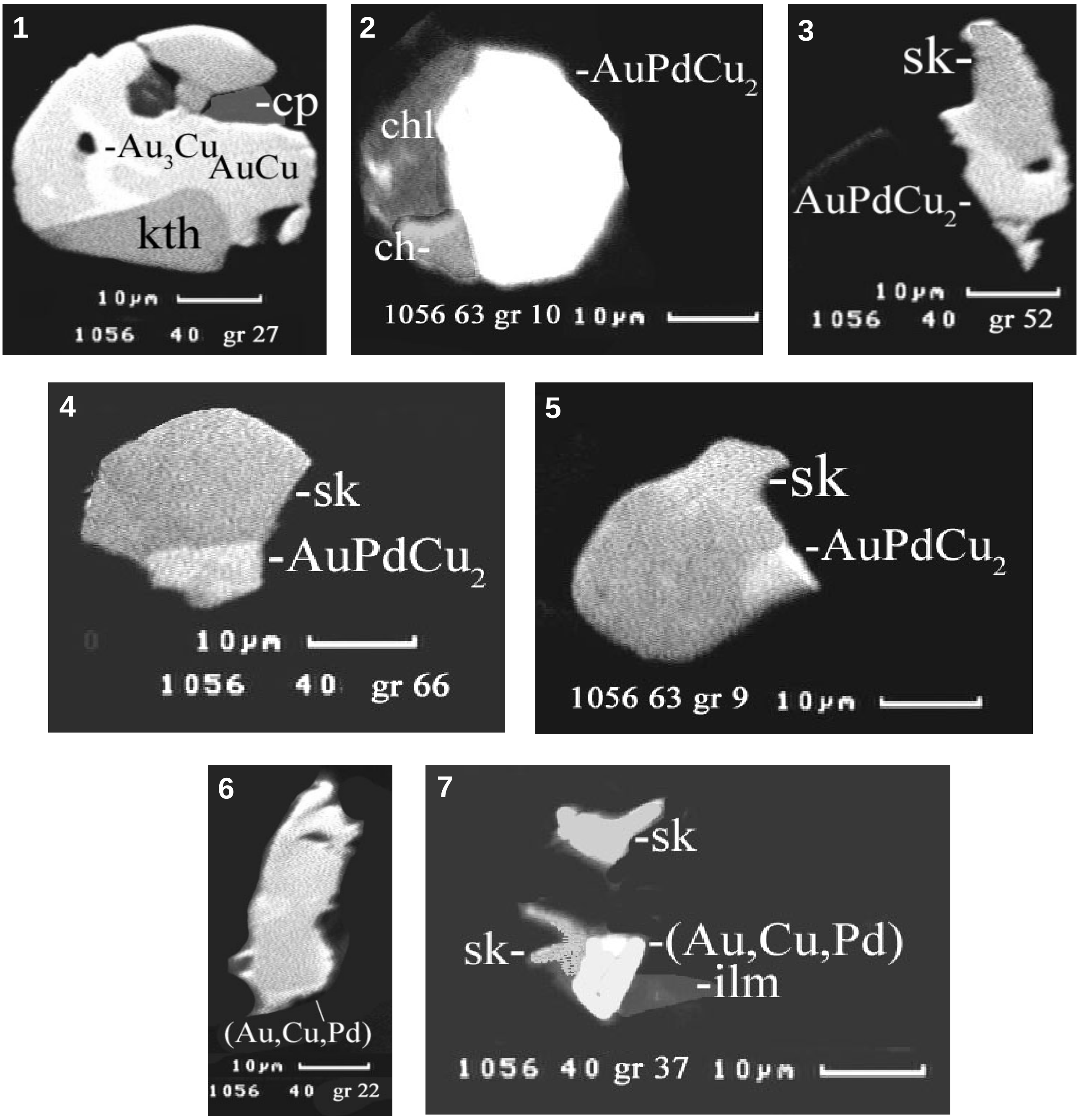
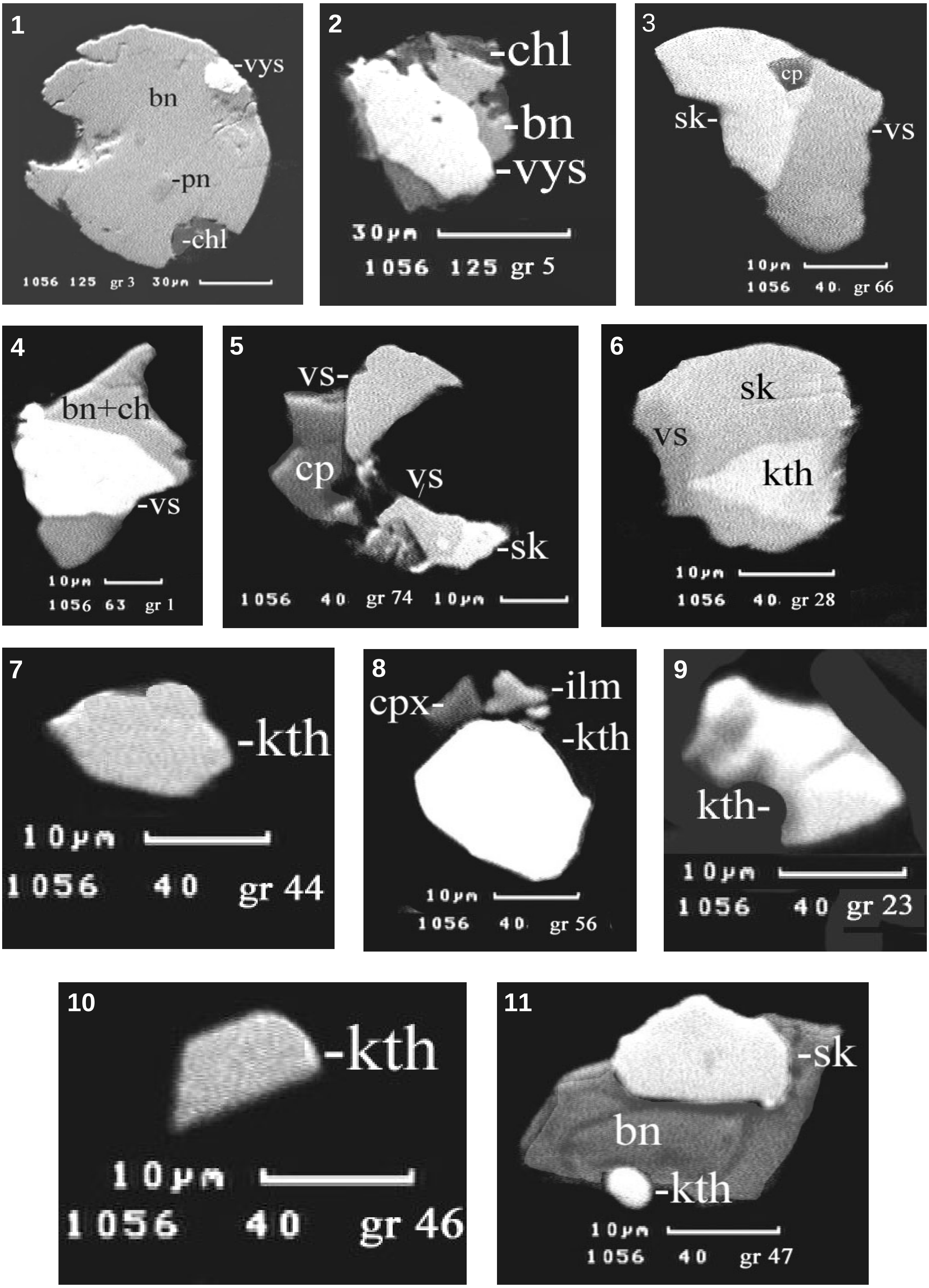


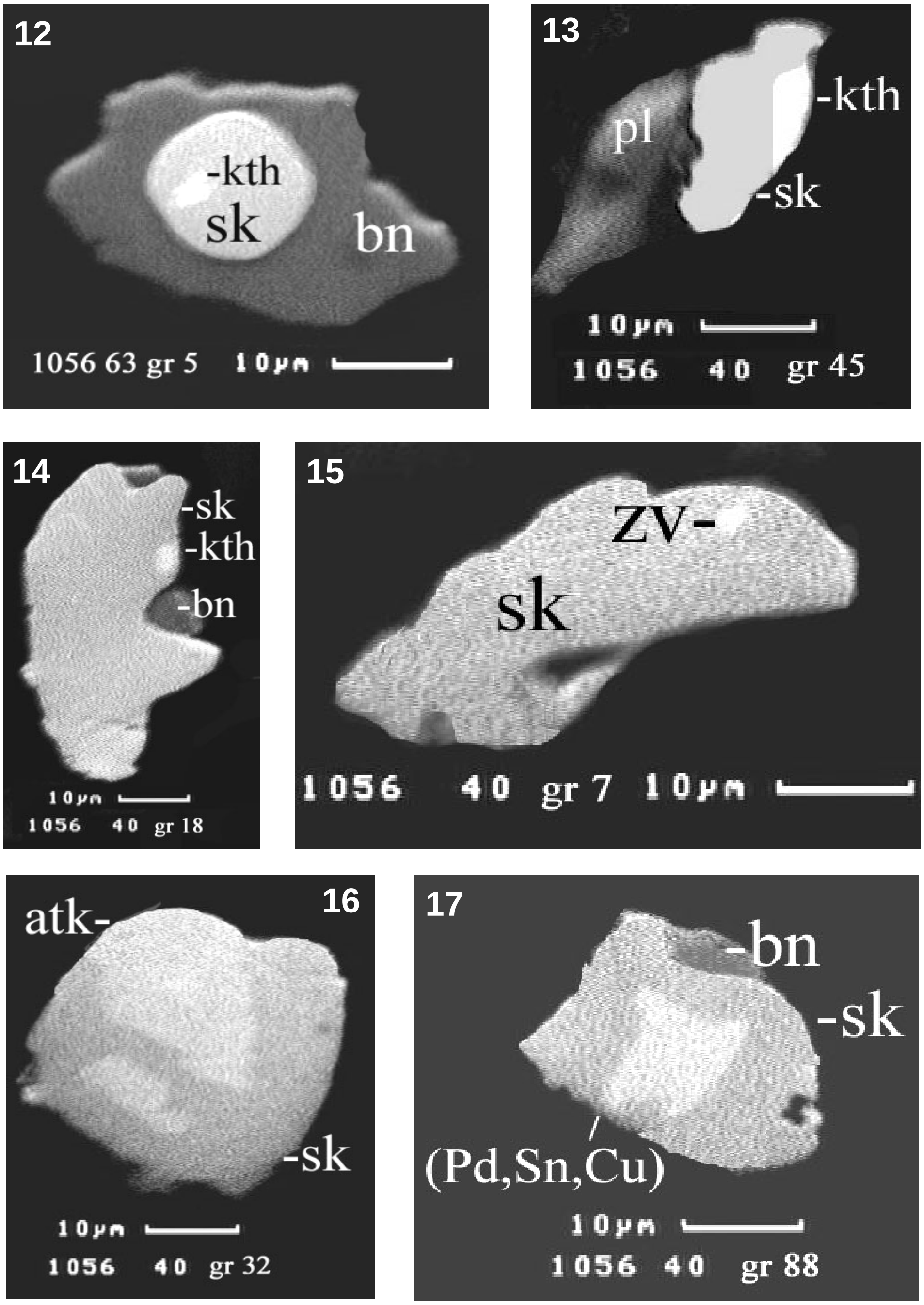
Plate 6

Grains, represented by different (Au,Cu,Pd) alloys (1-7) in heavy concentrates of the sample 90-24, 1056; polished section, SEM-image (BIE).

Plate 7

PGM grains containing vysotskite (vys; 1, 2), vasilite (vs; 3-6), keithkonnite (kth; 6-14), zvyagintsevite (zv; 15), atokite (atk; 16) and (Pd,Sn,Cu) alloy (17) in heavy concentrates of the sample 90-24 1056; polished section, SEM-image (BIE). Othher abbreviations: bn: bornite; pn: pentlandite; ch: chalcopyrite; pl: plagioclase cpx: clinopyroxene and chl: chlorite.


1
-vys
bn
-pn
-chl
1056 125 gr 3 30μm
2
-chl
-bn
-vys
30μm
1056 125 gr 5
3
cp
sk-
-vs
10μm
1056 40 gr 66
4
bn+ch
-vs
10μm
1056 63 gr 1
5
vs-
cp
vs
-sk
1056 40 gr 74 10μm
6
sk
vs
kth
10μm
1056 40 gr 28
7
-kth
10μm
1056 40 gr 44
8
cpx-
-ilm
-kth
10μm
1056 40 gr 56
9
kth-
10μm
1056 40 gr 23
10
-kth
10μm
1056 40 gr 46
11
-sk
bn
-kth
10μm
1056 40 gr 47


12
-kth
sk
bn
1056 63 gr 5 10μm
13
pl
-kth
-sk
10μm
1056 40 gr 45
14
-sk
-kth
-bn
10μm
1056 40 gr 18
15
zv-
sk
1056 40 gr 7 10μm
atk-
16
-sk
10μm
1056 40 gr 32
17
-bn
-sk
(Pd,Sn,Cu)
10μm
1056 40 gr 88