DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2010/74

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

Part 9: Sample 90-18 978

Nikolay S. Rudashevsky, Vladimir N. Rudashevsky
& Troels F. D. Nielsen

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
MINISTRY OF CLIMATE AND ENERGY

GEUS

DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2010/74

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

Part 9: Sample 90-18 978

Nikolay S. Rudashevsky, Vladimir N. Rudashevsky
& Troels F. D. Nielsen

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
MINISTRY OF CLIMATE AND ENERGY

GEUS

ABSTRACT 3

Introduction 5

Sample 90-18 978 ... 5

Mineralogical investigation 6

Analytical techniques ... 6

Results 7

Rock forming minerals and sulphide mineralogy ... 7
Silicates and oxides ... 7
Sulphides ... 7
Precious metal minerals: recovery, grain size and relations to host rock ... 8
Recovery ... 8
Grain size ... 9
Petrographic observations ... 10
Description and chemistry of precious metal minerals ... 12
Skaergaardite (Pd,Au)(Cu,Fe,Zn,Sn) ... 12
Tetra-auricupride (Au,Pd,Pt)Cu ... 15
Unnamed $(Au,Pd)_3Cu$ ... 15
Vysotskite (Pd,Cu,Ni)S ... 15
Keithconnite $(Pd,Cu)_3(Te,Pb)$ ... 16
Atokite $(Pd,Cu)_3Sn$ ... 16
(Pd,Cu,Sn) alloy ... 16
Unnamed $Pd_2(Cu,Fe)TeBi$ ... 17
(Ag,Cu) alloy ... 17
Bulk composition of PGMs of the sample 90-18 978 ... 17

Discussion 18

PGM-paragenesis ... 18

Summary 20

References 21

ABSTRACT

The report presents the results of mineralogical investigations of the sample 90-18, 978. This is the Pd2b level in the core 90-18 between 978 and 979 meters. Assays give 1051 ppb Pd, 241 ppb Au, and 28 ppb Pt for the interval.

The sample (800 g) was crushed in small portions using a shatter box with small cavities (200 ml) for short periods (0.3-0.5 min) and sieved to remove the fine fraction (sieve -125 µm) after each crushing session. The residual coarse fraction >125 µm was re-crushed again until the entire sample has 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, and 4) 80-125 µm. All fractions were processed through wet magnetic separation.

The non-magnetic parts of every fraction from the sample 90-18 978 were hydroseparated by means of the computer controlled device CNT HS-11. As the result, the monolayered 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 did not contain precious metal grains.

The gabbro in sample 90-18, 978 has characteristic structure showing reaction relationships between cumulus and intercumulus phases: rims of olivine at the boundaries between accumulated grains of Fe-Ti-oxides and two-pyroxenes. In general, this is a “dry” rock - H_2O-bearing minerals are locally represented in very insignificant quantities in intergrowths with Cu-Fe-sulphides.

The HS-concentrates contain numerous sulphide grains identified as sulphide droplets. They are formed by one or more Cu-sulphides – chalcosine+bornite (58 %), more rarely by chalcosine (sometimes digenite) - (42 %). Several of these droplets and sulphide grains contain inclusions of various PGMs.

Based on microprobe investigations of the heavy concentrates, a representative selection of PGMs in 157 grains was studied in detail. The dominating precious metal mineral is skaergaardite (Pd,Au)(Cu,Fe,Zn,Sn) 94.9 vol. %. The remaining 5 wol. % of the precious metal mineral paragenesis includes7 minerals: tetra-auricupride (Au,Pd,Pt)(Cu,Fe) (3.4 vol. %), unnamed $(Au,Pd)_3(Cu,Fe)$ (0.4 vol. %), vysotskite (Pd,Cu,Ni)S (0.2 vol. %), keithconnite $(Pd,Cu)_3(Te,Pb,Sn)$ (0.6 vol. %), atokite Pd_3Sn (0.4 vol. %), (Pd,Cu,Sn) alloy (0.1 vol. 5), and unnamed $Pd_{ь}$(Cu,Fe)TeBi (<0.1 vol. %). Besides, one grain of (Ag,Cu) alloy is found in the heavy mineral HS concentrate.

The grain size of PGE and Au minerals (ECD) varies from 2 to 74 µm with an average grain size of 27 µm.

Average composition of skaergaardite (from 126 analyses) is (wt. %): Pd 59.4, Pt 0.1, Au 2.3, Cu 31.1, Fe 3.6, Zn 1.4, Sn 1.0, Te 0.3, Pb 0.4 Total 99.6;

$(Pd_{0.96}Au_{0.02})_{0.98}(Cu_{0.85}Fe_{0.11}Zn_{0.04}Sn_{0.02})_{1.02}$.

The estimated bulk composition of the sample (assay of whole rock in brackets) is (ppb): Pd 1222 (1051), Au 96 (241), Pt 2 (28). Pd is concentrated in skaergaardite (~97 %), some in other Pd-PGMs (~2 %) and in gold minerals (~1 %). Au is distributed between Au minerals (tetra-auricupride and unnamed Au_3Cu, 52 %) and skaergaardite (48 %). Pt was found in skaergaardite and in unidentified very fine grain of a Pd-Pt-Cu sulphide (?). It should be noted that the Pt content in the studied sample is close to the level of detection of the mineralogical analysis.

The majority of the identified grains of precious metal minerals, beside several grains of Au and (Ag,Cu) alloy, belong to a single paragenesis together with Cu-Fe sulphides.

Introduction

The report describes the mineralogy of sample 90-18 978 from the Pd2b level in the "Platinova Reef" of the Skaergaard intrusion (Nielsen et al, 2005) The investigation has been carried out by CNT-MC (St. Petersburg, Russia) on the request of the Geological Survey of Denmark and Greenland. The report is based on the data recovered from concentrates produced using the newly patented Hydroseparator CNT HS-11, and one polished section of a the gabbro. Monolayer polished sections of HS concentrates and one polished section of host rock have been studied using electron microscopy and electron microprobe analysis (Camscan-4DV, Link AN-10 000). The report gives description of the grain characteristics, the parageneses and the compositional variations within the identified groups of minerals, alloys, sulphide droplets, and host gabbro, and discuss the genesis of the Skaergaard precious metal mineralisation.

Sample 90-18 978

Sample 90-18 978 (c. 800 g) was collected from BQ drill core #90-18, and is a representative bulk sample in the 978-979 m interval. The core was collared at 20 meters a.s.l. on the eastern shore of Skærgårdsbugt, and drilled with an azimuth of 0^{o} and an inclination of $70^{o.}$ Sample 90-18 978 collects the Pd2b level of the Skaergaard mineralisation and assays show 1051 ppb Pd, 241 ppb Au, and 28 ppb Pt for this interval (Watts, Griffis & McOuat, 1991. The core has previously been sampled for other purposes and the recovery was app. 70%. The sample collects 1/3 of the diameter of the preserved core.

Mineralogical investigation

Analytical techniques

Analytical techniques are described in Nielsen et al. (2003). The heavy mineral concentrates, enriched in precious metal minerals (Plate 2) were produced using a newly patented computer controlled Hydroseparator CNT HS-11, and newly patented GST glass separation tube (Rudashevsky et al., 2006 and 2007; see www.cnt-mc.com).

The available core material was crushed to –125μm. After complete grinding, the sample was passed through standard sieves with water (wet sieving): <40μm (368.1 g) , 40-63μm (111.6 g), 63-80μm (92.9 g), 80-125μm (179.9 g), followed by wet magnetic separation. The non-magnetic fractions (<40μm, 40-63μm, 63-80μm, 80-125μm) were subsequently passed through hydroseparator CNT HS-11 in which the concentrates for the monolayer polished sections were produced.

Results

Rock forming minerals and sulphide mineralogy

Silicates and oxides

The silicates and oxides related to sulphides are: 1) *plagioclase*, An_{45-49-} (Table 1, analyses 1-3) 2) *monoclinic ferrous pyroxene*, Mg# = 0.63 (Table 1, analyses 4, 5); 3) *orthorhombic ferrous pyroxene*, Mg# = 0.52 (Table 1, analysis 6); 4) *Fe-rich olivine*, Mg# = 0.40-0.43 (Table 1, analysis 7-9); and Fe-Ti oxides including 5) *ilmenite* (Table 1, analyses 10-12) and 7) *titaniferous magnetite* (Table 1, analyses 13-15). Monoclinic and orthorhombic pyroxenes form typical herringbone exsolution textures (Plate 1, #*1, 4, 5*).

The Fe-Ti-oxides occur as anhedral aggregates, 1-3 mmin size. They fill space between grains of plagioclase and pyroxenes (see Plate 1, #*3-5*) and are clearly intercumulus grains. The host gabbro exhibits a characteristic reaction relationship between cumulus and intercumulus phases. Olivine forms rims at the boundaries between accumulated grains of Fe-Ti-oxides and pyroxenes (Plate 1, #*3-5*).

Sulphides

The host gabbro is relatively poor in sulphides. In the investigated polished section only one sulphide grain (chalcosine+bornite) was found. It was located at the boundary between plagioclase and exsolution aggregate of pyroxenes (Plate 1, #*1, 2*).

The non-magnetic heavy concentrates are ilmenite-rich products (>97 %) enriched in grains of sulphide and PGMs (see Plate 2). The sulphide grains are represented by droplet-like microglobules: chalcosne+bornite (Plate 3, #*1-8;* Plate 4, #1-6, 22, 24-27, 29 etc) and chacosine (Plate 3, #*22-25* etc), or irregular aggregates: chalcosine+bornite (Plate 3, #*9-21*; Plate 4, #*7, 9, 10-12, 14-17, 19, 20, 28, 28, 31-35, 37-42,* etc), chalcosine (Plate 3, #*26-31*; Plate 4, *21, 30, 36* etc), and bornite (Plate 4, #*8, 18* etc) having sizes up to 0.1 mm.

The following rock-forming minerals are often found adjacent to sulphide and/or PGM grains: ilmenite (Plate 5, #*1-4*), clinopyroxenes (Plate 5, #*6*), plagioclase (Plate 5, #*5*), magnetite (Plate 7, #*9*); chlorite (Plate 3, *21*; Plate 5, #*9-11*; Plate 8, #*1*), hornblende (Plate 3, #*21*; Plate 5, #*7, 8*) and tremolite (Plate 8, #*5*).

More than half of the sulphide grains (58%) are composed of bornite only, or bornite and chalcosine (sometimes with digenite), and remaining (42 %) consists of chalcosine (sometimes digenite). The concentrates also contain rare chalcopyrite (Plate 4, #*4)* and cobalt-pentlandite (Plate 7, #*4*) which in the heavy mineral HS concentrates are found in associations with PGMs. Bornite and chalcosine form classic exsolution textures inside sulphide microglobules and grains (see Plate 3, *1-6, 9-14* etc.).

The chemical composition of chalcosine (Table 2, analyses 1-6, 8, 9, 11-15, 17, 18, 20, 21, 30), bornite (Table 2, analyses 7, 24-29), digenite (Table 2, analysis 10, 16, 19, 23) and cobalt-pentlandite (Table 2, analysis 22) are close to stoichiometry.

Precious metal minerals: recovery, grain size and relations to host rock

Recovery

No PGM grains were found during SEM studies of the polished section of the host gabbro of sample 90-18 978. The heavy mineral concentrates, however, have yielded many precious metal grains. The representative selection of 157 grains of a wide size range (from <40μm up to 80-125μm) was studied in detail. In total, at least 8 different PGE and Au minerals are documented in the sample 90-18 978. They include (Table 3):

1. *skaergaardite* (Pd,Au)(Cu,Fe,Zn,Sn) – 140 grains
2. *tetra-auricupride* (Au,Pd,Pt)(Cu,Fe) –12 grains
3. *unnamed* $(Au,Pd)_3(Cu,Fe)$ – 2 grains
4. *vysotskite* (Pd,Cu,Ni)S–2 grains
5. *keithconnite* $(Pd,Cu)^3(Te,Pb,Sn)$ – 6 grains
6. *atokite* $(Pd,Cu)_3Sn$ – 4 grains
7. *alloy* (Pd,Cu,Sn) – one grain
8. *unnamed* $Pd_2(Cu,Fe)TeBi$ – one grain
9. *alloy* (Ag,Cu) – one grain

Skaergaardite makes up almost 95% of the entire precious metal mineral paragenesis (Table 3 and Fig. 1). The volumetric proportions are calculated from the area of the grains recovered.

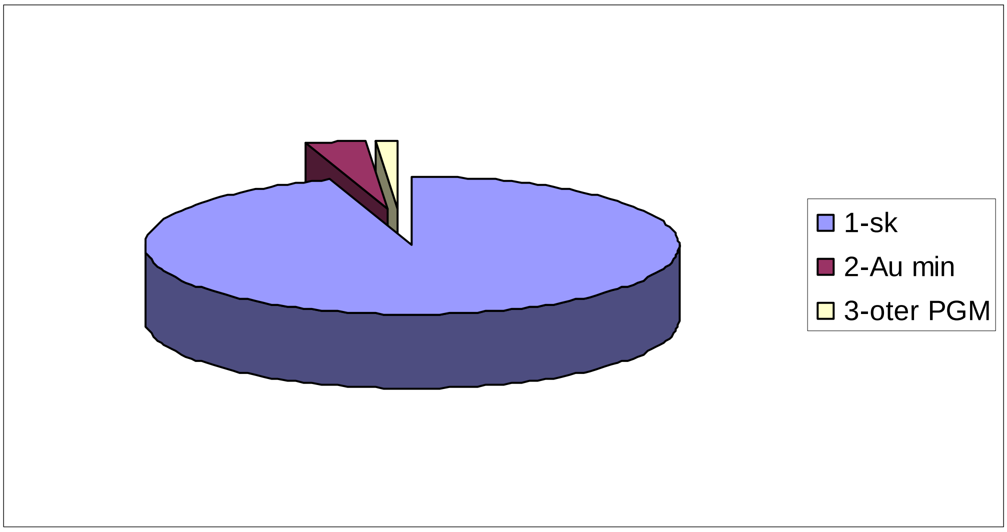


Fig. 1. Relative contents of PGE and Au, the sample 90-18, 978 (see Table 3). 1 – skaergaardite, 94.9 vol. %; 2 –Au minerals (tetra-auricupride and unnamed Au_3Cu) 3.8 vol. %; 4 - other PGMs – 1.3 vol. %.

Grain size

Grain sizes were measured as the effective diameter of the grains (ECD) using the ImageJ software. They vary from 2 to 74µm with an average of 27µm (Table 4; Fig. 2).

The histogram of grain sizes (Fig. 2) shows a close to normal distribution for the statistical selection (n=157). According to this histogram, size of PGE and Au mineral grains are distributed as follows:

Grain size, µm	Number of grains
0-10	18
10-20	33
20-30	44
30-40	34
40-50	30
50-60	2
60-70	4
70-80	2

The SEIs (scanning electron images) show that majority of precious metal mineral grains are well preserved and have kept their primary shape and size (Plates 4-8). Grains have not been broken during production of the concentrates. Most of the PGM grains occur as inclusions in Cu-Fe sulphides globules and grains, or as completely liberated grains.

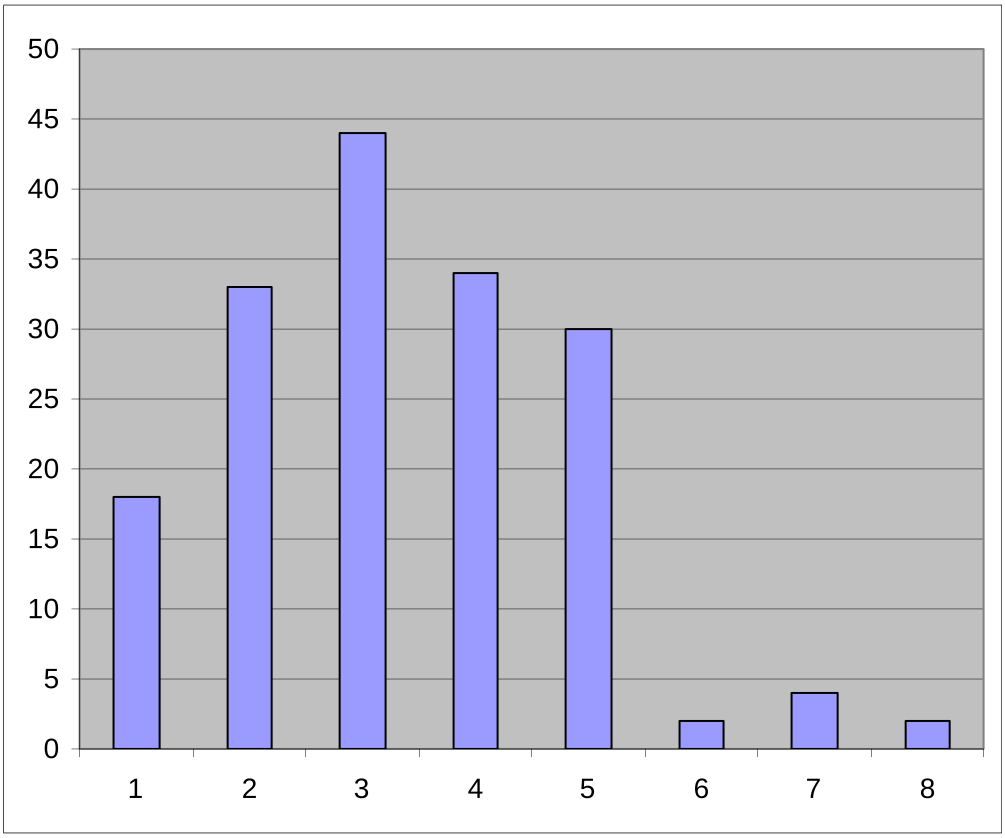


Fig 2. Histogram of size of PGE and Au mineral grains (n=157), extracted in the heavy concentrates of the sample 90-18, 978.In abscissa: 1 – 0-10 µm, 2 – 10-20 µm, 3 – 20-30 µm, 4 – 30-40 µm; 5 – 40-50 µm, 6 – 50-60 µm, 7 – 60-70 µm, 8 – 70-80 µm.

Petrographic observations

Perfect separation of accessory minerals has been achieved by gentle crushing and disintegration of the studied sample. The method of disintegration allows the preservation of primary grains, and preserves the important information on the precious metal minerals. The concentrates provide information needed for the reconstruction of primary grain shapes and sizes, the parageneses, the relationships with the minerals of the host rock, and modelling of the mineralisation process.

In the heavy concentrates of the sample 90-18 978 the precious metal mineral grains (n=157) occur in the following mineral associations (Fig. 3; Table 5):

Table 5. The petrographic associations of PGE and Au mineral grains in heavy concentrates of the sample 90-18 978.

Association	PGM-grains, number	PGM-grains, vol. %
bms	77	30.6
bms-L	28	27.6
L	33	32.3
L+	5	2.4
sag	11	5.5
ag	3	1.5

Bms: intergrowths with base metal sulphides (chalcosine, bornite, digenite); **bms-L**: liberated particles with <10 % attached base metal sulphides; **L**: completely liberated (free) particles; **L$^+$**: more than one precious metal mineral as completely liberated (free) particles, **sag**: sulphide and gangue (ilmenite, clinopyroxenes, chlorite, talc, ferrosaponite) attached to PGMs; **ag**: PGMs attached to gangue (ilmenite, ferrosaponite).

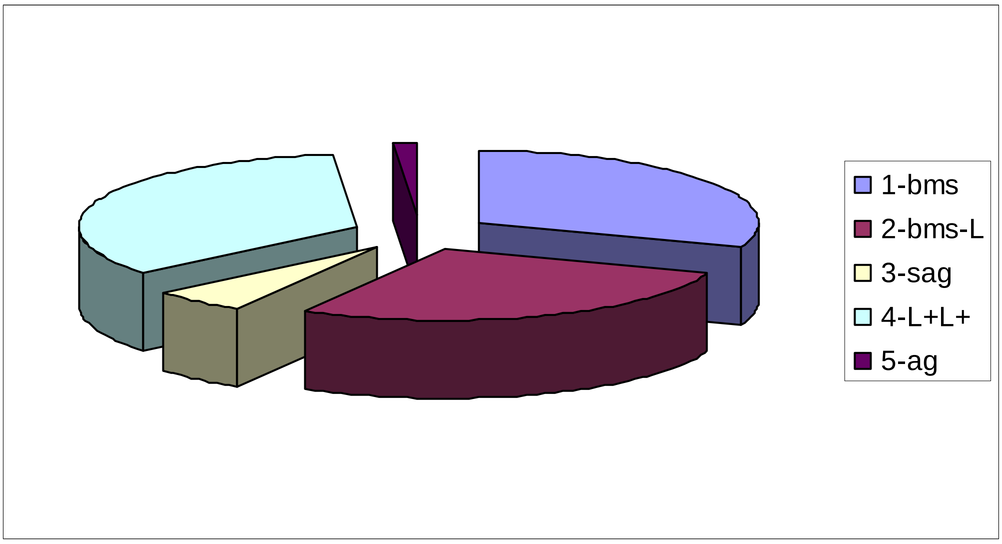


Fig. 3. PGE and Au minerals grouped by associations, sample 90-18, 978; see Table 5.

1- 30.6 vol. % **(bms)** – PGE and Au minerals attached to base metal sulphides; 2 – 27.6 vol. % (**bms-L)** liberated PGE and Au mineral grains attached to base metal sulphides but less than 10 %; 3 – 5.5 % (**sag),** PGE and Au minerals attached to sulphides and gangue; 4 **-** 34.7 % (**L+L$^+$**) completely liberated (free) particles of PGE and Au minerals; 5 – 1.5 % (**ag**), PGE and Au minerals attached to gangue.

The total of completely liberated precious metal mineral grains (**L+L$^+$**) from the heavy mineral concentrate is 34.7 %, and the total of grains attached to bms (**bms**+**bms-L**+**sag** associations) 63.7 % (Fig 3). Only 1.5 % of PGE and Au minerals are attached to gangue (**ag** association).

Based on Scanning Electron images (SEI), the precious metal minerals in the heavy concentrates can be divided into five different groups:

1. skaergaardite-bearing grains attached to base metal sulphides (**bms, bms-L**, Plate 4)
2. skaergaardite-bearing grains with different associations, attached to sulphides and gangue (**sag**) , and attached to gangue only (**ag**, Plate 5)
3. completely liberated skaergaardite grains (**L**, Plate 6)
4. rare, other PGMs than skaergaardite (Plate 7)
5. grains of Au and Ag minerals (Plate 8)

Description and chemistry of precious metal minerals

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

Description

Skaergaardite is the main precious metal mineral in the heavy concentrates of sample 90-18 978 (94.9 vol.%). The Skaergaard intrusion is the type locality for this mineral and skaergaardite was first described by the authors of this report (Rudashevsky et.al, 2004). It is found in the heavy mineral concentrates in the following forms:

1. dominant type, intergrowths with base metal sulphides (Cu-Fe sulphides and cobalt-pentlandite) - **bms** (Plate 4, #*1-54*; Plate 7, #*2;* **bms-L** (Plate 4, #*55-94*; Plate 7, #*4, 8*);
2. intergrowths with sulphide and gangue, **sag:** ilmenite (Plate 5, #*1-3*), chlorite (Plate 5, #*9-11*), hornblende (Plate 5, #*7, 8*);
3. intergrowth with gangue, **ag**: ilmenite (Plate 5, #*4*), plagioclase (Plate 5, #*5*), clinopyroxene (Plate 5, #*6*);
4. completely liberated (free) grains: **L** (Plate 6, #*1-28*).
5. intergrowths with other PGMs – vysotskite (Plate 7, #*8*), atokite (Plate 7, #*3, 4, 8*), and (Pd,Cu,Sn) alloy (Plate 7, #*2*).

The skaergaardite-bearing sulphide forms droplet (Plate 4, #*1-6, 13, 22, 24-27, 29* etc); or irregular-shaped grains (Plate 4, #*7-12, 14-21, 23, 28,30-54* etc).

Skaergaardite grains occur as:

1. isometric droplet-like grains with the rounded outlines (Plate 4, #*1-9, 55-62;* Plate 5, #*1, 2*; Plate 6, #*1-8, 13*; Plate 7, #*2, 3*);
2. euhedral crystals or partially euhedral grains (Plate 4, #*24-49, 63-77*; Plate 8, #*9*);
3. irregular shape grains (Plate 4, #*10-23, 50-54, 78-94*; Plate 5, #*3-11*; Plate 6, #*10-12, 14-28*; Plate 7, #*4-8*).

The relationships of skaergaarditre and sulphide phases are the following:

1. skaergaardite grains localized at the margin of sulphide globules or aggregates (Plate 4, #*1-6, 8, 9, 11-26, 28-51;* Plate 5*, #2*, *7-9*);
2. skaergaardite grains, inside globules and sulphide aggregates (Plate 4, #*7, 10*, *27*).

Rock-forming minerals (ilmenite, clinopyroxene, plagioclase, chlorite), are as a rule localized at the marginal part of skaergaardite grains (Plate 5, #*1-6, 9-11*).

Grain size of skaergaardite (140 grains) is 4-73μm with an average of 28μm (Table 3).

Mineral chemistry

The composition of skaergaardite is given in 126 analyses of 126 individual grains (Table 6, analyses 1-126). The average composition of skaergaardite (Table 6, analysis 127, wt%) is: Pd 59.4, Pt 0.1, Au 2.3, Cu 31.1, Fe 3.6, Zn 1.4, Sn 1.0, Te 0.3, Pb 0.4 Total 99.6, which corresponds to the formula:

$$(Pd_{0.96}Au_{0.02})_{0.98}(Cu_{0.85}Fe_{0.11}Zn_{0.04}Sn_{0.02})_{1.02}.$$

Typical substitutions in skaergaardite are: Pt up to 5.5 % (Table 6, analysis 19), Au up to 23.5 % (Table 6, analysis 53), Fe up to 6.6 % (Table 6, analysis 61), Zn up to 5.8 % (Table 6, analysis 44), Sn up to 19.6 % (Table 6, analysis 19), Te up to 1.9 % (Table 6, analysis 119), Pb up to 5.7 % (Table 6, analysis 104). The characteristic substitutions in the studied grains of skaergaardite are: Sn, Au, Te and Fe.

Elevated concentrations of Pt (1-5.5wt. %) are found in just 7 grains, whereas Au concentrations in skaergaardite (n=126) are distributed as follows (Table 7; Fig. 4).

Table 7: Au concentration in skaergaardite grains of the sample 90 18, 978

Interval, Au wt %	Number of analyses - Au
0-1	59
1-2.5	28
2.5-5	23
5-10	11
10-15	3
15-20	1
20-25	1

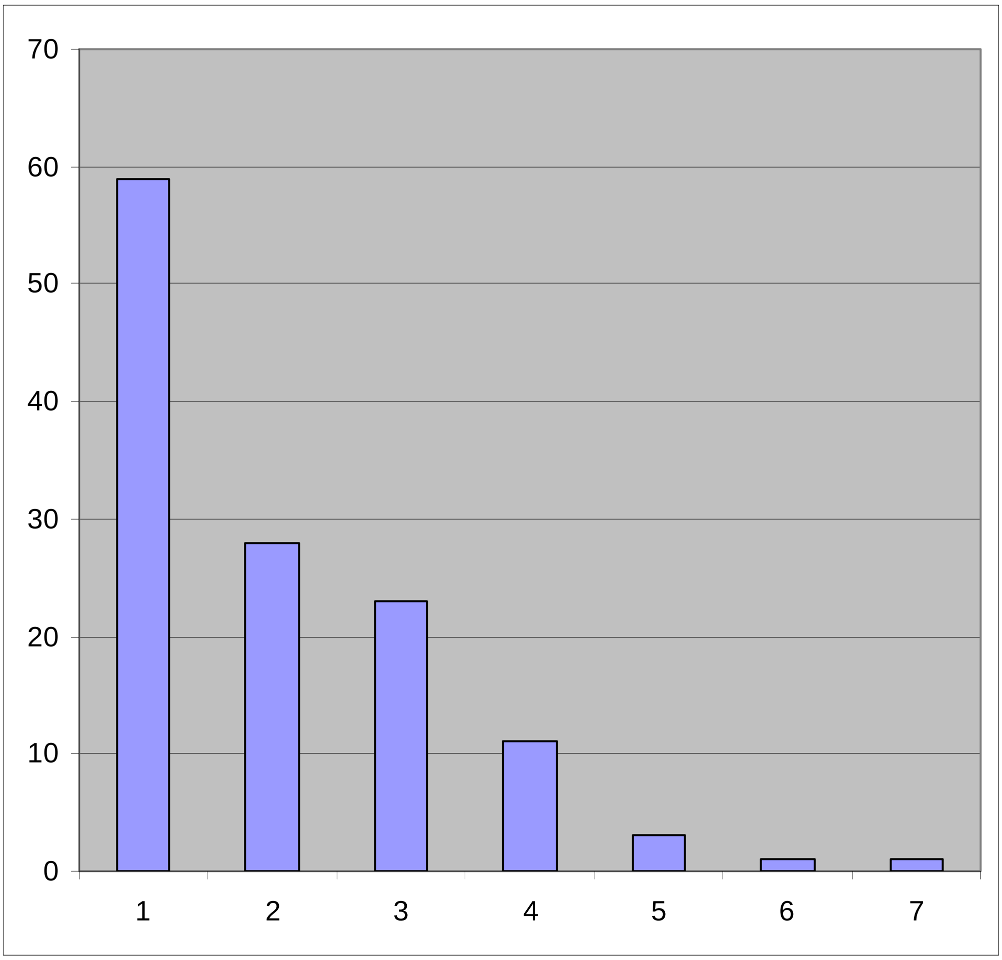


Fig. 4. Histogram of Au concentrations in skaergaardite grains (n=157), extracted in the heavy concentrates of the sample 90-18, 978. In abscissa: 1- 0-1 % Au, 2 – 1-2.5 %, 3 – 2.5-5 %, 4 – 5-10 %, 5 – 10-15 %, 6 – 15-20 % , 7 – 20-25 5 Au

Tetra-auricupride (Au,Pd,Pt)Cu

Twelve grains of tetra-auricupride (3.4 vol. % of all PGE and Au minerals) with irregular shapes were found in heavy mineral concentrates (see Table 3; Table 8, analyses 1-12). They are from 6 to 32μm in size, with an average of 20μm.

Tetra-auricupride is in the heavy concentrates found in the following forms:

1. intergrowths with base metal sulphides (**bms) -** (Plate 8, #*1, 8)*;
2. intergrowths with sulphides and gangue (**sag):** chlorite (Plate 8, #*1*) and tremolite - (Plate 8, #*5*);
3. completely liberated (free) grains (**L) -** (Plate 8, #*9*);
4. intergrowths with other precious metal minerals including keithconnite (Plate 8, #*2, 6-8*) and unnamed Au_3Cu (Plate 8, #*10, 11*).

Mineral chemistry

The composition of tetra-aucupride is given by 12 analyses of 12 individual grains (Table 8, analyses 1-12). The average composition of tetra-auricupride (Table 8, analysis 13, wt%) is: Pd 12.9, Pt 0.9, Au 59.6, Cu 25.7, Fe 0.5, Total 99.6; which corresponds to the formula:

$$(Au_{0.72}Pd_{0.29}Pt_{0.01})_{1.02}(Cu_{0.96}Fe_{0.02})_{0.98}.$$

Typical substitutions in tetra-auricupride are: Pd up to 20.1 % (Table 8, analysis 8), Pt up to 7.9 % (Table 8, analysis 1), Fe up to 1.3 % (Table 8, analysis 5).

Unnamed $(Au,Pd)_3Cu$

Two grains of the unnamed mineral $(Au,Pd)_3Cu$ were found in the heavy mineral concentrates. $(Au,Pd)_3Cu$ accounts 0.4 vol. % of all PGE and Au minerals in the studied sample. It forms irregular shaped grains with a size from 15 to 20 μm, and an average of 18 μm (see Table 3). Unnamed phase $(Au,Pd)_3Cu$ and tetra-auricupride occur in the heavy mineral HS concentrates as completely liberated grains (**L^+**, Plate 8, *10, 11*).

The chemical composition of unnamed $(Au,Pd)_3Cu$ is given by 2 analyses of 2 individual grains (Table 8, analyses 14, 15). The average composition of $(Au,Pd)_3Cu$ (Table 8, analysis 16) is (wt. %): Pd 12.8, Au 74.1, Cu 12.3, Fe 0.6, Total 99.8. The composition corresponds to the formula:

$$(Au_{2.16}Pd_{0.68})_{2.84}(Cu_{1.11}Fe_{0.05})_{1.16}.$$

Vysotskite (Pd,Cu,Ni)S

Two grains of vysotskite are found in heavy mineral concentrates. Vysotskite forms 0.2 vol. % of all PGE and Au minerals. It forms irregular shape grains 9-14 μm in size, with an average of 12 μm (see Table 3).

Vysotskite was found as inclusion in the marginal part of the interstitial chalcosine-bornite (**bms**, Plate 7, #*7*), or as inclusions together with atokite in skaergaardite grains associated with bornite (**bms-L**, Plate *7, 8*).

The composition of vysotskite is near-stoikiometric, as given in 2 analyses of 2 different grains (Table 9, analyses 1, 2).

Keithconnite $(Pd,Cu)_3(Te,Pb)$

Six grains of keithconnite (0.6 vol. % of all PGE and Au minerals) with irregular shapes were found (Table 3; Table 9, analyses 4-6). Their grain size varies from 6 to 32 μm, with an average of 20μm. Keithconnite is found in the following forms:

1. intergrowths with base metal sulphides (**bms**, Plate 7, #5, 6);
2. intergrowths with tetra-auricupride associated with chalcosine (**bms**, Plate 7, #8);
3. intergrowths with tetra-auricupride, only **(L^+**, Plate 8, #6, 7).

The composition of kethconnite is giver in 3 analyses of 3 individual grains (Table 9, analyses 4-6).

Atokite $(Pd,Cu)_3Sn$

Four grains of atokite (0.4 vol. % of all PGE and Au minerals) with irregular shapes are found in the heavy mineral concentrates (see Table 3; Table 9, analyses 7-9). Their size varies between 3 and 17μm with an average of 10μm. Atokite is found in the concentrates as:

1. inclusions in the marginal part of sulphide globule (Plate 7, #*1)* or inclusions of atokite+vysotskite in skaergaardite attached to interstitial bornite (**bms**, Plate 7, #*8*)

2. inclusions in the marginal part of skaergaardite grains (Plate 7, #*3, 4*); that may be completely liberated (**L^+**, Plate 7, #*3*), or attached to base metal sulphides (bornite+chalcosine or cobalt-pentlandite) (**bms**, Plate 7, #*2, 4*);

The chemical composition of atokite is given by 3 analyses of 3 individual grains (Table 9, analyses 7-9).

(Pd,Cu,Sn) alloy

Only one grain of (Pd,Cu,Sn) alloy with an irregular shape and a size of 12μm (0.1 vol. % of all PGE, Table 3) was found. It forms an inclusion in the marginal part of a skaergaardite grain attached to a bornite-chalcosine globule (see Plate 7, #*2*; Table 9, analysis 10).

Unnamed $Pd_2(Cu,Fe)TeBi$

This new and unnamed PGM with the formula $Pd_2(Cu,Fe)TeBi$ (Table 9, analysis 11) was found as a single, 8μm, inclusion in interstitial bornite (Plate 7, #*11*).

(Ag,Cu) alloy

One completely liberated irregular grain (16μm) of (Cu,Ag) alloys was found in the concentrates (Plate 8, #*12*; Table 8, analyses 17).

One, small (< 10 μm) PGM inclusion was found in one of the sulphide globules. It has a very complicated mineralogy (Plate 7, #*9, 10*), and is composed of by at least three PGMs: 1) (Cu,Pt)? alloy, 2) $(Cu,Pd,Pt)_{2+x}S$? (Table 9, analysis 3), 3) Pd-Cu-Pt-Ni-Pb sulphide (?) Precise compositions could not be obtained for these phase due to the very small grain size.

Bulk composition of PGMs of the sample 90-18 978

The relative concentrations of Pd, Au and Pt in the sample 90-18 978 can be calculated from the total concentration of precious metals, the determined recovery, the modal proportions and the compositions of the PGE and Au phases (Tables 3, 6-9). The estimated bulk compositions of the sample (assays of whole rock in brackets) are (ppb): Pd 1222 (1051), Au 96 (241), Pt 2 (28). Pd is concentrated in skaergaardite (~97 %), in other Pd PGMs (~2 %), and in gold minerals (~1 %). Au is distributed between Au minerals (tetra-auricupride and unnamed Au_3Cu, 52 %) and skaergaardite (48%). Pt is found in skaergaardite and in very fine grains of Pd-Pt-Cu sulphide (?). It is noted that the Pt concentration in the studied grains and bulk sample often are close to the level of detection.

Discussion

PGM-paragenesis

The mineralogical data shows that the the precious metal mineral paragenesis of sample 90-18 978 is totally dominanted by skaergaardite (94.9 vol.%) with minor Au minerals (tetra-auricupride and unnamed Au_3Cu, 3.8 vol.%), and rare PGMs (1.3 vol.%)

All the observations and the intergrain relations (Plates 4-8) suggest that all precious metal minerals, apart from Au mineral grains and (Ag,Cu) alloy, belong to a single paragenesis related to Cu-Fe sulphides. The Cu-Fe sulphides and precious metal minerals are synchronous and crystallized later than the bulk of the host gabbro and the rock-forming minerals: plagioclase, clinopyroxene, orthopyroxene, ilmenite and titaniferous magnetite.

The Cu-rich sulphide droplets contain droplets composed of several PGMs. The characteristic structure suggests the occurrence of two immiscible melts: 1) Cu-Fe sulphide melt and 2) metal melt enriched by Cu, Pd, Au and Pt which was separated from Cu-Fe sulphide melt. In their investigation of the Pd-Cu-S system (Karup-Møller & Makovicky, 1999) demonstrate the formation of Pd-rich immiscible, low S, melt during cooling. The Pd-rich droplets in Cu-rich droplets could be the example of the experimentally observed immiscibilty between Cu-rich and Pd-rich S-poor melts.

Two other samples from core 90-18 have previously been studied, one from the lowest parts of the mineralisation in Pd5 (depth 1012) and one from the Pd2a peak (depth 972), app. 5 meters above the top of the here studied sample. It is noted that Au is disolved in (Pd,Cu) alloys including Skaergaardite in the lower part of the intrusion and that increasing proportions of gold is concentrated in Au-minerals with stratigraphic height. It is also noted that within the Pd2 level the proportion of Au in Au-minerals increases from 50 to 100% in Pd2b and Pd2a. This evolution in a single mineralised levels of the mineralisation parallels the general evolution in the entire mineralisation, with Au (etc.) being concentrated in the top level of the mineralisation, irrespectively of the total stratigraphic height of the mineralisation. The observed variation in the three samples (from top to bottom) is:

Pd2a:	972m	100 % in Au minerals
Pd2b:	978m	~ 50 % in Au minerals
Pd5:	1012m	0 % in Au minerals

This stratigraphic variation is accompagnied by a general increase in the proportions of rare PGMs and in the diversity with increasing occurrence of intermetallides of Pd and a variety of elements including Sn, Te, Pb, As, Bi, Hg. A general fractionation of the elements of the Skaergaard mineralisation is observed.

We should also mention the close association of gold minerals with keithconnite. This is a characteristic for the Skaergaard mineralisation (Plate 7, #*6-8*). The positive correlations between Au and Te in skaergaardite are demonstrated by Rudashevsky et al. (2004).

The many observations of very small grains of atokite and (Pd,Cu,Sn) alloy at the margins of skaergaardite (Plate 8, #*2-4,*) and of keithconnite at the margin of tetra-auricupride (Plate 8, #*2, 6, 7*) seems best explained as the result of reaction between the sulphide-metallic phase and a metal-bearing residual fluid phase.

Many precious metal minerals grains, представляющих в “тяжелых» HS-concentrates are completely liberated (**L** and **L$^+$)** and attached to gangue (**ag**) associations. They include first of all of gold and silver minerals, and may also include grains of skaergaardite. They are best explained as grains crystallised interstitially between rock-forming minerals from a metal-bearing melts/fluid (volatile-rich), and not from the sulphide phase.

The observations allow the proposal of fractionation and redistribution of the more and most incompatible of the precious metals (Au, Ag, etc) from the lower to the upper part of the mineralisation by rising melt/fluid in equilibrium with the late hydrous phases observed in gangue. The heavy metals, especially gold, silver and tellurium would be transported up and by reaction be concentrated in sulphides already crystallised interstitially in residual space in the solidifying gabbro. The individual levels of mineralisation and the entire Skaergaard mineralisation is always relatively enriched in Au, Ag, etc. and a fractionation and transportation of Au, Ag, etc in late melt/fluid is a general process in the mineralisation.

Summary

1. A total of 157 PGM-grains were found in the heavy concentrates of sample 90-18 978 (800 g) using the newly patented hydroseparator CNT HS-11.

2. The dominating precious metal mineral is skaergaardite (Pd,Au)(Cu,Fe,Zn,Sn, 94.9 vol.%). Skaergaardite is followed by 7 minerals (~5 % of all precious metal minerals of the sample) including tetra-auricupride (Au,Pd,Pt)Cu (3.4 vol.%), keithconnite $(Pd,Cu)_3(Te,Pb,Sn)$(0.6 vol.%), atokite Pd_3Sn (0.4 vol.%), unnamed $(Au,Pd)_3Cu$ (0.4 vol.%), vysotskite (Pd,Cu,Ni)S (0.2 vol.%), (Pd,Cu,Sn) alloy (0.1 vol.%), unnamed $Pd_{ъ}$(Cu,Fe)TeBi (<0.1 vol.%), and one grain of (Ag,Cu) alloy.

3. The estimated bulk compositions of the sample (assays of whole rock in brackets) are (ppb): Pd 1222 (1051), Au 96 (241), Pt 2 (28). Pd is concentrated in skaergaardite (~97 %). in other Pd PGMs (~2 %), and in gold minerals (~1 %). Pt is found in skaergaardite and in very small grains of Pd-Pt-Cu sulphide (?). It is noted that the Pt concentration in the studied grains and bulk sample often are close to the level of detection.

4. All the observations and the intergrain relations suggest that all precious metal minerals (not accounting some grains of Au mineral and (Ag,Cu) alloy) belong to a single paragenesis together with Cu-Fe sulphides. The Cu-Fe sulphides and precious metal minerals are synchronous and crystallized later than primocrystic plagioclase, clinopyroxene, orthopyroxene, ilmenite and titaniferous magnetite.

5. The sulphide droplets contain droplets of PGMs. The characteristic structure suggests in accordance with experimental phase relations the occurrence of two immiscible melts: 1) Cu-Fe sulphide melt and 2) metal melt enriched by Cu, Pd, Au and Pt which was separated from Cu-Fe sulphide melt.

6. Heavy metals such as Au, Ag, Te, etc. were transported from the lower to the upper mineralised levels of the mineralisation by a complex melt/fluid compound, that would been in equilibrium with late interstitial and hydrous silicates, etc. The heavy metals were concentrated into Cu-Fe sulphide globules by reaction between this late melt/fluid and pre-existing interstitial sulphide aggregations.

References

Karup-Møller, S., and Makovicky, E., 1999, The phase system Cu-Pd-S at 900 degrees, 725 degrees, 550 degrees, and 400 degrees C: Neues Jahrbuch Für Mineralogie-Monatshefte, v. 1999, p. 551-567.

Nielsen, T.F.D., Andersen, J.C.Ø & Brooks, C.K. (2005). The Platinova Reef of the Skaergaard intrusion. Mineralogical Association of Canada Short Course **35**, 431-455.

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

Rudashevsky, N.S., MacDonalds, A.M., Cabri, L.J., Nielsen, T.D.F., Stanley, C.J., Kretzer, Yu.L., Rudashevsky, V.N., Skaergaardite, PdCu, a new platinum group intermetallic mineral from the Skaergaard intrusion, Greenland. *Mineralogical Magazine*, 2004, vol. 68 (4). Pp. 615-632.

Rudashevsky, N.S., Rudashevsky, V.N. Patent of Russian Federation #2281808, invention "Hydraulic Classifier", Moscow, August 20 , 2006.

Rudashevsky, N.S., Rudashevsky, V.N. Patent of Russian Federation #69418, industrial (useful) model, "Device for separation of solid particles", Moscow, December 27, 2007.

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 formulas of silicates and Fe-Ti oxides of oxide-rich tholeiitic gabbro (sample 90-18 978)**

Anal. #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Mineral	pl	pl	pl	cpx	cpx	opx	ol	ol	ol	ilm	ilm	ilm	timt	timt	timt
Analysis															
SiO_2	55.8	56.2	55.5	50.4	50.4	51.2	33.9	33.4	33.4	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
TiO_2	n.d.	n.d.	n.d.	0.30	0.70		n.d.	n.d.	n.d.	51.80	51.80	52.10	4.10	28.10	28.20
Al_2O_3	27.70	27.30	27.80	1.60	1.20	0.60	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	3.40	2.20	1.80
V_2O_3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.40	0.40	n.d.	1.90	1.00	1.10
Fe_2O_3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	2.20	2.00	1.10	55.20	10.50	11.20
FeO	n.d.	n.d.	n.d.	13.30	13.30	27.70	45.80	47.60	47.60	43.50	43.70	44.00	34.30	55.90	56.20
MnO	n.d.	n.d.	n.d.	0.40	0.30	0.60	0.70	0.60	0.60	0.40	0.60	0.40	0.20	0.50	0.30
MgO	n.d.	n.d.	n.d.	12.00	12.50	16.90	19.50	17.80	17.90	1.50	1.30	1.80	0.60	1.20	0.60
CaO	9.20	9.80	9.50	21.30	20.90	2.60	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Na_2O	6.30	5.70	6.20	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
K_2O	0.60	0.30	0.40	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
sum	99.60	99.30	99.40	99.30	99.30	99.60	99.90	99.40	99.50	99.80	99.80	99.40	99.70	99.40	99.40
Atomic proportions															
Si	2.52	2.54	2.52	1.94	1.93	1.98	1.00	1.00	1.00	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Ti	n.d.	n.d.	n.d.	0.01	0.02	n.d.	n.d.	n.d.	n.d.	0.98	0.98	0.99	0.11	0.79	0.79
Al	1.48	1.45	1.48	0.07	0.05	0.03	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.15	0.10	0.08
V	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.01	0.01	n.d	0.06	0.03	0.03
Fe^{3+}	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.04	0.04	0.02	1.56	0.29	0.31
Fe^{2+}	n.d.	n.d.	n.d.	0.43	0.43	0.90	1.13	1.19	1.19	0.91	0.91	0.91	1.08	1.75	1.74
Mn	n.d.	n.d.	n.d.	0.02	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.00	0.01	0.01
Mg	n.d.	n.d.	n.d.	0.69	0.72	0.98	0.85	0.79	0.80	0.06	0.05	0.07	0.03	0.03	0.03
Ca	0.45	0.48	0.46	0.88	0.86	0.11	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Na	0.55	0.50	0.54	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
K	0.04	0.02	0.02	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.

pl: plagioclase, cpx: clinopyroxene, ol: olivine, ilm: ilmenite, and timt: titanomagnetite.

Table 2. **Chemical composition and formulas of base metal sulphides in PGM-bearing globules of the heavy concentrates (sample 90-18 978)**

				weight percent of element						*atomic proportions*					
Anal. #	**Grain**	**Association**	**Mineral**	**Cu**	**Fe**	**Ni**	**Co**	**S**	**Total**	***Cu***	***Fe***	***Ni***	***Co***	***S***	***Total***
1	40 gr 3c	ch	ch	76.9	2.1	n.d.	n.d.	20.3	99.3	*1.93*	*0.06*	*n.d.*	*n.d.*	*1.01*	*3*
2	40 gr 17a	ch	ch	80.0	0.0	n.d.	n.d.	20.2	100.2	*2.00*	*0.00*	*n.d.*	*n.d.*	*1.00*	*3*
3	40 gr28	sk+ch	ch	78.1	1.4	n.d.	n.d.	19.9	99.4	*1.97*	*0.04*	*n.d.*	*n.d.*	*0.99*	*3*
4	63 gr2	ch	ch	79.8	0.7	n.d.	n.d.	20.1	100.6	*1.99*	*0.02*	*n.d.*	*n.d.*	*0.99*	*3*
5	63 gr14a	ch	ch	76.2	2.9	n.d.	n.d.	20.3	99.4	*1.91*	*0.08*	*n.d.*	*n.d.*	*1.00*	*3*
6	63 gr14b	ch	ch	76.4	2.3	n.d.	n.d.	19.8	99.5	*1.94*	*0.07*	*n.d.*	*n.d.*	*1.00*	*3*
7	63 gr15	sk+bn	bn	63.2	11.5	n.d.	n.d.	25.1	100.8	*5.01*	*1.04*	*n.d.*	*n.d.*	*3.95*	*10*
8	63 gr15a	ch	ch	79.1	0.6	n.d.	n.d.	20.2	99.9	*1.98*	*0.02*	*n.d.*	*n.d.*	*1.00*	*3*
9	63 gr15b	ch	ch	79.2	0.8	n.d.	n.d.	20.1	100.1	*1.98*	*0.02*	*n.d.*	*n.d.*	*1.00*	*3*
10	63 gr16	sk+dg	dg	75.0	2.7	n.d.	n.d.	21.4	99.1	*8.71*	*0.35*	*n.d.*	*n.d.*	*4.93*	*14*
11	63 gr17a	ch	ch	78.8	0.5	n.d.	n.d.	20.0	99.3	*1.99*	*0.01*	*n.d.*	*n.d.*	*1.00*	*3*
12	63 gr18a	ch	ch	79.5	0.9	n.d.	n.d.	20.3	100.7	*1.97*	*0.03*	*n.d.*	*n.d.*	*1.00*	*3*
13	63 gr18b	ch	ch	77.3	1.9	n.d.	n.d.	19.9	99.1	*1.95*	*0.05*	*n.d.*	*n.d.*	*1.00*	*3*
14	63 gr18d	ch	ch	78.6	0.9	n.d.	n.d.	19.9	99.4	*1.98*	*0.03*	*n.d.*	*n.d.*	*0.99*	*3*
15	63 gr18e	ch	ch	79.2	0.6	n.d.	n.d.	20.1	99.9	*1.98*	*0.02*	*n.d.*	*n.d.*	*1.00*	*3*
16	63 gr18f	dg	dg	75.7	2.2	n.d.	n.d.	21.3	99.2	*8.80*	*0.29*	*n.d.*	*n.d.*	*4.91*	*14*
17	63 gr18g	ch	ch	78.1	1.0	n.d.	n.d.	19.9	99	*1.97*	*0.03*	*n.d.*	*n.d.*	*1.00*	*3*
18	63 gr20a	ch	ch	79.1	0.7	n.d.	n.d.	20.3	100.1	*1.98*	*0.02*	*n.d.*	*n.d.*	*1.00*	*3*
19	63 gr21	sk+dg	dg	76.6	2.2	n.d.	n.d.	21.2	100	*8.85*	*0.29*	*n.d.*	*n.d.*	*4.86*	*14*
20	63 gr44	at+ch	ch	79.7	0.9	n.d.	n.d.	20.2	100.8	*1.98*	*0.03*	*n.d.*	*n.d.*	*0.99*	*3*
21	63 gr70	sk+ch	ch	77.5	2.3	n.d.	n.d.	20.2	100.0	*1.93*	*0.07*	*n.d.*	*n.d.*	*1.00*	*3*
22	63 gr93	sk+at+copn	copn	10.5	12.2	21.0	23.9	32.7	100.3	*1.29*	*1.71*	*2.80*	*3.18*	*8.01*	*17*
23	125 gr2a	dg+bn	dg	76.5	1.7	n.d.	n.d.	21.5	99.7	*8.84*	*0.23*	*n.d.*	*n.d.*	*4.93*	*14*
24	125 gr2a	dg+bn	bn	63.7	10.8	n.d.	n.d.	25.2	99.7	*5.06*	*0.98*	*n.d.*	*n.d.*	*3.97*	*10*
25	125 gr2c	bn+ch	bn	62.7	11.3	n.d.	n.d.	25.3	99.3	*4.99*	*1.02*	*n.d.*	*n.d.*	*3.99*	*10*
26	125 gr2d	ch+bn	bn	62.2	11.6	n.d.	n.d.	25.3	99.1	*4.95*	*1.05*	*n.d.*	*n.d.*	*3.99*	*10*
27	125 gr2e	ch+bn	bn	63.3	11.1	n.d.	n.d.	25.3	99.7	*5.02*	*1.01*	*n.d.*	*n.d.*	*3.98*	*10*
28	125 gr2g	ch+bn	bn	62.8	11.4	n.d.	n.d.	25.3	99.5	*4.99*	*1.03*	*n.d.*	*n.d.*	*3.98*	*10*
29	125 gr2h	ch+bn	bn	62.9	11.1	n.d.	n.d.	25.4	99.4	*5.00*	*1.00*	*n.d.*	*n.d.*	*4.00*	*10*
30	125 gr2h	ch+bn	ch	79.2	0.0	n.d.	n.d.	20.0	99.2	*2.00*	*0.00*	*n.d.*	*n.d.*	*1.00*	*3*

ch: chalcopyritr, dg:digenite, copn: cobalt pentlandite, bn: bornite, Sk: skaergaardite, at: atokite.

Table 3. **PGE and Au minerals in heavy concentrates (sample 90-18 978)**

N	Mineral	General formula	Number of grains	Grain size, µm min	max	average	Vol. %
1	Skaergaardite	(Pd,Au)(Cu,Fe,Zn,Sn)	140	4	73	28	94.9
2	Tetra-auricupride	(Au,Pd,Pt)(Cu,Fe)	12	6	32	20	3.4
3	Unnamed	$(Au,Pd)_3(Cu,Fe)$	2	15	20	18	0.4
4	Vysotskite	(Pd,Cu,Ni)S	2	9	14	12	0.2
5	Keithconnite	$(Pd,Cu)_3(Te,Pb)$	6	1	25	10	0.6
6	Atokite	$(Pd,Cu)_3Sn$	4	3	17	10	0.4
7	Alloy	(Pd,Cu,Sn)	1	-	-	12	0.1
8	Unnamed	$Pd_2(Cu,Fe)TeBi$	1	-	-	8	<0.1

Table 4. Size of precious metal mineral grains (sample 90-18 978)

N	Grain	Association	Type	Mineral	Area, μm^2	ECD, μm
1	125-1	sk-bn-ch	bms	sk	132	13.0
2	125-2	kth-ch-bn	bms	kth	10	3.6
3	40-10	sk-bn-ch-ilm	sag	sk	25	5.6
4	40-11	sk	L	sk	3256	64.4
5	40-12	kth-ch-bn	bms	kth	100	11.3
6	40-13	AuCu-bn-ch-chl	sag	AuCu	257	18.1
7	40-14	sk	L	sk	948	34.8
8	40-15	sk	L	sk	3107	62.9
9	40-16	sk-bn-ch-hb	sag	sk	145	13.6
10	40-17	sk	L	sk	1420	42.5
11	40-18	sk-ch-bn	bms	sk	12	3.9
12	40-19	sk-ch-bn	bms	sk	1698	46.5
13	40-1	sk	L	sk	4129	72.5
14	40-20	sk-bn	bms-L	sk	463	24.3
15	40-21	sk-ch-bn	bms-L	sk	1100	37.4
16	40-22	sk-ch-bn-hb	sag	sk	111	11.9
17	40-23	sk	L	sk	1684	46.3
18	40-24	sk-ch-bn	bms	sk	110	11.8
19	40-25	sk	L	sk	2007	50.6
20	40-26	sk-ch-bn	bms	sk	111	11.9
21	40-27	sk	L	sk	410	22.9
22	40-28	sk-ch	bms	sk	36	6.8
23	40-29	$Pd_2CuTeBi$-bn	bms	un	49	7.9
24	40-2	sk-bn	bms-L	sk	1471	43.3
25	40-30	sk	L	sk	961	35.0
26	40-31	sk-ch	bms-L	sk	1736	47.0
27	40-32	sk-bn	bms	sk	1250	39.9
28	40-33	sk	L	sk	2254	53.6
29	40-34	sk-ch-bn	bms	sk	284	19.0
30	40-35	sk-ch-bn	bms	sk	1615	45.4
31	40-36	sk	L	sk	1767	47.4
32	40-37	sk-ch-bn-mt	sag	sk	1322	41.0
33	40-3	sk+ch	bms	sk	360	21.4
34	40-4	sk+bn	bms	sk	337	20.7
35	40-5	sk+bn	bms-L	sk	3880	70.3
36	40-6	sk-bn-ch	bms	sk	3742	69.0
37	40-7	vys-bn-ch	bms	vys	149	13.8
38	40-8	sk-bn-ch	bms-L	sk	2847	60.2
39	40-9	sk-bn-ch	bms	sk	1463	43.2
40	63-100	sk	L	sk	396	22.5
41	63-101	sk-ch	bms	sk	20	5.0
42	63-102	sk-ch-bn	bms	sk	319	20.2
43	63-103	sk-ch-bn	bms	sk	119	12.3
44	63-104	sk-bn	bms	sk	151	13.9
45	63-105	sk-ch	bms	sk	195	15.8
46	63-106	sk-ch-bn	bms	sk	53	8.2
47	63-107	sk	L	sk	113	12.0
48	63-108	sk	L	sk	475	24.6
49	63-109	AuCu	L	AuCu	565	26.8
50	63-10	sk-bn	bms	sk	1650	45.8
51	63-111	sk-ch-bn	bms	sk	762	31.2
52	63-112	(Ag,Cu)	L	(Ag,Cu)	190	15.6
53	63-113	sk-bn-ch	bms	sk	329	20.5

table 4 continued

N	Grain	Association	Type	Mineral	Area, μm^2	ECD, μm
54	63-114	sk-bn-ilm	sag	sk	888	33.6
55	63-116	sk-bn-ch	bms	sk	670	29.2
56	63-117	sk-ch	bms	sk	172	14.8
57	63-118	sk-ch	bms	sk	35	6.7
58	63-11	sk-ch	bms	sk	376	21.9
59	63-12	sk-ch	bms-L	sk	1168	38.6
60	63-13	sk-ch-bn-chl	sag	sk	1264	40.1
61	63-14	sk	L	sk	1229	39.6
62	63-15	sk-bn	bms	sk	66	9.2
63	63-16	sk-dg	bms	sk	891	33.7
64	63-17	sk-bn-ch	bms	sk	869	33.3
65	63-18	sk-bn-ch	bms	sk	82	10.2
66	63-19	sk-bn-ch	bms-L	sk	1152	38.3
67	63-1	sk-bn-ch	bms	sk	260	18.2
68	63-20	sk-bn-cp	bms	sk	44	7.5
69	63-21	sk-dg	bms	sk	560	26.7
70	63-22	sk	L	sk	980	35.3
71	63-23	sk-ch	bms-L	sk	1740	47.1
72	63-24	sk-ilm	ag-L	sk	1354	41.5
73	63-25	sk-ch-bn	bms	sk	226	17.0
74	63-26	sk-bn-ch	bms	sk	621	28.1
75	63-27	sk	L	sk	508	25.4
76	63-28	sk-bn	bms-L	sk	1173	38.7
77	63-29	sk-bn	bms-L	sk	983	35.4
78	63-2	sk-ch	bms	sk	268	18.5
79	63-30	sk	L	sk	1134	38.0
80	63-31	sk	L	sk	441	23.7
81	63-32	sk	L	sk	601	27.7
82	63-33	sk-bn-ch	bms	sk	419	23.1
83	63-34	AuCu-bn-trm	sag	AuCu	218	16.7
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

table 4 continued

N	Grain	Association	Type	Mineral	Area, µm^2	ECD, µm
108	40-88	sk-(Pd,Sn,Cu)-bn	bms-L	sk	289	19.2
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
				total	66334	
					avr	27.4
					max	74
					min	1.6

Abbreviations

Minerals

(Pd,Sn,Cu)	alloy
(Ag,Cu)	alloy
AuCu	auricupride
$AuPdCu_2$	alloy, unnamed mineral
bn	bornite
ch	chalcosine
chl	chlorite
cp	chalcopyrite
dg	digenite
hb	hornblende
ilm	ilmenite
kth	keithconnite
mt	magnetite
$Pd_2CuTeBi$	alloy, unnamed mineral
sk	skaergaardite
trm	tremolite
vs	vasilite
vys	vysotskite
zv	zviaginsevite

Association

ag-L	with gangue, mostly liberated (>90%)
bms	intergrowth w. base metal sulfides
bms-L	mostly liberated (>90%)
L	liberated grains
LP	
sag	with gangue

Table 5

Table 5 can be found in the main text, page 11

Table 6. **Chemical composition and formulas of the skaergaardite in PGM-grains of the heavy concentrates (sample 90-18 978)**

			Analysis										*atomic proportions*								
Anal #	**Grain**	**Association**	**Pd**	**Pt**	**Au**	**Cu**	**Fe**	**Zn**	**Sn**	**Te**	**Pb**	**Total**	***Pd***	***Pt***	***Au***	***Cu***	***Fe***	***Zn***	***Sn***	***Te***	***Pb***
1	40 gr1	sk	61.9	0.0	0.0	30.9	3.8	1.6	1.4	0.0	0.0	99.6	*0.99*	*0.00*	*0.00*	*0.83*	*0.12*	*0.04*	*0.02*	*0.00*	*0.00*
2	40 gr2	sk+bn	61.3	0.0	0.0	32.2	3.1	0.9	1.8	0.0	0.0	99.3	*0.99*	*0.00*	*0.00*	*0.87*	*0.10*	*0.02*	*0.03*	*0.00*	*0.00*
3	40 gr3	sk+ch	60.3	0.0	1.7	31.0	3.6	2.4	0.0	0.9	0.0	99.9	*0.97*	*0.00*	*0.01*	*0.83*	*0.11*	*0.06*	*0.00*	*0.01*	*0.00*
4	40 gr4	sk+bn	57.6	0.0	4.3	30.8	4.1	1.8	0.0	0.9	0.0	99.5	*0.94*	*0.00*	*0.04*	*0.84*	*0.15*	*0.05*	*0.00*	*0.01*	*0.00*
5	40 gr5	sk+bn	62.1	0.0	0.0	30.6	3.6	1.8	1.1	0.0	0.0	99.5	*1.00*	*0.00*	*0.00*	*0.82*	*0.12*	*0.05*	*0.02*	*0.00*	*0.00*
6	40 gr6	sk+bn+ch	62.4	0.0	0.0	31.2	4.1	1.6	0.0	0.0	0.0	99.3	*1.00*	*0.00*	*0.00*	*0.83*	*0.13*	*0.04*	*0.00*	*0.00*	*0.00*
7	40 gr8	sk+bn+ch	62.4	0.0	0.0	31.1	3.5	1.2	1.6	0.0	0.0	99.8	*1.00*	*0.00*	*0.00*	*0.84*	*0.11*	*0.03*	*0.02*	*0.00*	*0.00*
8	40 gr9	sk+bn+ch	60.5	0.0	2.4	30.5	4.4	1.2	0.0	1.0	0.0	100.0	*0.98*	*0.00*	*0.02*	*0.82*	*0.13*	*0.03*	*0.00*	*0.01*	*0.00*
9	40 gr10	sk+bn+ch+ilm	60.5	0.0	0.0	31.0	2.2	1.4	2.4	0.0	3.3	100.8	*0.99*	*0.00*	*0.00*	*0.85*	*0.07*	*0.04*	*0.04*	*0.00*	*0.03*
10	40 gr11	sk	61.9	0.0	0.0	31.3	4.0	1.5	0.9	0.0	0.0	99.6	*0.99*	*0.00*	*0.00*	*0.84*	*0.12*	*0.04*	*0.01*	*0.00*	*0.00*
11	40 gr14	sk	61.1	0.0	0.0	31.9	3.5	1.4	1.1	0.0	0.0	99.0	*0.98*	*0.00*	*0.00*	*0.86*	*0.11*	*0.04*	*0.02*	*0.00*	*0.00*
12	40 gr15	sk	61.2	0.0	0.0	30.8	4.2	0.7	1.3	0.0	1.0	99.2	*0.99*	*0.00*	*0.00*	*0.83*	*0.13*	*0.02*	*0.02*	*0.00*	*0.01*
13	40 gr16	sk+bn+ch+hb	61.5	0.0	0.9	31.1	3.5	2.9	0.0	0.0	0.0	99.9	*0.98*	*0.00*	*0.01*	*0.83*	*0.11*	*0.07*	*0.00*	*0.00*	*0.00*
14	40 gr17	sk	61.6	0.0	0.0	31.3	3.2	1.0	2.5	0.0	0.0	99.6	*0.99*	*0.00*	*0.00*	*0.85*	*0.10*	*0.03*	*0.04*	*0.00*	*0.00*
15	40 gr20	sk+bn	62.5	0.0	0.0	32.0	3.7	0.6	1.0	0.0	0.0	99.8	*1.00*	*0.00*	*0.00*	*0.86*	*0.11*	*0.02*	*0.01*	*0.00*	*0.00*
16	40 gr21	sk+bn+ch	61.4	0.0	0.0	31.4	3.9	1.3	1.1	0.0	0.0	99.1	*0.99*	*0.00*	*0.00*	*0.84*	*0.12*	*0.03*	*0.02*	*0.00*	*0.00*
17	40 gr22	sk+bn+ch+hb	60.0	0.0	3.2	31.3	4.2	1.5	0.0	0.0	0.0	100.2	*0.96*	*0.00*	*0.03*	*0.84*	*0.13*	*0.04*	*0.00*	*0.00*	*0.00*
18	40 gr23	sk	62.3	0.0	0.0	31.5	4.6	0.6	0.7	0.0	0.0	99.8	*0.99*	*0.00*	*0.00*	*0.84*	*0.14*	*0.02*	*0.01*	*0.00*	*0.00*
19	40 gr24	sk+bn+ch	53.0	5.5	6.9	13.3	0.4	0.0	19.6	0.0	1.0	99.7	*1.05*	*0.06*	*0.07*	*0.44*	*0.02*	*0.00*	*0.35*	*0.00*	*0.01*
20	40 gr25	sk	62.1	0.0	0.0	31.8	3.9	0.9	0.8	0.0	0.0	99.5	*0.99*	*0.00*	*0.00*	*0.85*	*0.12*	*0.02*	*0.01*	*0.00*	*0.00*
21	40 gr26	sk+ch+bn	56.9	0.0	2.7	34.1	3.0	1.3	0.0	1.7	0.0	99.7	*0.91*	*0.00*	*0.02*	*0.92*	*0.09*	*0.03*	*0.00*	*0.02*	*0.00*
22	40 gr27	sk	54.0	0.0	8.8	31.1	2.6	2.0	0.0	1.1	0.0	99.6	*0.90*	*0.00*	*0.08*	*0.87*	*0.08*	*0.06*	*0.00*	*0.02*	*0.00*
23	40 gr28	sk+ch	62.6	0.0	1.0	30.7	3.4	1.0	0.0	0.6	1.1	100.4	*1.01*	*0.00*	*0.01*	*0.83*	*0.10*	*0.03*	*0.00*	*0.01*	*0.01*
24	40 gr30	sk	60.1	0.0	0.0	34.5	2.7	0.0	2.6	0.0	0.0	99.9	*0.96*	*0.00*	*0.00*	*0.92*	*0.08*	*0.00*	*0.04*	*0.00*	*0.00*
25	40 gr31	sk+ch	62.2	0.0	0.0	30.5	4.3	1.4	0.0	1.1	0.0	99.5	*1.00*	*0.00*	*0.00*	*0.82*	*0.13*	*0.04*	*0.02*	*0.00*	*0.00*
26	40 gr32	sk	61.8	0.0	0.0	30.8	4.7	0.9	0.0	0.0	1.3	99.5	*0.99*	*0.00*	*0.00*	*0.83*	*0.14*	*0.02*	*0.00*	*0.00*	*0.01*
27	40 gr33	sk	62.6	0.0	0.0	31.7	4.2	1.4	0.6	0.0	0.0	100.5	*0.99*	*0.00*	*0.00*	*0.84*	*0.13*	*0.04*	*0.01*	*0.00*	*0.00*
28	40 gr34	sk+ch+bn	59.1	0.0	0.0	26.3	0.4	0.0	12.5	0.0	1.4	99.7	*1.02*	*0.00*	*0.00*	*0.76*	*0.01*	*0.00*	*0.19*	*0.00*	*0.01*
29	40 gr35	sk+ch+bn	61.7	0.0	0.0	31.5	4.3	0.5	1.2	0.0	0.0	99.2	*0.99*	*0.00*	*0.00*	*0.85*	*0.13*	*0.01*	*0.02*	*0.00*	*0.00*
30	40 gr36	sk	61.9	0.0	0.0	29.5	5.3	1.4	0.0	1.3	0.0	99.4	*0.99*	*0.00*	*0.00*	*0.79*	*0.16*	*0.04*	*0.02*	*0.00*	*0.00*
31	40 gr37	sk+ch+bn	61.4	0.0	0.0	32.4	4.6	0.7	0.0	0.0	0.0	99.1	*0.98*	*0.00*	*0.00*	*0.86*	*0.14*	*0.04*	*0.00*	*0.00*	*0.00*
32	40 gr38	sk+ch+bn+bt+ilm	60.9	0.0	0.0	31.3	1.8	1.3	2.9	0.0	1.7	99.9	*0.99*	*0.00*	*0.00*	*0.86*	*0.06*	*0.03*	*0.04*	*0.00*	*0.01*

table 6 continued

Anal #	Grain	Association	Analysis Pd	Pt	Au	Cu	Fe	Zn	Sn	Te	Pb	Total	*atomic proportions Pd*	*Pt*	*Au*	*Cu*	*Fe*	*Zn*	*Sn*	*Te*	*Pb*
33	63 gr1	sk+bn+ch	60.0	0.0	1.2	29.8	4.8	2.5	0.0	0.8	0.0	99.1	*0.96*	*0.00*	*0.01*	*0.80*	*0.15*	*0.07*	*0.00*	*0.01*	*0.00*
34	63 gr2	sk+ch	55.2	0.0	5.8	32.9	3.5	1.1	0.0	0.7	0.0	99.2	*0.90*	*0.00*	*0.05*	*0.90*	*0.11*	*0.03*	*0.00*	*0.01*	*0.00*
35	63 gr3	sk+bn+ch	61.6	0.0	0.0	28.8	6.3	2.3	0.0	0.0	0.0	99.0	*0.98*	*0.00*	*0.00*	*0.77*	*0.19*	*0.06*	*0.00*	*0.00*	*0.00*
36	63 gr5	sk	61.2	0.0	0.0	32.5	3.1	0.4	2.3	0.0	0.0	99.5	*0.99*	*0.00*	*0.00*	*0.88*	*0.09*	*0.01*	*0.03*	*0.00*	*0.00*
37	63 gr6	sk+bn	60.6	0.0	0.0	31.5	2.2	0.9	3.5	0.0	1.7	100.4	*0.98*	*0.00*	*0.00*	*0.86*	*0.07*	*0.02*	*0.05*	*0.00*	*0.01*
38	63 gr7	sk+ch	62.4	0.0	0.0	31.2	5.7	0.6	0.0	0.0	0.0	99.9	*0.99*	*0.00*	*0.00*	*0.83*	*0.17*	*0.02*	*0.00*	*0.00*	*0.00*
39	63 gr10	sk+bn	61.1	0.0	0.0	31.4	3.9	1.2	1.4	0.0	0.0	99.0	*0.98*	*0.00*	*0.00*	*0.85*	*0.12*	*0.03*	*0.02*	*0.00*	*0.00*
40	63 gr11	sk+ch	59.7	0.0	1.3	31.7	3.4	2.1	0.0	0.6	1.0	99.8	*0.96*	*0.00*	*0.01*	*0.85*	*0.11*	*0.06*	*0.00*	*0.01*	*0.01*
41	63 gr12	sk+ch	61.3	0.0	0.0	33.0	5.2	0.0	0.0	0.0	0.0	99.5	*0.97*	*0.00*	*0.00*	*0.87*	*0.16*	*0.00*	*0.00*	*0.00*	*0.00*
42	63 gr14	sk	61.1	0.0	0.0	31.3	3.1	1.4	2.3	0.0	0.0	99.2	*0.99*	*0.00*	*0.00*	*0.85*	*0.10*	*0.03*	*0.00*	*0.00*	*0.00*
43	63 gr16	sk+dg	60.1	0.0	1.4	30.6	5.2	1.4	0.0	1.0	0.0	99.6	*0.96*	*0.00*	*0.01*	*0.82*	*0.16*	*0.04*	*0.00*	*0.01*	*0.00*
44	63 gr17	sk+bn+ch	59.9	0.0	0.0	32.4	0.9	5.8	0.0	0.0	0.0	99.0	*0.99*	*0.00*	*0.00*	*0.90*	*0.03*	*0.00*	*0.09*	*0.00*	*0.00*
45	63 gr19	sk+bn+ch	59.8	0.0	2.1	30.3	4.9	1.5	0.0	0.9	0.0	99.5	*0.96*	*0.00*	*0.02*	*0.82*	*0.15*	*0.04*	*0.00*	*0.01*	*0.00*
46	63 gr20	sk+cp+bn	59.7	0.0	0.0	32.3	2.0	1.1	2.0	0.0	1.4	99.1	*0.97*	*0.00*	*0.00*	*0.90*	*0.06*	*0.03*	*0.03*	*0.00*	*0.01*
47	63 gr21	sk+dg	60.6	0.0	1.5	33.2	3.2	1.3	0.0	0.0	0.0	99.8	*0.97*	*0.00*	*0.01*	*0.89*	*0.10*	*0.03*	*0.00*	*0.00*	*0.00*
48	63 gr22	sk	61.1	0.0	0.0	29.8	3.5	1.0	4.2	0.0	0.0	99.6	*0.99*	*0.00*	*0.00*	*0.81*	*0.11*	*0.03*	*0.06*	*0.00*	*0.00*
49	63 gr23	sk	62.4	0.0	0.0	31.2	4.6	2.1	0.0	0.0	0.0	100.3	*0.98*	*0.00*	*0.00*	*0.82*	*0.14*	*0.05*	*0.00*	*0.00*	*0.00*
50	63 gr24	sk+ilm	62.0	0.0	0.0	31.9	3.6	1.2	0.9	0.0	0.0	99.6	*0.99*	*0.00*	*0.00*	*0.85*	*0.11*	*0.03*	*0.01*	*0.00*	*0.00*
51	63 gr25	sk+bn+ch	60.2	0.0	0.0	33.0	1.6	0.0	5.2	0.0	0.0	100.0	*0.98*	*0.00*	*0.00*	*0.90*	*0.05*	*0.00*	*0.08*	*0.00*	*0.00*
52	63 gr26	sk+bn+ch	61.9	0.0	0.0	31.0	3.2	0.6	3.6	0.0	0.0	100.3	*1.00*	*0.00*	*0.00*	*0.84*	*0.10*	*0.02*	*0.05*	*0.00*	*0.00*
53	63 gr27	sk	40.9	1.8	23.5	31.4	1.4	0.0	0.0	1.1	0.0	100.1	*0.74*	*0.02*	*0.23*	*0.95*	*0.05*	*0.00*	*0.00*	*0.02*	*0.00*
54	63 gr28	sk+bn	61.7	0.0	0.0	31.4	2.1	0.0	3.1	0.0	1.4	99.7	*1.01*	*0.00*	*0.00*	*0.86*	*0.07*	*0.00*	*0.05*	*0.00*	*0.01*
55	63 gr29	sk+bn	61.0	0.0	0.0	31.9	2.8	0.5	1.9	0.0	1.7	99.8	*0.99*	*0.00*	*0.00*	*0.87*	*0.09*	*0.01*	*0.03*	*0.00*	*0.01*
56	63 gr30	sk	59.1	0.0	2.1	31.0	1.1	0.0	3.9	1.1	1.7	100.0	*0.99*	*0.00*	*0.02*	*0.87*	*0.04*	*0.00*	*0.06*	*0.02*	*0.01*
57	63 gr31	sk	52.7	0.0	9.3	32.0	3.2	1.3	0.0	0.8	0.0	99.3	*0.88*	*0.00*	*0.08*	*0.89*	*0.10*	*0.04*	*0.00*	*0.01*	*0.00*
58	63 gr32	sk	63.0	0.0	0.0	29.2	4.5	2.8	0.0	0.0	0.0	99.5	*1.01*	*0.00*	*0.00*	*0.78*	*0.14*	*0.07*	*0.00*	*0.00*	*0.00*
59	63 gr33	sk+bn+ch	56.9	0.0	4.9	31.3	4.1	1.6	0.0	0.8	0.0	99.7	*0.92*	*0.00*	*0.04*	*0.85*	*0.13*	*0.04*	*0.00*	*0.01*	*0.00*
60	63 gr35	sk+at	60.0	0.0	0.0	31.5	0.6	0.0	5.2	0.0	2.7	100.0	*1.00*	*0.00*	*0.00*	*0.88*	*0.02*	*0.00*	*0.00*	*0.00*	*0.02*
61	63 gr36	sk+bn+ch	60.5	0.0	1.6	30.8	6.6	0.6	0.0	0.0	0.0	100.1	*0.96*	*0.00*	*0.01*	*0.81*	*0.20*	*0.02*	*0.00*	*0.00*	*0.00*
62	63 gr37	sk+ch+bn	60.4	0.0	1.7	30.7	4.3	2.1	0.0	0.9	0.0	100.1	*0.97*	*0.00*	*0.01*	*0.82*	*0.13*	*0.06*	*0.00*	*0.01*	*0.00*
63	63 gr38	sk+bn	55.4	0.0	7.5	31.8	3.5	2.2	0.0	0.0	0.0	100.6	*0.90*	*0.00*	*0.07*	*0.87*	*0.11*	*0.06*	*0.00*	*0.00*	*0.00*
64	63 gr39	sk+fbn+chl	57.8	0.0	3.7	33.4	3.9	1.3	0.0	0.7	0.0	100.8	*0.92*	*0.00*	*0.03*	*0.89*	*0.12*	*0.03*	*0.00*	*0.01*	*0.00*
65	63 gr40	sk+bn+ch	60.5	0.0	0.0	31.8	2.4	1.6	1.5	0.0	1.9	99.7	*0.98*	*0.00*	*0.00*	*0.86*	*0.08*	*0.04*	*0.02*	*0.00*	*0.02*
66	63 gr42	sk+ch+bn	47.4	0.0	16.7	32.3	1.6	0.0	0.0	1.5	0.0	99.5	*0.82*	*0.00*	*0.16*	*0.94*	*0.05*	*0.00*	*0.00*	*0.02*	*0.00*

table 6 continued

			weight percent of element										*atomic proportions*								
Anal #	**Grain**	**Association**	**Pd**	**Pt**	**Au**	**Cu**	**Fe**	**Zn**	**Sn**	**Te**	**Pb**	**Total**	***Pd***	***Pt***	***Au***	***Cu***	***Fe***	***Zn***	***Sn***	***Te***	***Pb***
67	63 gr43	sk+cpx	57.4	1.0	1.4	25.5	0.7	0.0	10.0	0.0	4.2	100.2	*1.01*	*0.01*	*0.01*	*0.75*	*0.02*	*0.00*	*0.16*	*0.00*	*0.04*
68	63 gr45	sk+ch+bn	60.9	0.0	0.0	31.6	4.8	2.1	0.0	0.0	0.0	99.4	*0.96*	*0.00*	*0.00*	*0.84*	*0.14*	*0.06*	*0.00*	*0.00*	*0.00*
69	63 gr46	sk	61.9	0.0	0.0	31.1	5.1	1.0	0.0	0.0	0.0	99.1	*0.99*	*0.00*	*0.00*	*0.83*	*0.15*	*0.03*	*0.00*	*0.00*	*0.00*
70	63 gr47	sk+bn+ch	59.3	0.0	2.2	31.8	5.0	1.5	0.0	0.6	0.0	100.4	*0.94*	*0.00*	*0.02*	*0.84*	*0.15*	*0.04*	*0.00*	*0.01*	*0.00*
71	63 gr52	sk+pl	49.9	1.0	11.8	30.9	2.9	1.6	0.0	0.9	0.0	99.0	*0.85*	*0.01*	*0.11*	*0.88*	*0.09*	*0.04*	*0.00*	*0.01*	*0.00*
72	63 gr53	sk+bn+ch	59.0	0.0	2.1	31.9	5.1	1.5	0.0	0.0	0.0	99.6	*0.94*	*0.00*	*0.02*	*0.85*	*0.15*	*0.04*	*0.00*	*0.00*	*0.00*
73	63 gr54	sk+ch+bn	57.8	0.0	1.9	32.8	4.7	2.1	0.0	0.0	0.0	99.3	*0.92*	*0.00*	*0.02*	*0.87*	*0.14*	*0.05*	*0.00*	*0.00*	*0.00*
74	63 gr55	sk+bn+ch	57.0	0.0	4.4	31.2	3.7	1.2	0.0	1.3	0.0	98.8	*0.94*	*0.00*	*0.04*	*0.86*	*0.12*	*0.03*	*0.00*	*0.02*	*0.00*
75	63 gr56	sk+bn	59.7	0.0	2.2	31.8	3.9	1.5	0.0	0.6	0.0	99.7	*0.96*	*0.00*	*0.02*	*0.85*	*0.12*	*0.04*	*0.00*	*0.01*	*0.00*
76	63 gr57	sk+bn	60.5	0.0	1.7	29.4	4.4	2.2	0.0	0.8	0.0	99.0	*0.98*	*0.00*	*0.02*	*0.80*	*0.14*	*0.06*	*0.00*	*0.01*	*0.00*
77	63 gr58	sk	58.6	0.0	3.7	30.7	3.5	1.4	0.0	1.3	0.0	99.2	*0.96*	*0.00*	*0.03*	*0.84*	*0.11*	*0.04*	*0.00*	*0.02*	*0.00*
78	63 gr60	sk+ch	49.6	0.0	13.1	32.6	2.2	1.8	0.0	0.0	0.0	99.3	*0.84*	*0.00*	*0.12*	*0.92*	*0.07*	*0.05*	*0.00*	*0.00*	*0.00*
79	63 gr61	sk+ch+bn	51.5	0.0	10.3	31.5	3.8	1.0	0.0	0.0	1.5	99.6	*0.86*	*0.00*	*0.09*	*0.88*	*0.12*	*0.03*	*0.00*	*0.00*	*0.01*
80	63 gr62	sk+bn+ch	60.2	0.0	0.0	31.2	0.8	0.0	4.2	0.0	3.3	99.7	*1.01*	*0.00*	*0.00*	*0.88*	*0.03*	*0.00*	*0.06*	*0.00*	*0.03*
81	63 gr63	sk+bn	56.9	0.0	6.3	30.4	3.4	1.5	0.0	1.5	0.0	100.0	*0.94*	*0.00*	*0.06*	*0.84*	*0.11*	*0.04*	*0.02*	*0.02*	*0.00*
82	63 gr64	sk+bn	61.0	0.0	0.0	31.0	5.0	1.4	0.0	1.0	0.0	99.4	*0.97*	*0.00*	*0.00*	*0.83*	*0.15*	*0.04*	*0.00*	*0.01*	*0.00*
83	63 gr66	sk+ch	57.8	0.0	4.8	31.0	4.0	1.1	0.0	1.1	0.0	99.8	*0.94*	*0.00*	*0.04*	*0.85*	*0.12*	*0.03*	*0.00*	*0.02*	*0.00*
84	63 gr67	sk+ch+bn	58.9	0.0	4.5	29.6	3.8	3.8	0.0	0.0	0.0	100.6	*0.95*	*0.00*	*0.04*	*0.80*	*0.12*	*0.10*	*0.00*	*0.00*	*0.00*
85	63 gr68	sk+bn+ch	59.9	0.0	0.0	31.4	4.1	2.8	0.0	0.0	1.2	99.4	*0.96*	*0.00*	*0.00*	*0.84*	*0.12*	*0.07*	*0.00*	*0.00*	*0.00*
86	63 gr69	sk+(Pd,Cu,Sn)+bn+ch	57.1	0.0	3.0	31.6	0.5	0.0	4.9	0.0	2.8	99.9	*0.96*	*0.00*	*0.03*	*0.89*	*0.02*	*0.00*	*0.07*	*0.00*	*0.02*
87	63 gr73	sk+bn+ch	61.1	0.0	0.0	33.2	3.3	0.0	1.2	0.0	1.3	100.1	*0.98*	*0.00*	*0.00*	*0.89*	*0.10*	*0.00*	*0.02*	*0.00*	*0.01*
88	63 gr74	sk	60.2	0.0	1.5	31.1	4.8	1.7	0.0	0.5	0.0	99.8	*0.96*	*0.00*	*0.01*	*0.83*	*0.15*	*0.04*	*0.00*	*0.01*	*0.00*
89	63 gr75	sk+bn+ch	59.9	0.0	2.3	30.6	4.5	2.0	0.0	0.0	0.0	99.3	*0.97*	*0.00*	*0.02*	*0.82*	*0.14*	*0.05*	*0.00*	*0.00*	*0.00*
90	63 gr76	sk+bn	61.3	0.0	0.0	32.3	3.9	1.7	0.0	0.0	0.0	99.2	*0.98*	*0.00*	*0.00*	*0.86*	*0.12*	*0.04*	*0.00*	*0.00*	*0.00*
91	63 gr77	sk+vys+at+bn	59.7	0.0	0.0	32.4	4.7	1.5	1.1	0.0	0.0	99.4	*0.95*	*0.00*	*0.00*	*0.86*	*0.14*	*0.04*	*0.02*	*0.00*	*0.00*
92	63 gr78	sk+ch+bn	58.2	0.0	3.4	31.3	4.2	2.0	0.0	0.0	0.0	99.1	*0.94*	*0.00*	*0.03*	*0.85*	*0.13*	*0.05*	*0.00*	*0.00*	*0.00*
93	63 gr79	sk+bn	57.8	0.0	3.3	31.8	3.2	1.9	0.0	1.0	0.0	99.0	*0.94*	*0.00*	*0.03*	*0.87*	*0.10*	*0.05*	*0.00*	*0.01*	*0.00*
94	63 gr80	sk+bn+ch	52.9	0.0	7.8	34.4	3.0	1.0	0.0	0.9	0.0	100.0	*0.86*	*0.00*	*0.07*	*0.94*	*0.09*	*0.03*	*0.00*	*0.01*	*0.00*
95	63 gr81	sk+bn	61.3	0.0	1.3	31.3	4.9	2.2	0.0	0.0	0.0	101.0	*0.96*	*0.00*	*0.01*	*0.82*	*0.15*	*0.06*	*0.00*	*0.00*	*0.00*
96	63 gr82	sk+ch+bn	60.5	0.0	1.4	31.6	5.2	0.9	0.0	0.6	0.0	100.2	*0.96*	*0.00*	*0.01*	*0.84*	*0.16*	*0.02*	*0.00*	*0.01*	*0.00*
97	63 gr83	sk+bn	55.7	0.0	5.7	31.2	2.7	1.9	0.0	0.0	2.3	99.5	*0.92*	*0.00*	*0.05*	*0.87*	*0.08*	*0.05*	*0.00*	*0.00*	*0.02*
98	63 gr84	sk+bn	60.0	0.0	1.6	32.2	4.7	1.4	0.0	0.0	0.0	99.9	*0.95*	*0.00*	*0.01*	*0.86*	*0.14*	*0.04*	*0.00*	*0.00*	*0.00*
99	63 gr85	sk+bn	60.2	0.0	2.1	31.0	4.7	1.6	0.0	0.8	0.0	100.4	*0.96*	*0.00*	*0.02*	*0.83*	*0.14*	*0.04*	*0.00*	*0.01*	*0.00*
100	63 gr86	sk+ch+bn	62.4	0.0	0.0	31.4	5.0	0.9	0.0	0.0	0.0	99.7	*0.99*	*0.00*	*0.00*	*0.83*	*0.15*	*0.12*	*0.00*	*0.00*	*0.00*
101	63 gr88	sk+ch	59.8	0.0	0.0	35.4	2.3	2.1	0.0	0.0	0.0	99.6	*0.94*	*0.00*	*0.00*	*0.93*	*0.07*	*0.15*	*0.00*	*0.00*	*0.00*
102	63 gr89	sk+bn	61.2	0.0	0.0	31.0	4.9	2.7	0.0	0.0	0.0	99.8	*0.96*	*0.00*	*0.00*	*0.82*	*0.15*	*0.07*	*0.00*	*0.00*	*0.00*

table 6 continued

Anal #	Grain	Association	Analysis Pd	Pt	Au	Cu	Fe	Zn	Sn	Te	Pb	Total	*atomic proportions Pd*	*Pt*	*Au*	*Cu*	*Fe*	*Zn*	*Sn*	*Te*	*Pb*
103	63 gr91	sk+bn+ch	58.1	0.0	4.3	31.0	3.9	1.9	0.0	0.9	0.0	100.1	*0.94*	*0.00*	*0.04*	*0.84*	*0.12*	*0.05*	*0.00*	*0.01*	*0.00*
104	63 gr93	sk+at+copn	60.1	0.0	0.0	31.5	1.4	0.0	1.1	0.0	5.7	99.8	*1.01*	*0.00*	*0.00*	*0.88*	*0.05*	*0.00*	*0.02*	*0.00*	*0.05*
105	63 gr95	sk	53.2	0.0	8.8	32.8	2.6	1.3	0.0	0.9	0.0	99.6	*0.88*	*0.00*	*0.08*	*0.91*	*0.08*	*0.04*	*0.00*	*0.01*	*0.00*
106	63 gr97	sk+bn	61.3	0.0	0.0	32.3	3.8	2.0	0.0	0.0	0.0	99.4	*0.98*	*0.00*	*0.00*	*0.86*	*0.12*	*0.05*	*0.00*	*0.00*	*0.00*
107	63 gr99	sk+ch+bn	59.2	0.0	2.5	28.2	3.4	3.4	0.0	0.8	1.8	99.3	*0.97*	*0.00*	*0.02*	*0.78*	*0.11*	*0.09*	*0.00*	*0.01*	*0.01*
108	63 gr100	sk	62.3	0.0	0.0	33.2	5.2	0.0	0.0	0.0	0.0	100.7	*0.98*	*0.00*	*0.00*	*0.87*	*0.15*	*0.00*	*0.00*	*0.00*	*0.00*
109	63 gr102	sk+ch+bn	59.5	0.0	4.3	30.6	3.5	2.5	0.0	0.0	0.0	100.4	*0.96*	*0.00*	*0.04*	*0.83*	*0.11*	*0.07*	*0.00*	*0.00*	*0.00*
110	63 gr103	sk+ch+bn	53.4	1.7	7.9	30.6	3.1	1.5	0.0	0.8	0.0	99.0	*0.90*	*0.02*	*0.07*	*0.86*	*0.10*	*0.04*	*0.00*	*0.01*	*0.00*
111	63 gr104	sk+bn	56.6	0.0	6.5	30.6	2.7	2.1	0.0	0.9	0.0	99.4	*0.94*	*0.00*	*0.06*	*0.85*	*0.09*	*0.06*	*0.00*	*0.01*	*0.00*
112	63 gr105	sk+ch	55.8	0.0	4.8	33.4	3.5	1.1	0.0	0.6	0.0	99.2	*0.91*	*0.00*	*0.04*	*0.91*	*0.11*	*0.03*	*0.00*	*0.01*	*0.00*
113	63 gr106	sk+ch+bn	55.7	2.1	3.6	30.5	3.1	2.1	0.0	0.9	1.4	99.4	*0.92*	*0.02*	*0.03*	*0.84*	*0.10*	*0.06*	*0.00*	*0.01*	*0.01*
114	63 gr107	sk	62.5	0.0	0.0	29.9	2.2	1.7	1.9	0.0	1.2	99.4	*1.03*	*0.00*	*0.00*	*0.82*	*0.07*	*0.05*	*0.03*	*0.00*	*0.01*
115	63 gr108	sk	60.9	0.0	2.5	29.8	4.1	2.2	0.0	0.0	0.0	99.5	*0.99*	*0.00*	*0.02*	*0.81*	*0.13*	*0.06*	*0.00*	*0.00*	*0.00*
116	63 gr110	sk	59.2	0.0	3.6	30.0	4.3	2.0	0.0	0.0	0.0	99.1	*0.96*	*0.00*	*0.03*	*0.82*	*0.13*	*0.05*	*0.00*	*0.00*	*0.00*
117	63 gr111	sk+ch+bn	62.9	0.0	0.0	30.6	5.3	0.0	1.0	0.0	0.0	99.8	*1.00*	*0.00*	*0.00*	*0.82*	*0.16*	*0.00*	*0.01*	*0.00*	*0.00*
118	63 gr113	sk+bn+ch	60.6	0.0	1.1	30.0	4.6	0.7	0.0	0.6	1.4	99.0	*0.99*	*0.00*	*0.01*	*0.82*	*0.14*	*0.02*	*0.00*	*0.01*	*0.01*
119	63 gr114	sk+bn+ilm	59.2	0.0	2.9	31.0	3.3	1.7	0.0	1.9	0.0	99.9	*0.97*	*0.00*	*0.03*	*0.83*	*0.10*	*0.05*	*0.00*	*0.03*	*0.00*
120	63 gr115	sk	61.9	0.0	1.2	30.0	4.5	1.9	0.0	0.0	0.0	99.5	*0.99*	*0.00*	*0.01*	*0.81*	*0.14*	*0.05*	*0.00*	*0.00*	*0.00*
121	63 gr116	sk+bn+ch	60.3	0.0	3.0	29.9	5.0	1.5	0.0	0.0	0.0	99.7	*0.97*	*0.00*	*0.03*	*0.81*	*0.15*	*0.04*	*0.00*	*0.00*	*0.00*
122	63 gr117	sk+ch	61.5	0.0	0.0	31.0	3.9	3.1	0.0	0.0	0.0	99.5	*0.98*	*0.00*	*0.00*	*0.82*	*0.12*	*0.08*	*0.00*	*0.00*	*0.00*
123	80 gr1	sk+bn+ch+ilm	55.7	1.7	4.1	30.0	1.0	0.0	5.5	0.0	1.5	99.5	*0.95*	*0.02*	*0.04*	*0.86*	*0.03*	*0.00*	*0.08*	*0.00*	*0.01*
124	80 gr2	sk+ch+bn	58.0	0.0	3.8	31.0	4.2	1.5	0.0	1.1	0.0	99.6	*0.94*	*0.00*	*0.03*	*0.84*	*0.13*	*0.04*	*0.00*	*0.02*	*0.00*
124	80 gr3	sk+bn+ch	60.8	0.0	1.0	32.2	3.7	2.6	0.0	0.0	0.0	100.3	*0.96*	*0.00*	*0.01*	*0.85*	*0.11*	*0.07*	*0.00*	*0.00*	*0.00*
125	80 gr4	sk+bn+ch +chl	62.2	0.0	1.5	30.6	3.1	2.4	0.0	0.0	0.0	99.8	*1.00*	*0.00*	*0.01*	*0.83*	*0.09*	*0.06*	*0.00*	*0.00*	*0.00*
126	125 gr1	sk+ch+bn	62.7	0.0	1.1	31.4	3.2	2.3	0.0	0.0	0.0	100.7	*1.00*	*0.00*	*0.01*	*0.84*	*0.10*	*0.06*	*0.00*	*0.00*	*0.00*
		average	59.4	0.1	2.3	31.1	3.6	1.4	1.0	0.3	0.4	99.6	*0.96*	*0.00*	*0.02*	*0.85*	*0.11*	*0.04*	*0.02*	*0.00*	*0.00*
		max	63.0	5.5	23.5	35.4	6.6	5.8	19.6	1.9	5.7		*1.05*	*0.06*	*0.23*	*0.95*	*0.20*	*0.15*	*0.35*	*0.03*	*0.05*
		min	40.9	0.0	0.0	13.3	0.4	0.0	0.0	0.0	0.0		*0.74*	*0.00*	*0.00*	*0.44*	*0.01*	*0.00*	*0.00*	*0.00*	*0.00*

Abbreviations

at	atokite	cpx	clinopyroxene	vys	vysotskite
bn	bornite	dg	digenite	(pd,Cu,Sn)	unnamed mineral
bt	biotite	fbn			
ch	chalcosine	hb	hornblende		
chl	chlorite	ilm	ilmenite		
copn	Cobalt-pentlamdite	pl	plagioclase		
cp	chalcopyrite	sk	skaergaardite		

Table 7

Table 7 can be found in the main text, page 14

Table 8. Chemical composition and formulas of tetra-auricupride and unnamed Au_3Cu and (Ag,Cu) alloy in grains of the heavy concentrates (sample 90-18 978)

				weight percent of element							*atomic proportions*						
Anal. #	**Grain**	**Association**	**Mineral**	**Pd**	**Pt**	**Au**	**Ag**	**Cu**	**Fe**	**Total**	***Pd***	***Pt***	***Au***	***Ag***	***Cu***	***Fe***	***Total***
1	40 gr12	AuCu+kth+ch+bn	AuCu	8.4	7.9	53.5		29.9	0.0	99.7	*0.18*	*0.09*	*0.63*		*1.09*	*0.00*	*2*
2	40 gr13	AuCu+ch+bn+chl	AuCu	8.8	0.0	62.7		28.0	0.0	99.5	*0.20*	*0.00*	*0.76*		*1.05*	*0.00*	*2*
3	63 gr34	AuCu+bn+trm	AuCu	8.6	0.0	61.2		28.8	0.7	99.3	*0.19*	*0.00*	*0.72*		*1.06*	*0.03*	*2*
4	63 gr41	AuCu	AuCu	12.5	0.0	58.3		28.8	0.0	99.6	*0.27*	*0.00*	*0.68*		*1.05*	*0.00*	*2*
5	63 gr49	AuCu	AuCu	15.2	0.0	61.3		22.0	1.3	99.8	*0.35*	*0.00*	*0.76*		*0.84*	*0.06*	*2*
6	63 gr50	AuCu+kth	AuCu	15.3	0.0	61.2		22.7	0.7	99.9	*0.35*	*0.00*	*0.75*		*0.87*	*0.03*	*2*
7	63 gr51	AuCu+kth	AuCu	16.9	0.0	62.7		19.3	0.7	99.6	*0.40*	*0.00*	*0.80*		*0.77*	*0.03*	*2*
8	63 gr72	AuCu+Au_3Cu	AuCu	20.1	0.0	53.6		25.8	0.8	100.3	*0.43*	*0.00*	*0.62*		*0.92*	*0.03*	*2*
9	63 gr87	AuCu+Au_3Cu	AuCu	5.9	0.0	70.5		22.7	0.4	99.5	*0.14*	*0.00*	*0.92*		*0.92*	*0.02*	*2*
10	63 gr90	AuCu	AuCu	19.4	0	56.3		23.6	0.5	99.8	*0.43*	*0.00*	*0.67*		*0.88*	*0.02*	*2*
11	63 gr96	AuCu+kth+ch+bn	AuCu	13.8	2.9	51.4		30.9	0.7	99.7	*0.29*	*0.03*	*0.58*		*1.08*	*0.03*	*2*
12	63 gr109	AuCu	AuCu	10.3	0.0	62.7		26.4	0	99.4	*0.23*	*0.00*	*0.77*		*1.00*	*0.00*	*2*
13		average	AuCu	12.9	0.9	59.6		25.7	0.5	99.6	*0.29*	*0.01*	*0.72*		*0.96*	*0.02*	*2*
14	63 gr72	AuCu+Au_3Cu	Au_3Cu	20.7	0	66.3		12.2	0.4	99.6	*1.07*	*0.00*	*1.84*		*1.05*	*0.04*	*4*
15	63 gr87	AuCu+Au_3Cu	Au_3Cu	4.9	0	81.9		12.4	0.7	99.9	*0.28*	*0.00*	*2.48*		*1.17*	*0.07*	*4*
16		average	Au_3Cu	12.8	0.0	74.1		12.3	0.6	99.8	*0.68*	*0.00*	*2.16*		*1.11*	*0.06*	*4*
17	63 gr112	(Ag,Cu)	(Ag,Cu)				94.1	5.4	0.4	99.9				*0.90*	*0.09*	*0.01*	*1*

Abbreviations:

AuCu	tetra-auricupride
kth	keithconnite
ch	chalcosine
bn	bornite
trm	tremolite
Au_3Cu	unnamed mineral
(Ag,Cu)	alloy

Table 9. Chemical composition and formulas of different PGE-sulpides – vysotskite, unnamed $(Cu,Pt,Pd)_{2+X}S$, keithconnite, atokite, unnamed (Pd,Cu,Sn) alloy and unnamed $Pd_2CuTeBi$ - in PGM-grains of the heavy concentrates (sample 90-18 978)

Weight percent of element

Anal. #	Grain	Association	Mineral	Pd	Pt	Au	Cu	Fe	Ni	S	Sn	Te	Pb	Bi	Total
1	40 gr7	vys+bn+ch	vys	75.5	0.0	0.0	1.2	0.0	0.0	23.4					100.1
2	40 gr77	sk+vys+at+bn	vys	72.1	0.0	0.0	0.5	0.4	2.9	23.9					99.8
3	63 gr4	$(Cu,Pt,Pd)_{2+X}S$?+bn+ch	$(Cu,Pt,Pd)_{2+X}S$?	10.5	34.8	0.0	30.9	7.5		12.6	1.8		1.8		100.0
4	40 gr12	AuCu+kth+ch+bn	kth	69.3			4.0				2.0	13.8	10.2		99.3
5	63 gr50	kth+AuCu	kth	74.0			1.8				3.9	12.0	7.5		99.2
6	63 gr51	kth+AuCu	kth	68.0								29.5	1.5		99.0
7	63 gr35	sk+at	at	75.5			0.7				23.5				99.7
8	63 gr77	sk+vys+at+bn	at	75.2			1.8				23.4				100.4
9	63 gr93	sk+at+copn	at	69.4			1.5	1.0			27.6				99.5
10	63 gr69	sk+(Pd,Cu,Sn)+bn+ch	(Pd,Cu,Sn)	67.8			13.4	0.4			15.9	2.2			99.7
11	40 gr29	$Pd_2CuTeBi$+bn	$Pd_2CuTeBi$	34.2			7.4	1.7				20.6		35.7	99.6

Atomic proportions

Anal. #	*Grain*	*Association*	*Mineral*	*Pd*	*Pt*	*Au*	*Cu*	*Fe*	*Ni*	*S*	*Sn*	*Te*	*Pb*	*Bi*	*Total*
1	*40 gr7*	*vys+bn+ch*	*vys*	*0.97*	*0.00*	*0.00*	*0.03*	*0.00*	*0.00*	*1.00*					*2*
2	*40 gr77*	*sk+vys+at+bn*	*vys*	*0.91*	*0.00*	*0.00*	*0.01*	*0.01*	*0.07*	*1.00*					*2*
3	*63 gr4*	$(Cu,Pt,Pd)_{2+X}S$?+bn+ch	$(Cu,Pt,Pd)_{2+X}S$?	*0.22*	*0.41*	*0*	*1.11*	*0.31*		*0.9*	*0.04*		*0.02*		*3*
4	*40 gr12*	*AuCu+kth+ch+bn*	*kth*	*2.93*			*0.29*				*0.08*	*0.49*	*0.22*		*4*
5	*63 gr50*	*kth+AuCu*	*kth*	*3.14*			*0.13*				*0.15*	*0.42*	*0.16*		*4*
6	*63 gr51*	*kth+AuCu*	*kth*	*2.91*								*1.05*	*0.03*		*4*
7	*63 gr35*	*sk+at*	*at*	*3.09*			*0.05*				*0.86*				*4*
8	*63 gr77*	*sk+vys+at+bn*	*at*	*3.03*			*0.12*				*0.84*				*4*
9	*63 gr93*	*sk+at+copn*	*at*	*2.82*			*0.10*	*0.08*			*1.00*				*4*
10	*63 gr69*	*sk+(Pd,Cu,Sn)+bn+ch*	*(Pd,Cu,Sn)*	*0.63*			*0.21*				*0.13*	*0.02*			*1*
11	*40 gr29*	$Pd_2CuTeBi$+bn	$Pd_2CuTeBi$	*2.01*			*0.73*	*0.19*				*1.01*		*1.07*	*5*

Abbreviations

at	atokite	$Pd_2CuTeBi$	unnamed mineral
AuCu	tertra-auricupride	sk	Skaergaardite
bn	bornite	vys	vysotskite
ch	chalcosine	$(Cu,Pt,Pd)_{2+X}S$?	unnammed mineral
copn	cobalt-pentlandite	(Pd,Cu,Sn)	unnamed alloy
kth	keithconnite		

PLATES

Plate 1

Relationships of rock-forming minerals, Fe-Ti oxides and sulphides in the oxide-rich tholeitic gabbros of the sample 90-18, 978 (1-5); polished section, SEM-image (BIE). Pl –plagioclase, pyr (exs) – pyroxene exsolution texture: cpx – clinopyroxene, opx - orthopyroxene, ilm – ilmenite, timt – titano magnetite, ol – olivine, bn – bornite, ch – chalcosine, chl – chlorite; 2 is part of 1.

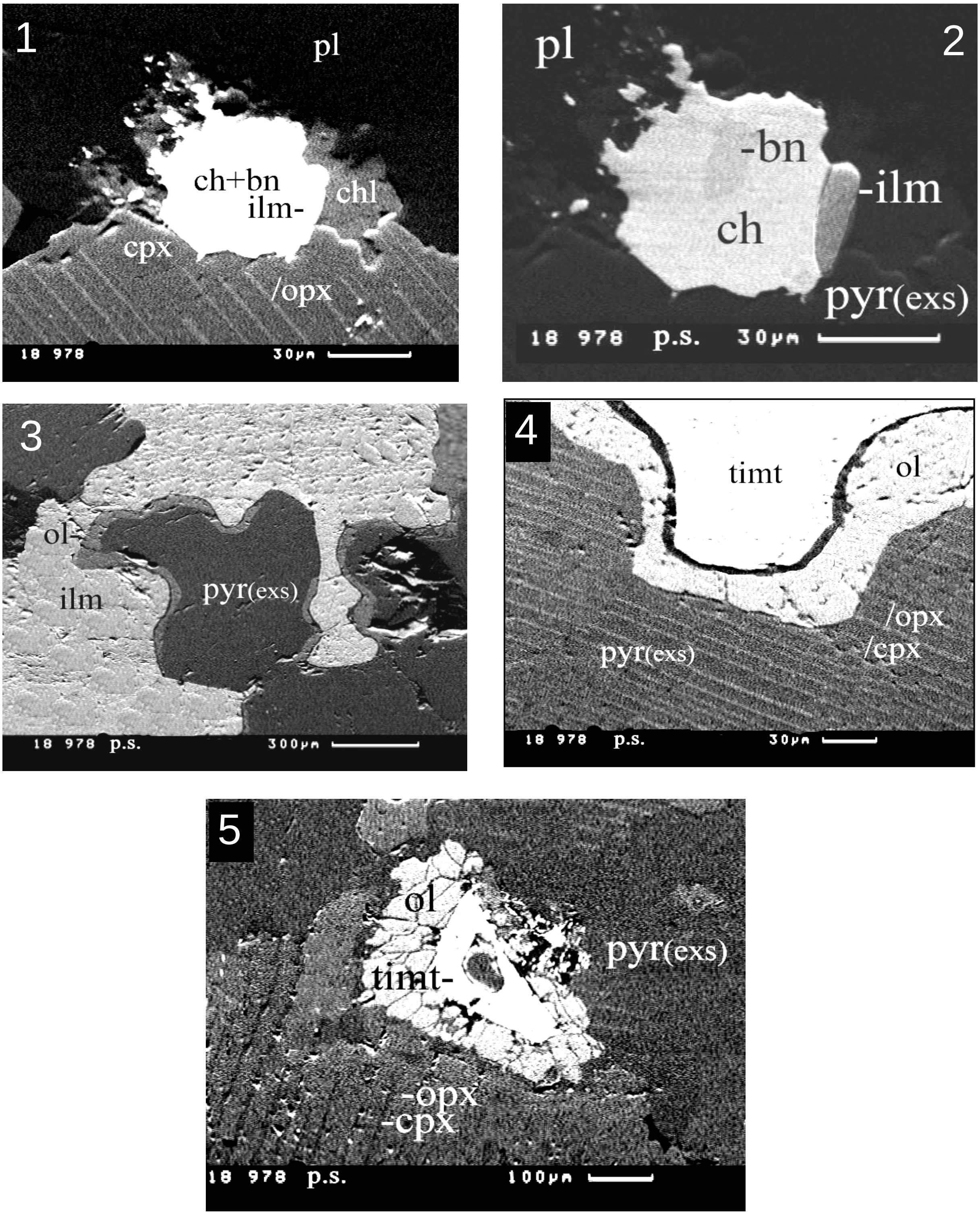

1
pl
ch+bn
ilm-
chl
cpx
/opx
18 978
30μm
2
pl
-bn
-ilm
ch
pyr(exs)
18 978 p.s. 30μm
3
ol-
ilm
pyr(exs)
18 978 p.s. 300μm
4
timt
ol
/opx
/cpx
pyr(exs)
18 978 p.s. 30μm
5
ol
pyr(exs)
timt-
-opx
-cpx
18 978 p.s. 100μm

Plate 2

Polished sections of heavy concentrates (1-4: 1 – fraction 80-125 µm; 2 - fraction 63-80 µm; 3, 4 - fraction 40-63 µm), sample 90-978, SEM-images (BIE); ilm – ilmenite, sk – skaergaardite, kth - keithconnite, bn – bornite, ch – chalcosine, cpx – clinopyroxenes.

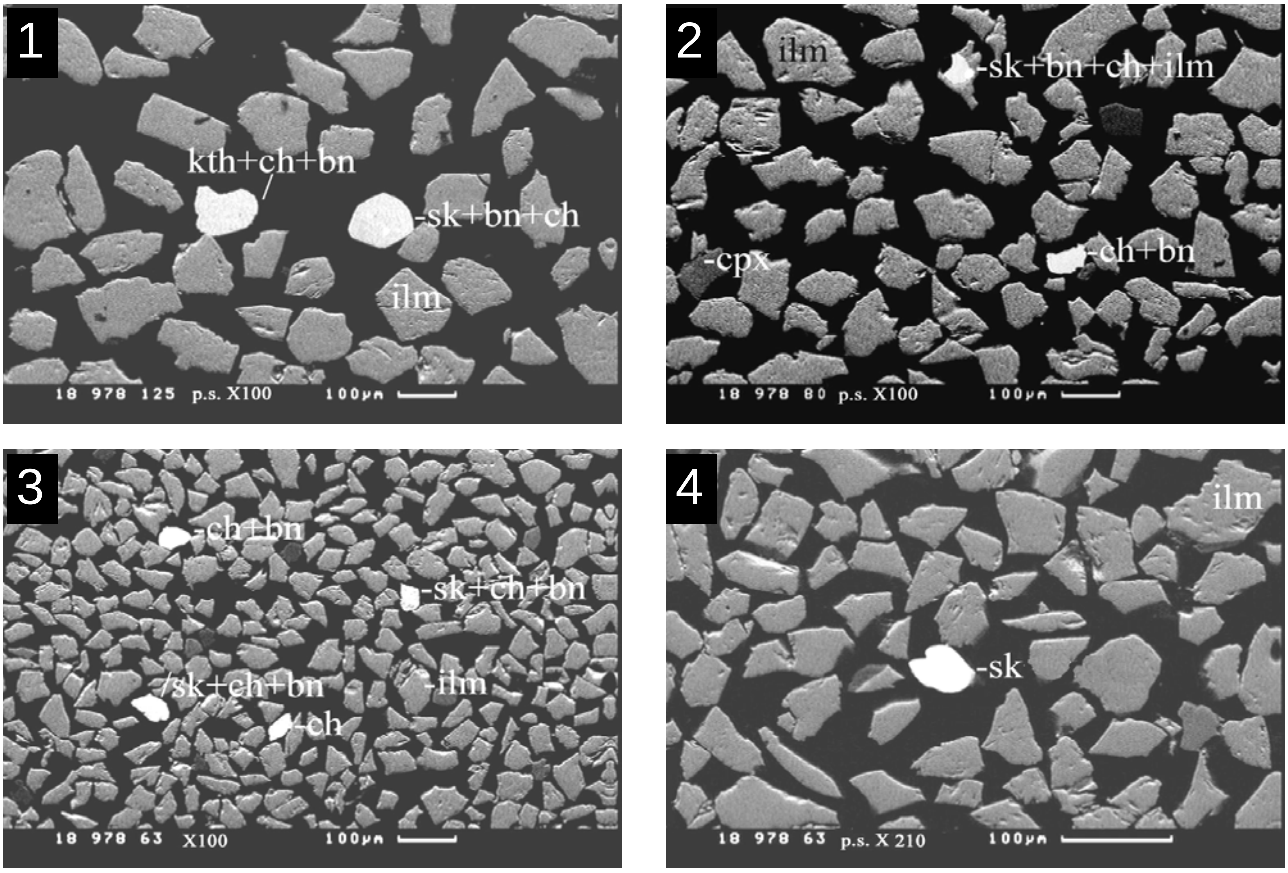
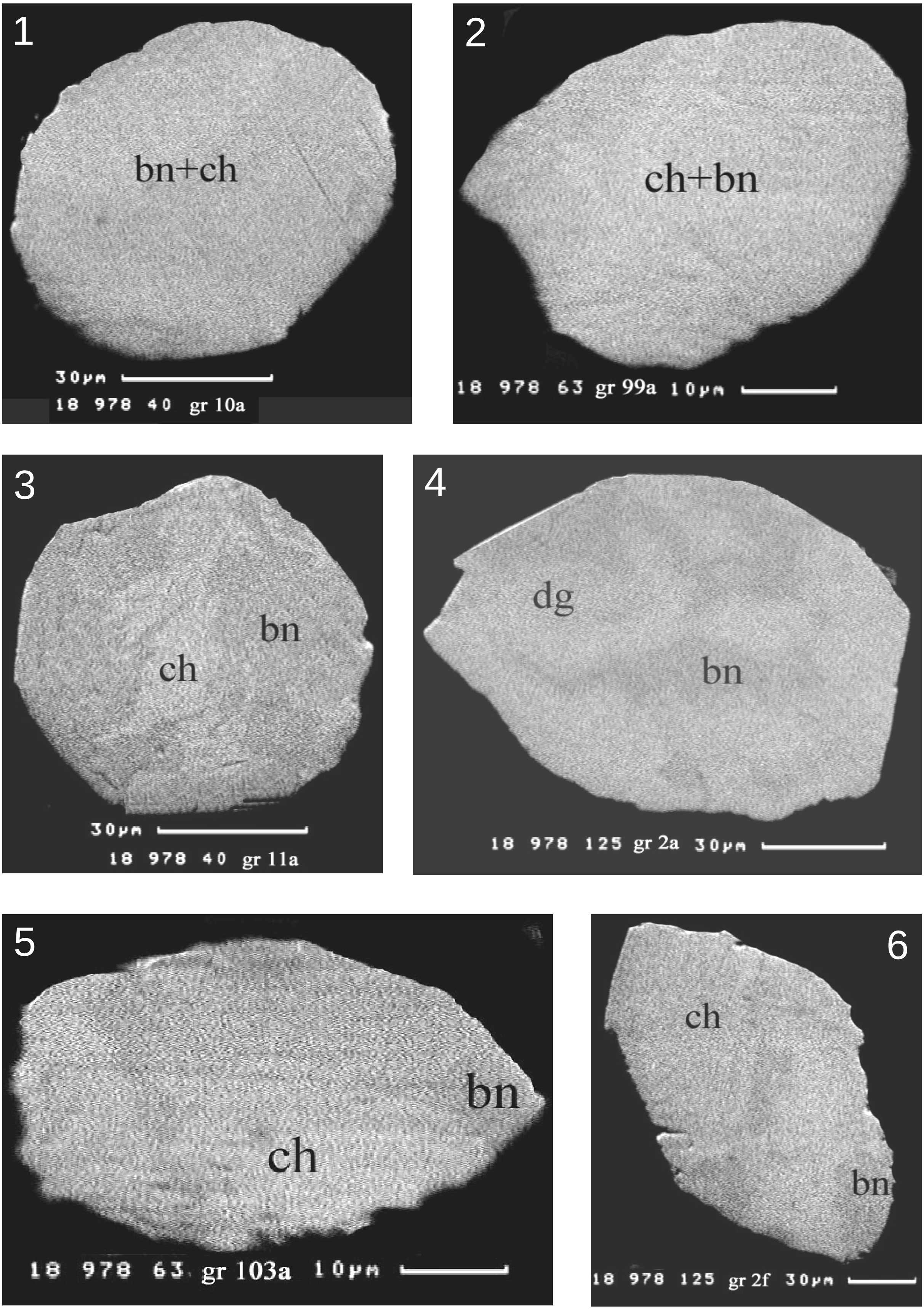
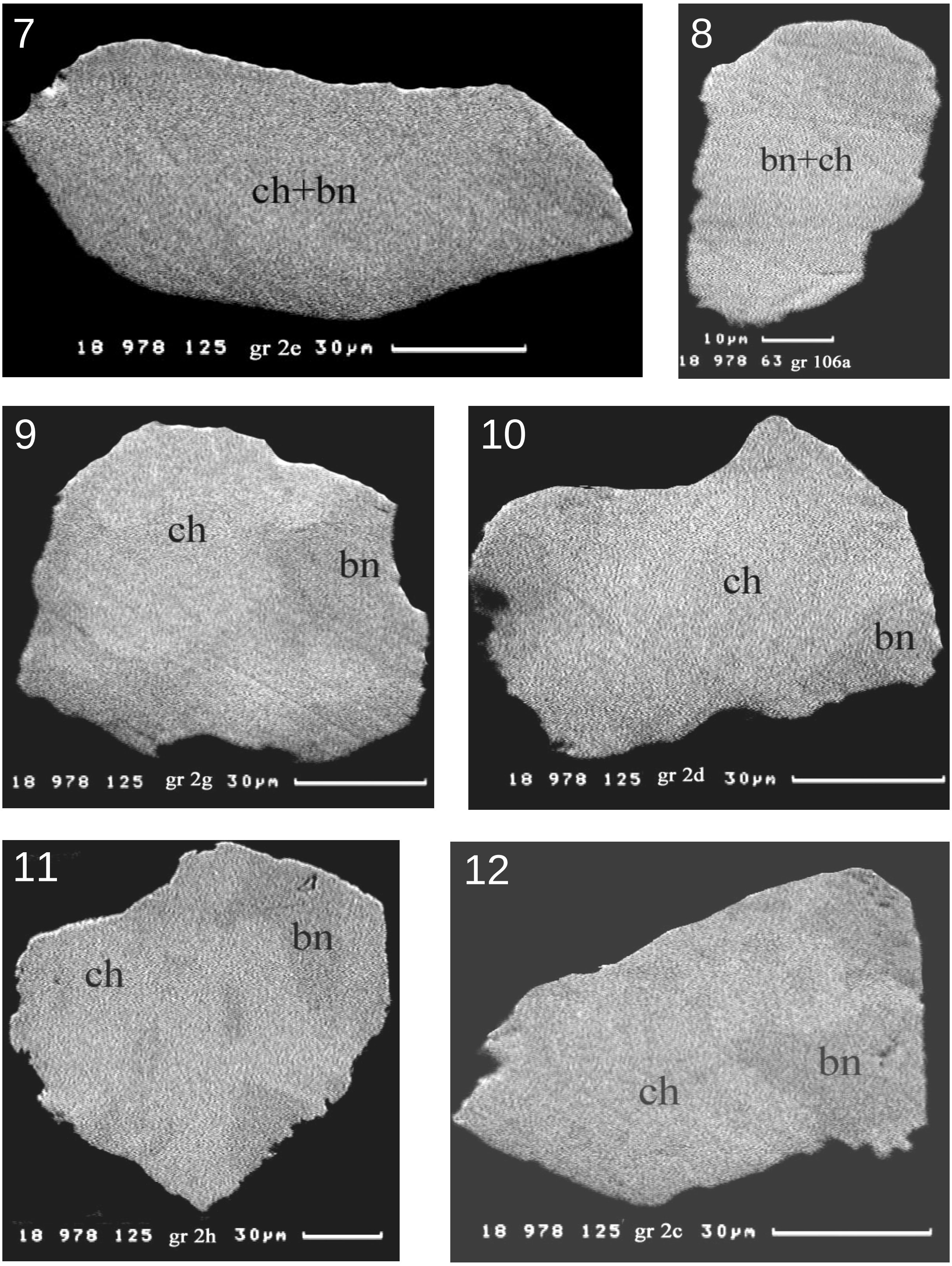
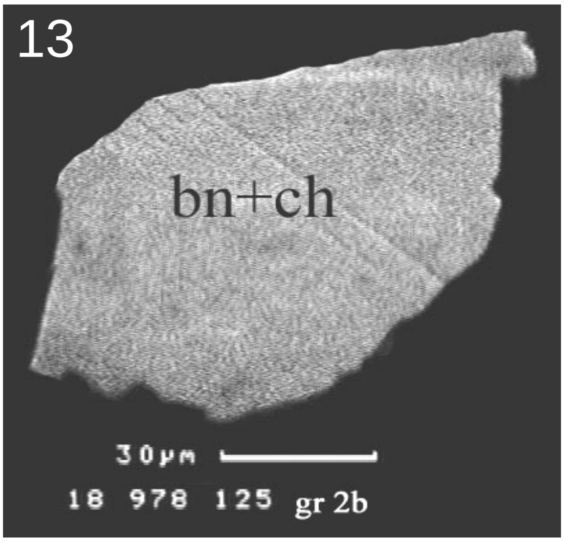

1
kth+ch+bn
-sk+bn+ch
ilm
18 978 125 p.s. X100 100µm
2
ilm
-sk+bn+ch+ilm
-cpx
-ch+bn
18 978 80 p.s. X100 100µm
3
-ch+bn
-sk+ch+bn
/sk+ch+bn
-ilm
-ch
18 978 63 X100 100µm
4
ilm
-sk
18 978 63 p.s. X 210 100µm

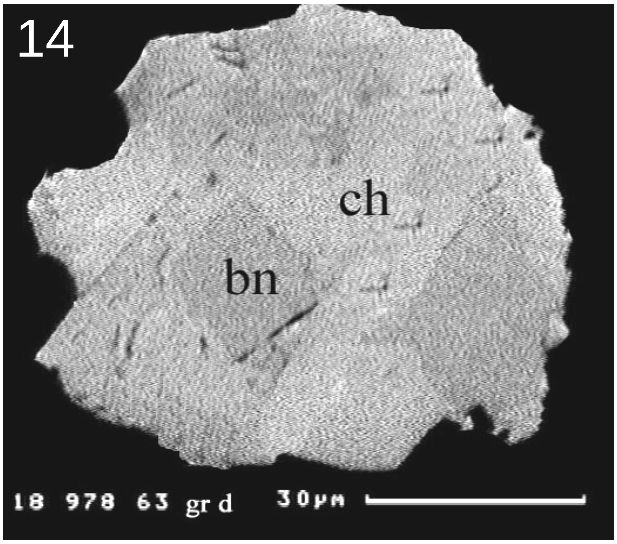
Plate 3

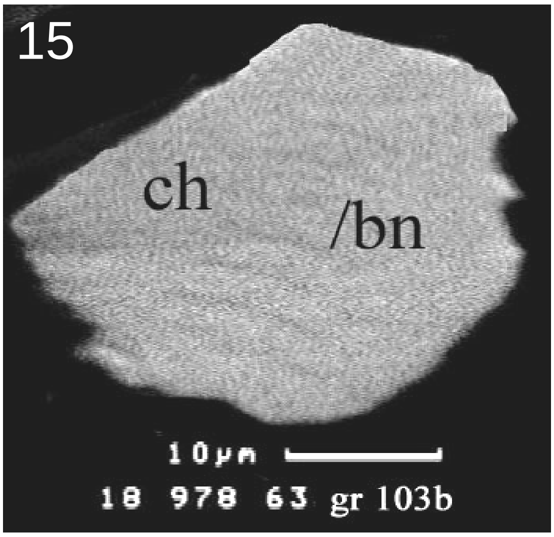
Sulphide mineralisation globules and irregular grains in oxide-rich tholeitic gabbros, sample 90-18, 978 (1-31), polished section of grains, concentrated in heavy concentrates, SEM-image (BIE); bn – bornite, ch – chalcosine, chl – chlorite, hb - hornblende.

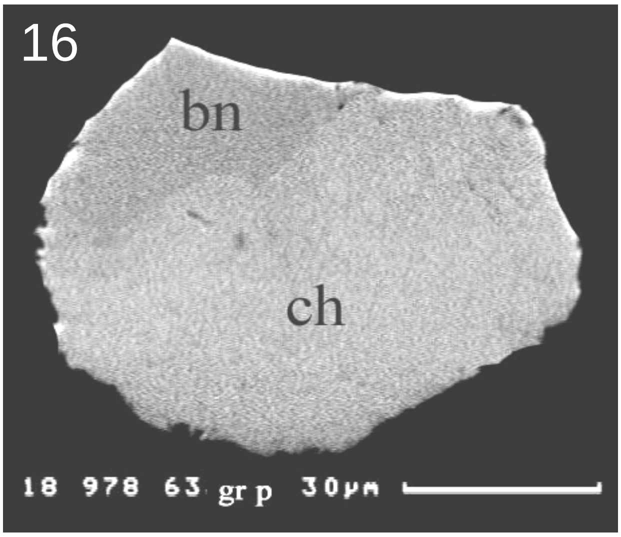

1
bn+ch
30μm
18 978 40 gr 10a
2
ch+bn
18 978 63 gr 99a 10μm
3
bn
ch
30μm
18 978 40 gr 11a
4
dg
bn
18 978 125 gr 2a 30μm
5
bn
ch
18 978 63 gr 103a 10μm
6
ch
bn
18 978 125 gr 2f 30μm

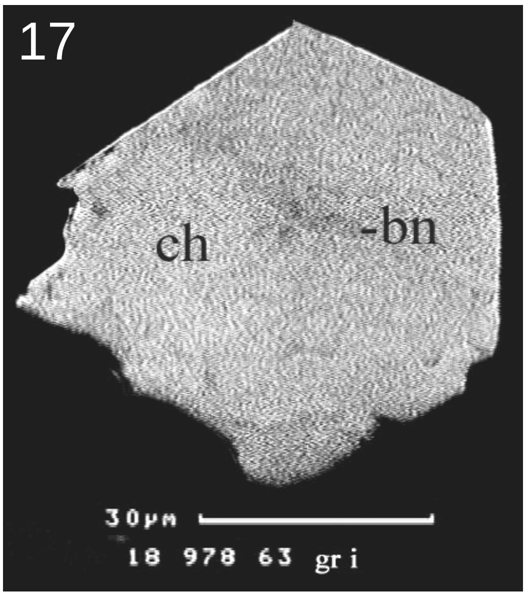

7
ch+bn
18 978 125 gr 2e 30μm
8
bn+ch
10μm
18 978 63 gr 106a
9
ch
bn
18 978 125 gr 2g 30μm
10
ch
bn
18 978 125 gr 2d 30μm
11
ch
bn
18 978 125 gr 2h 30μm
12
ch
bn
18 978 125 gr 2c 30μm

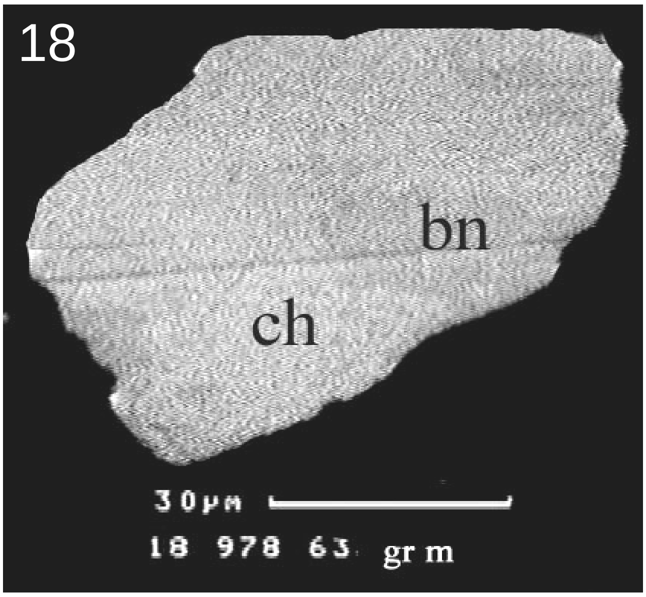

13
bn+ch
30µm
18 978 125 gr 2b

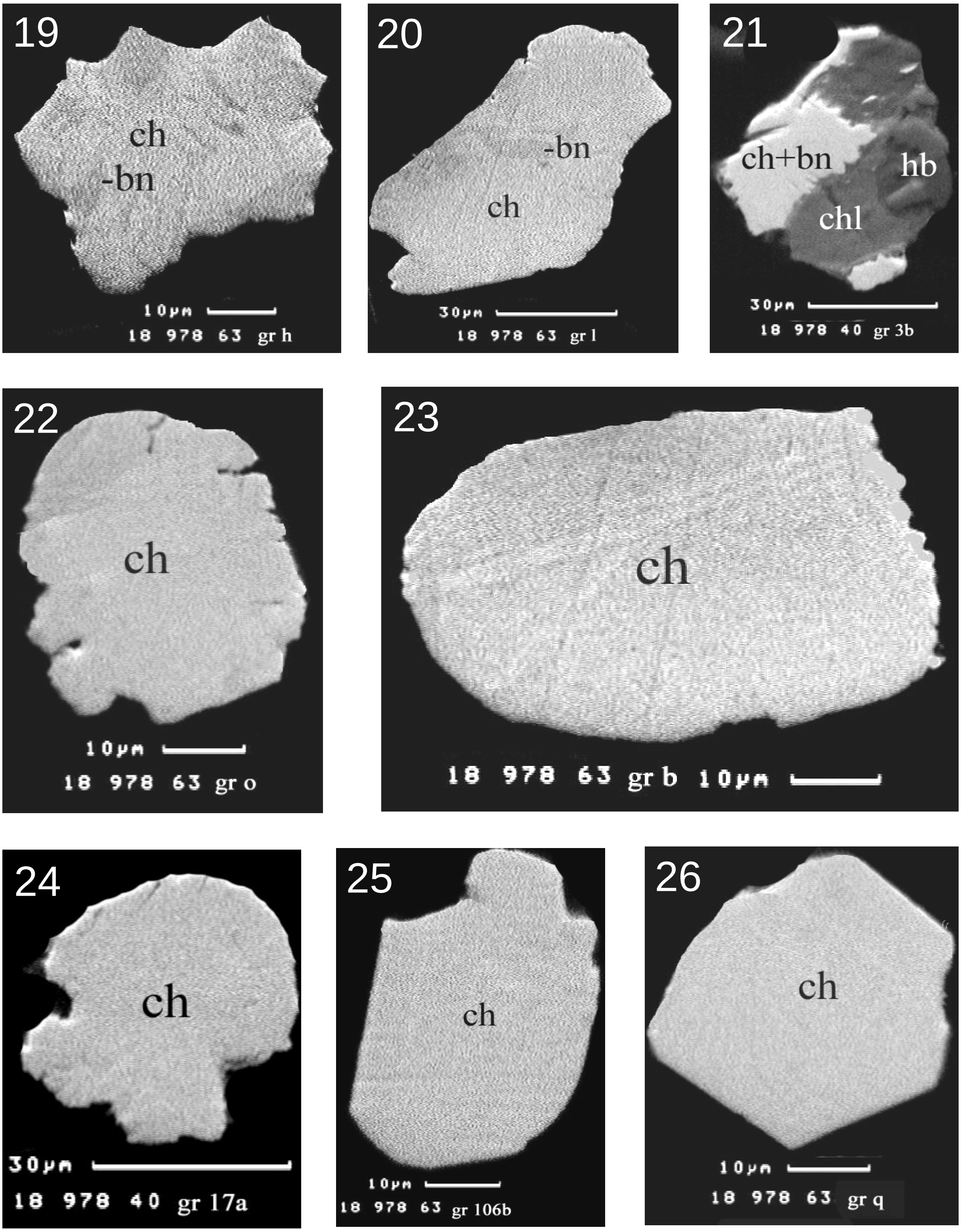

14
ch
bn
18 978 63 gr d
30µm

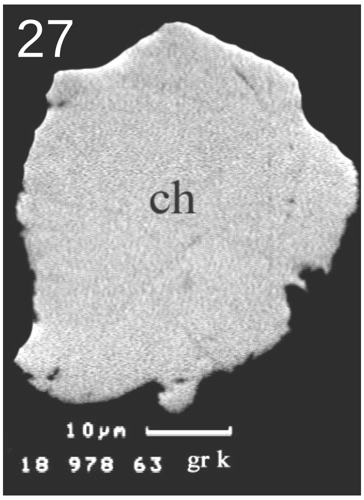

15
ch
/bn
10µm
18 978 63 gr 103b

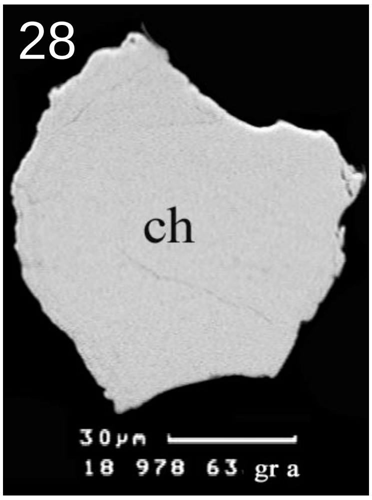

16
bn
ch
18 978 63 gr p
30µm

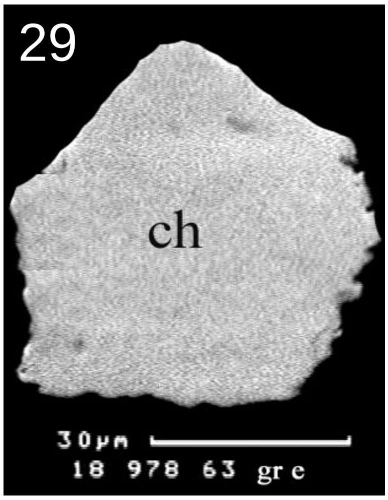

17
ch
-bn
30µm
18 978 63 gr i

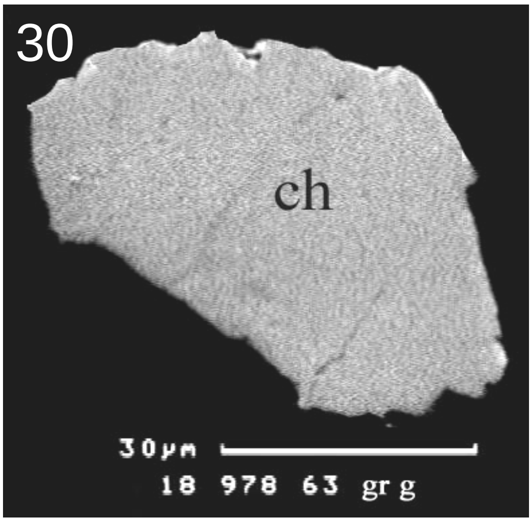

18
bn
ch
30µm
18 978 63 gr m


19
ch
-bn
10μm
18 978 63 gr h
20
-bn
ch
30μm
18 978 63 gr l
21
ch+bn
hb
chl
30μm
18 978 40 gr 3b
22
ch
10μm
18 978 63 gr o
23
ch
18 978 63 gr b 10μm
24
ch
30μm
18 978 40 gr 17a
25
ch
10μm
18 978 63 gr 106b
26
ch
10μm
18 978 63 gr q


27
ch
10μm
18 978 63 gr k


28
ch
30μm
18 978 63 gr a


29
ch
30μm
18 978 63 gr e


30
ch
30μm
18 978 63 gr g

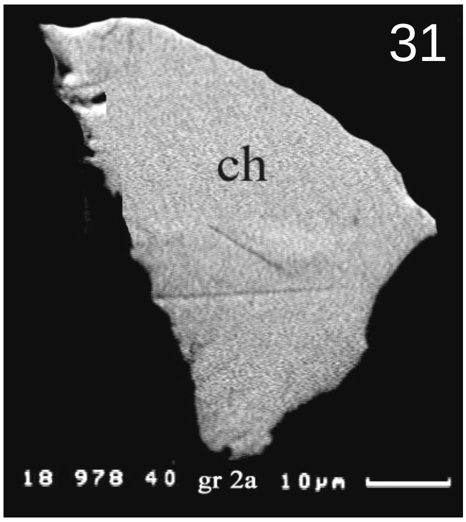
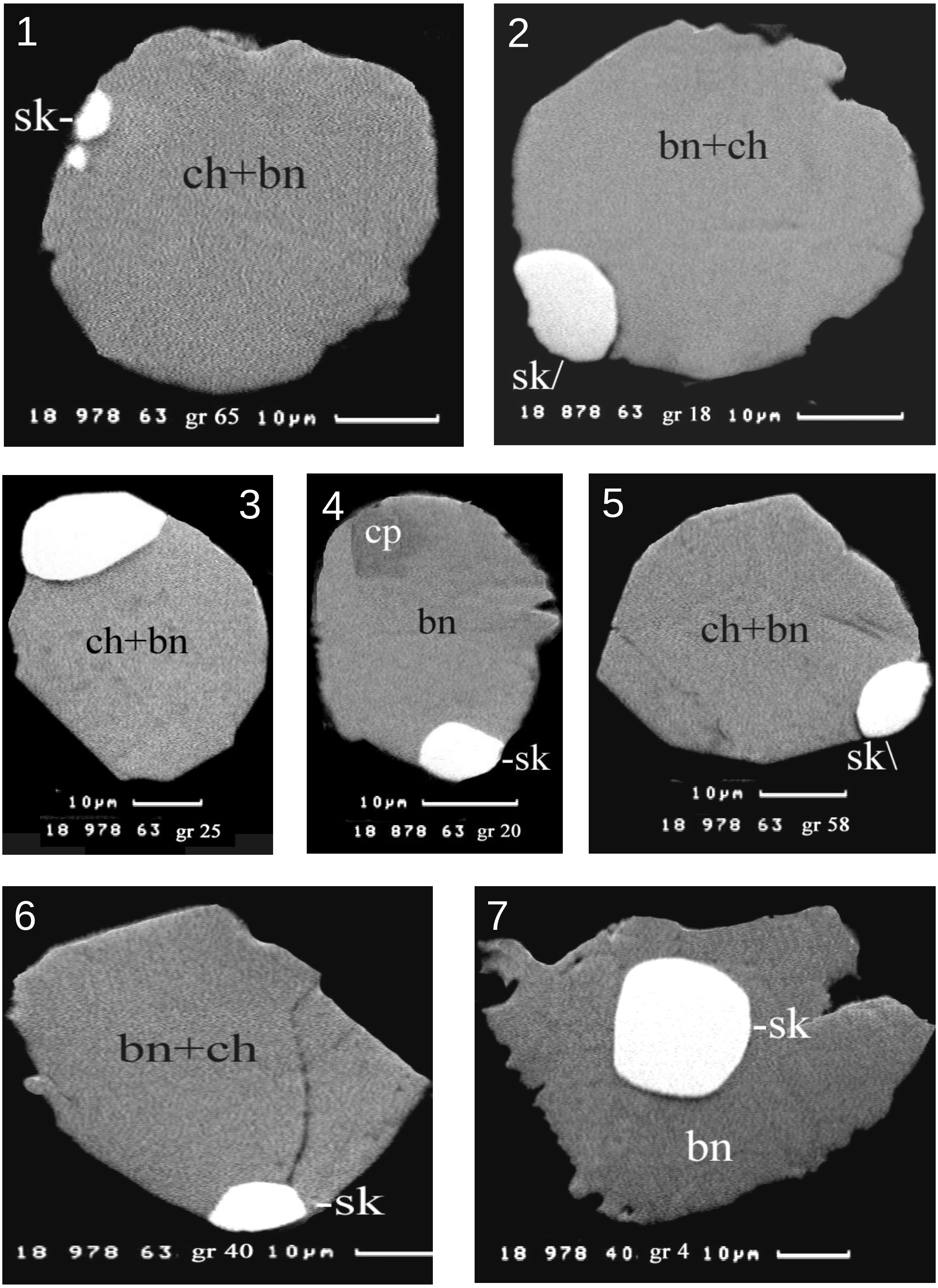
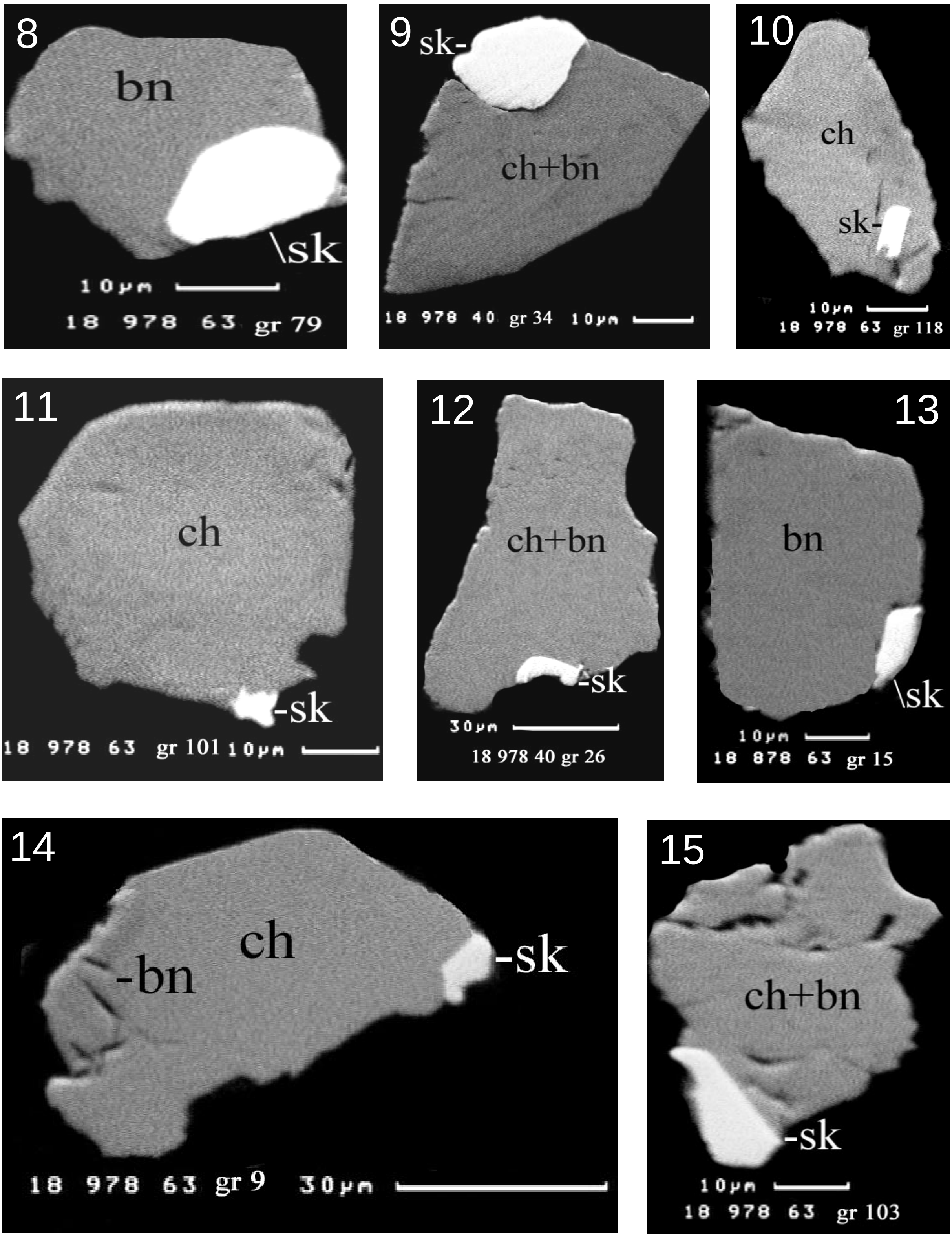
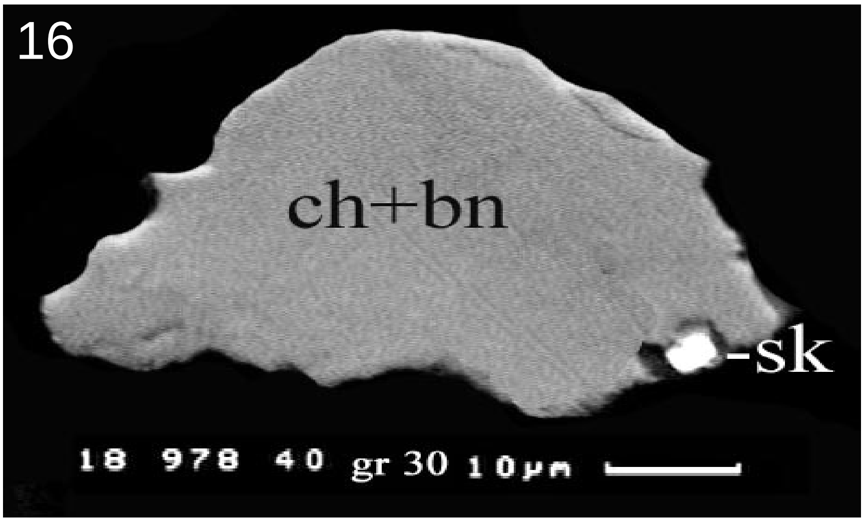

31
ch
18 978 40 gr 2a 10μm

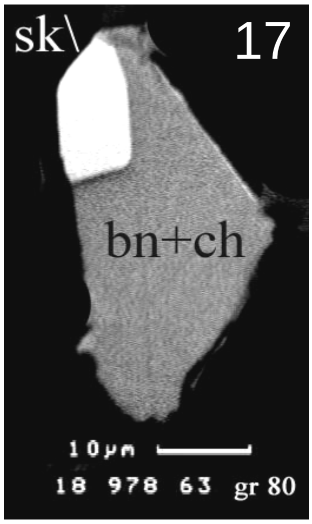
Plate 4

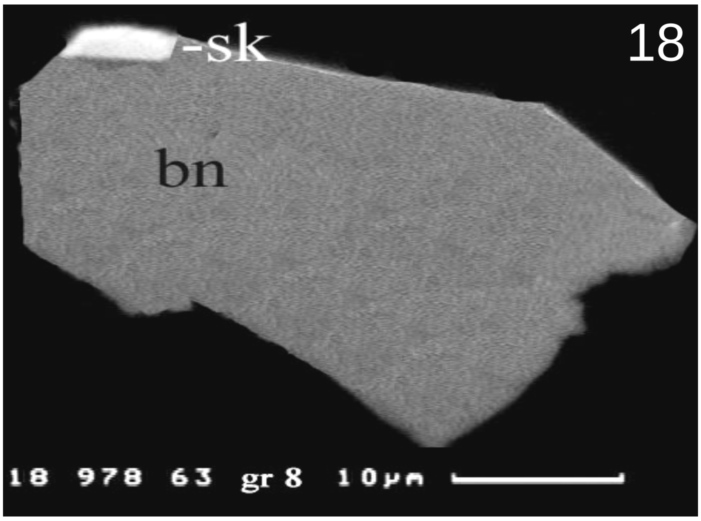
Sulphide globules and grains with inclusions of skaergaardite (**bms**), skaergaardite particles attached base metal sulphides (**bms-L**) in heavy concentrates of the sample 90-18, 978 (1-94); polished section, SEM-image (BIE); sk – skaergaardite, bn – bornite, ch – chalcosine, dg – digenite.

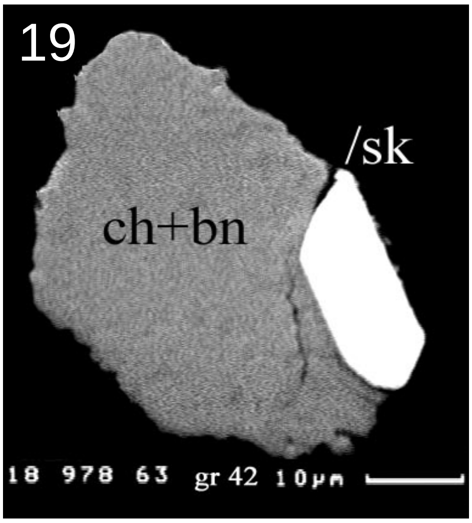

1
sk-
ch+bn
18 978 63 gr 65 10μm
2
bn+ch
sk/
18 878 63 gr 18 10μm
3
ch+bn
10μm
18 978 63 gr 25
4
cp
bn
-sk
10μm
18 878 63 gr 20
5
ch+bn
sk\
10μm
18 978 63 gr 58
6
bn+ch
-sk
18 978 63 gr 40 10μm
7
-sk
bn
18 978 40 gr 4 10μm

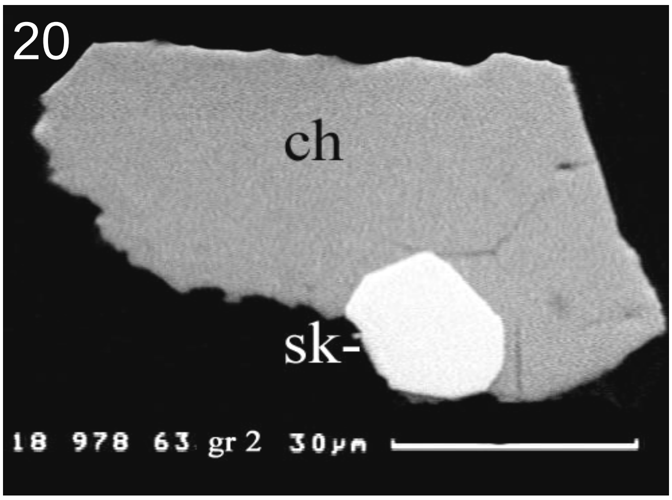

8
bn
\sk
10μm
18 978 63 gr 79
9
sk-
ch+bn
18 978 40 gr 34 10μm
10
ch
sk-
10μm
18 978 63 gr 118
11
ch
-sk
18 978 63 gr 101 10μm
12
ch+bn
-sk
30μm
18 978 40 gr 26
13
bn
\sk
10μm
18 878 63 gr 15
14
ch
-bn
-sk
18 978 63 gr 9 30μm
15
ch+bn
-sk
10μm
18 978 63 gr 103

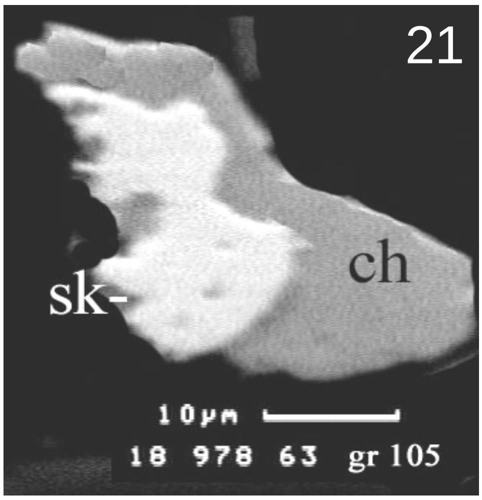

16
ch+bn
-sk
18 978 40 gr 30 10μm

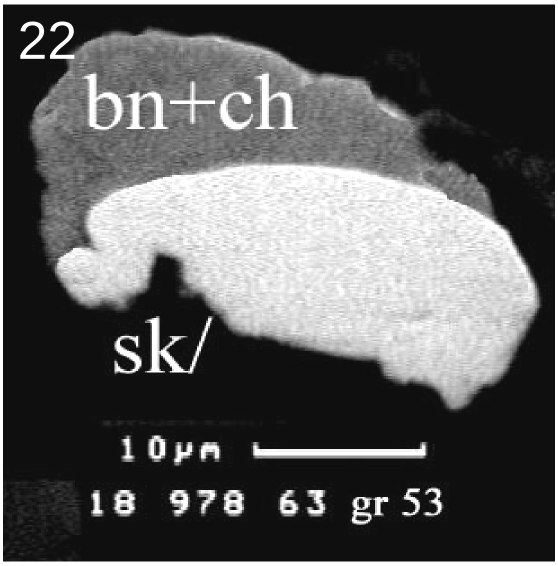

17
sk\
bn+ch
10μm
18 978 63 gr 80

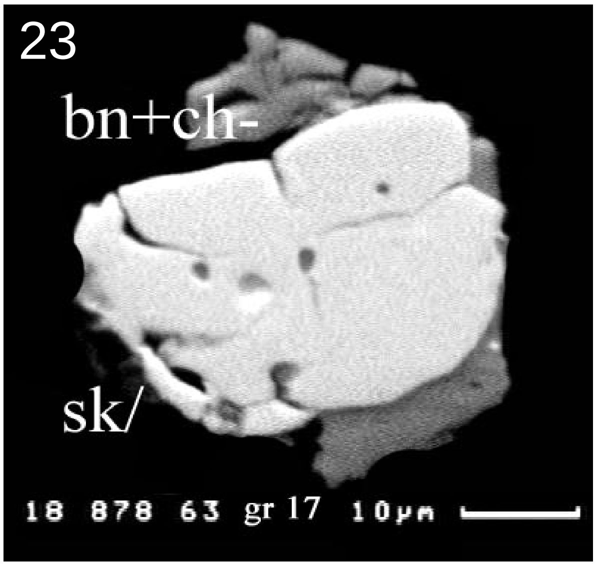

18
-sk
bn
18 978 63 gr 8 10μm

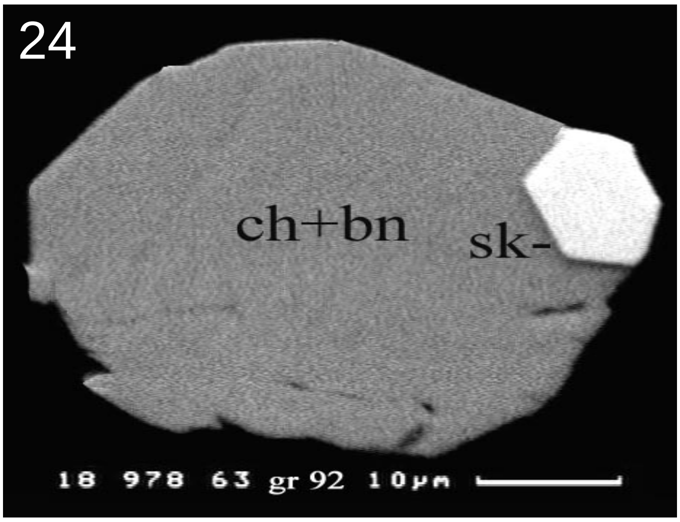

19
/sk
ch+bn
18 978 63 gr 42 10μm

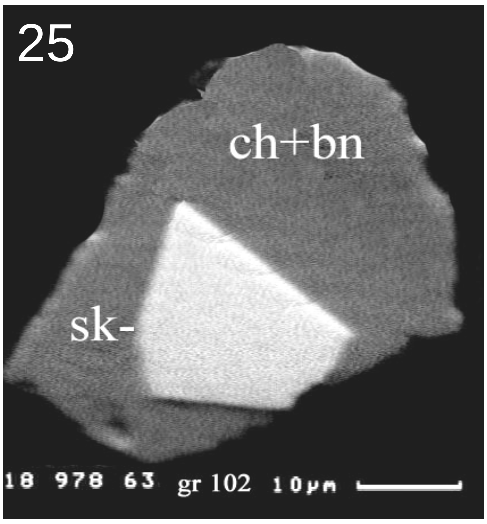

20
ch
sk-
18 978 63 gr 2 30μm

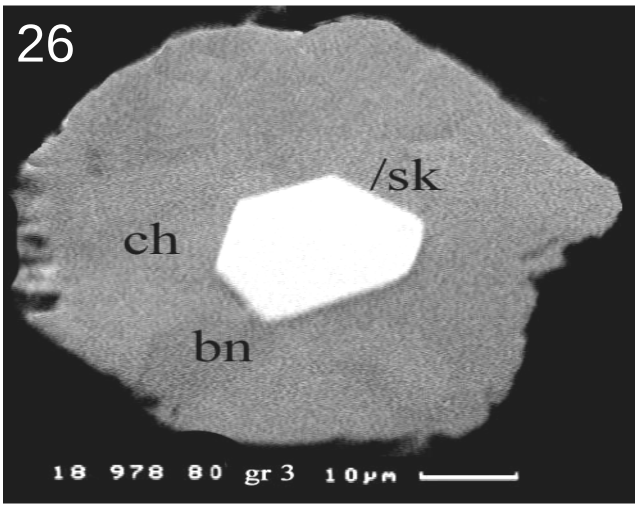

21
ch
sk-
10μm
18 978 63 gr 105

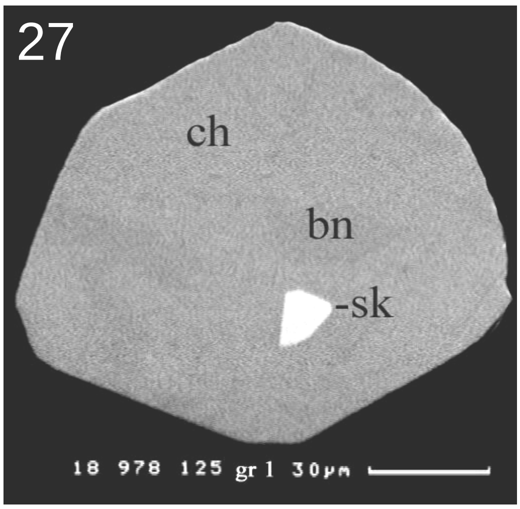

22
bn+ch
sk/
10μm
18 978 63 gr 53

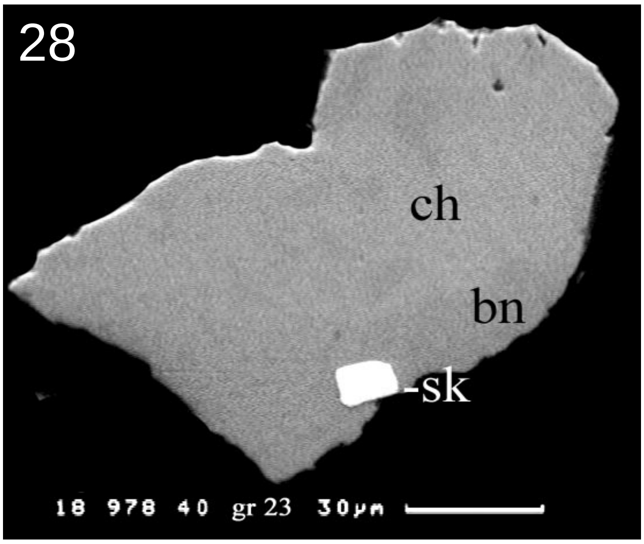

23
bn+ch-
sk/
18 878 63 gr 17 10μm

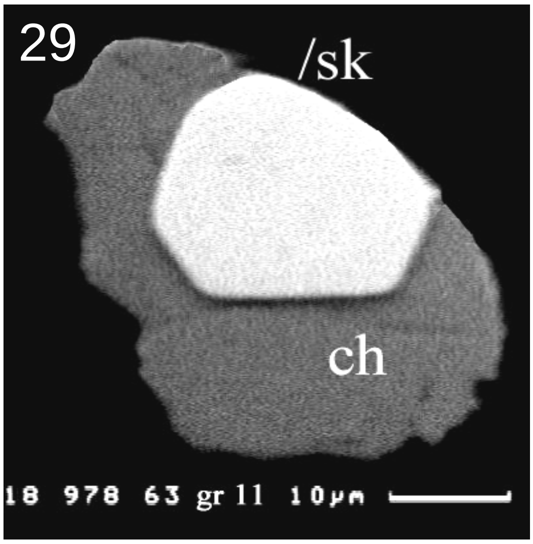

24
ch+bn
sk-
18 978 63 gr 92 10μm

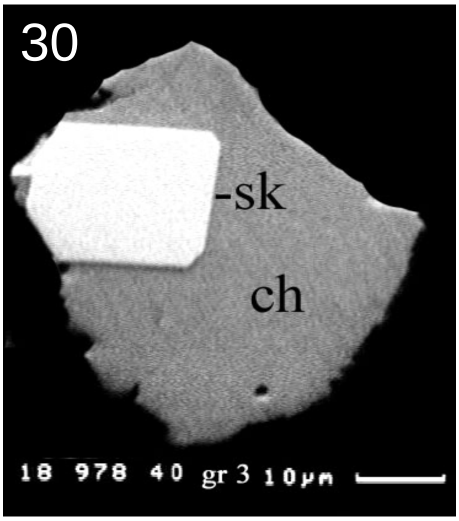

25
ch+bn
sk-
18 978 63 gr 102 10μm

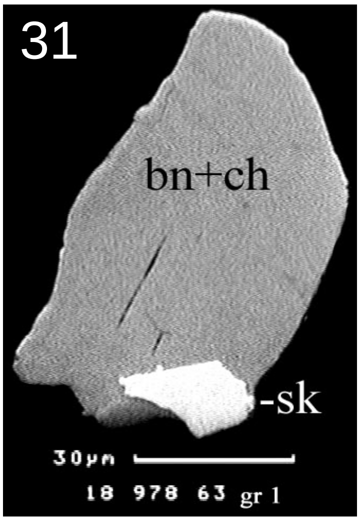

26
/sk
ch
bn
18 978 80 gr 3 10μm

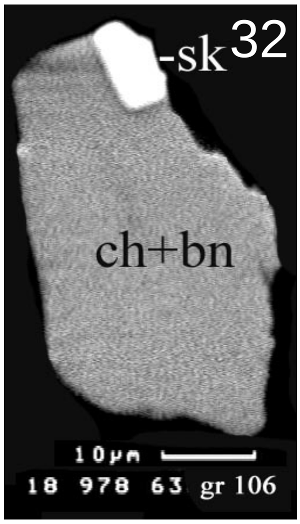

27
ch
bn
-sk
18 978 125 gr 1 30μm

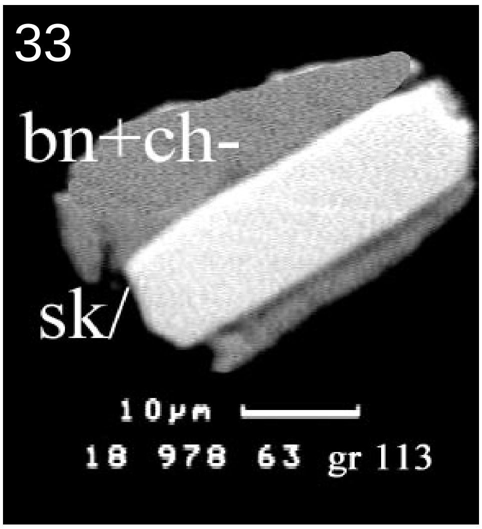

28
ch
bn
-sk
18 978 40 gr 23 30μm

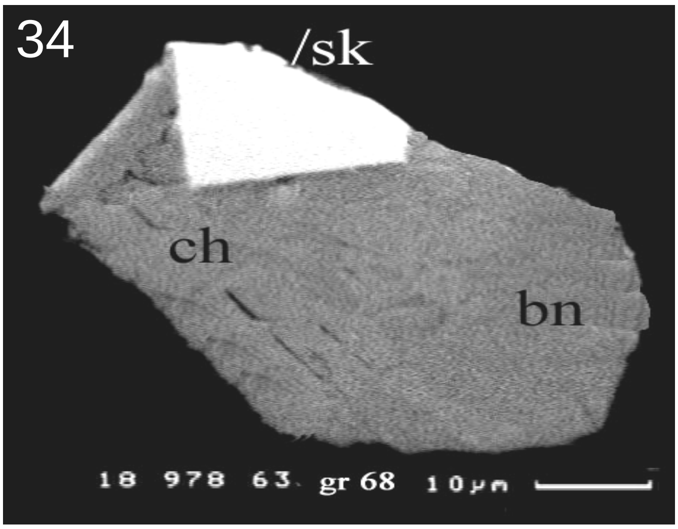

29
/sk
ch
18 978 63 gr 11 10μm

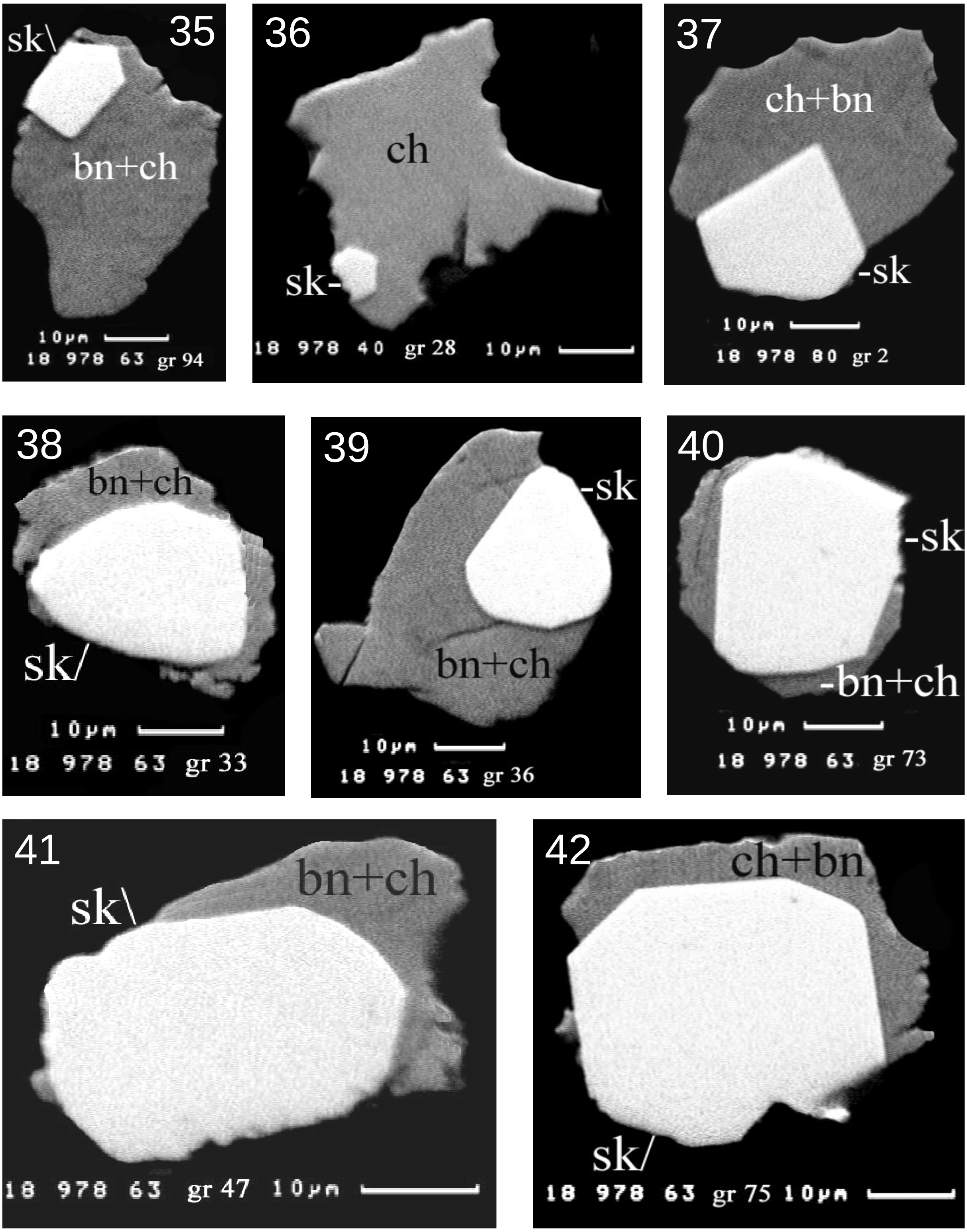

30
-sk
ch
18 978 40 gr 3 10μm

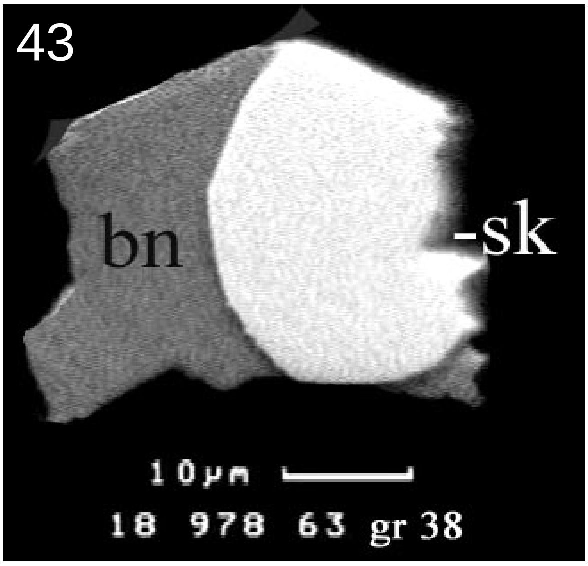

31
bn+ch
-sk
30μm
18 978 63 gr 1

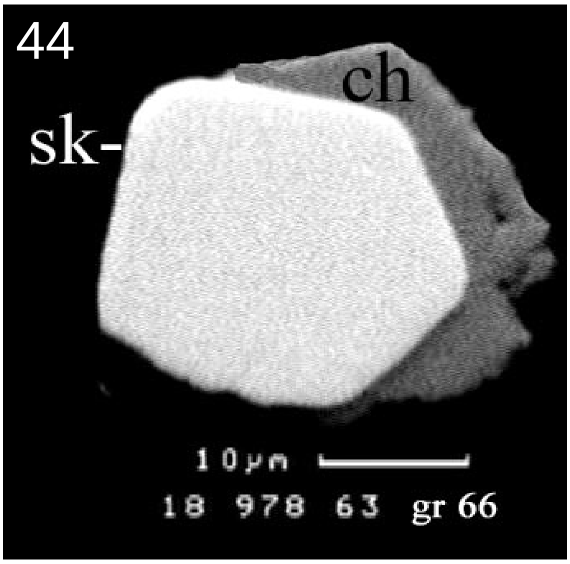

32
-sk
ch+bn
10μm
18 978 63 gr 106

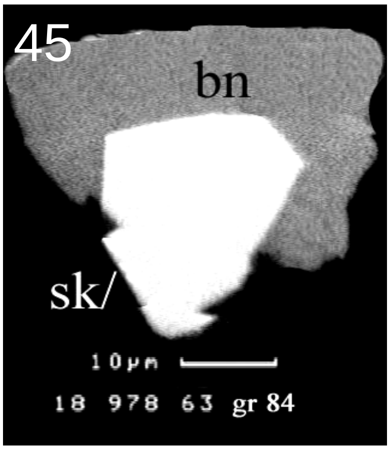

33
bn+ch-
sk/
10μm
18 978 63 gr 113

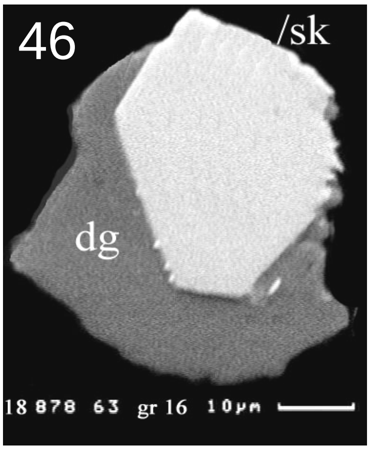

34
/sk
ch
bn
18 978 63. gr 68 10μm

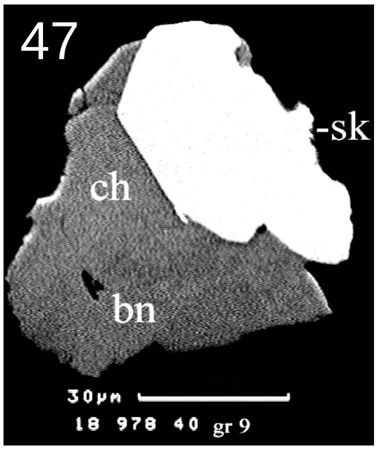

35
sk\
bn+ch
10µm
18 978 63 gr 94
36
ch
sk-
18 978 40 gr 28 10µm
37
ch+bn
-sk
10µm
18 978 80 gr 2
38
bn+ch
sk/
10µm
18 978 63 gr 33
39
-sk
bn+ch
10µm
18 978 63 gr 36
40
-sk
-bn+ch
10µm
18 978 63 gr 73
41
sk\
bn+ch
18 978 63 gr 47 10µm
42
ch+bn
sk/
18 978 63 gr 75 10µm

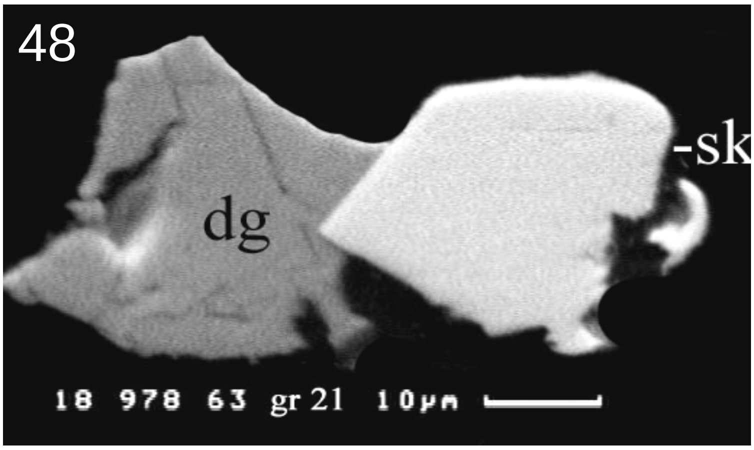

43
bn
-sk
10μm
18 978 63 gr 38

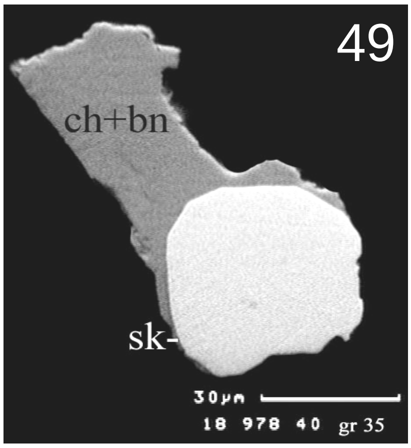

44
ch
sk-
10μm
18 978 63 gr 66

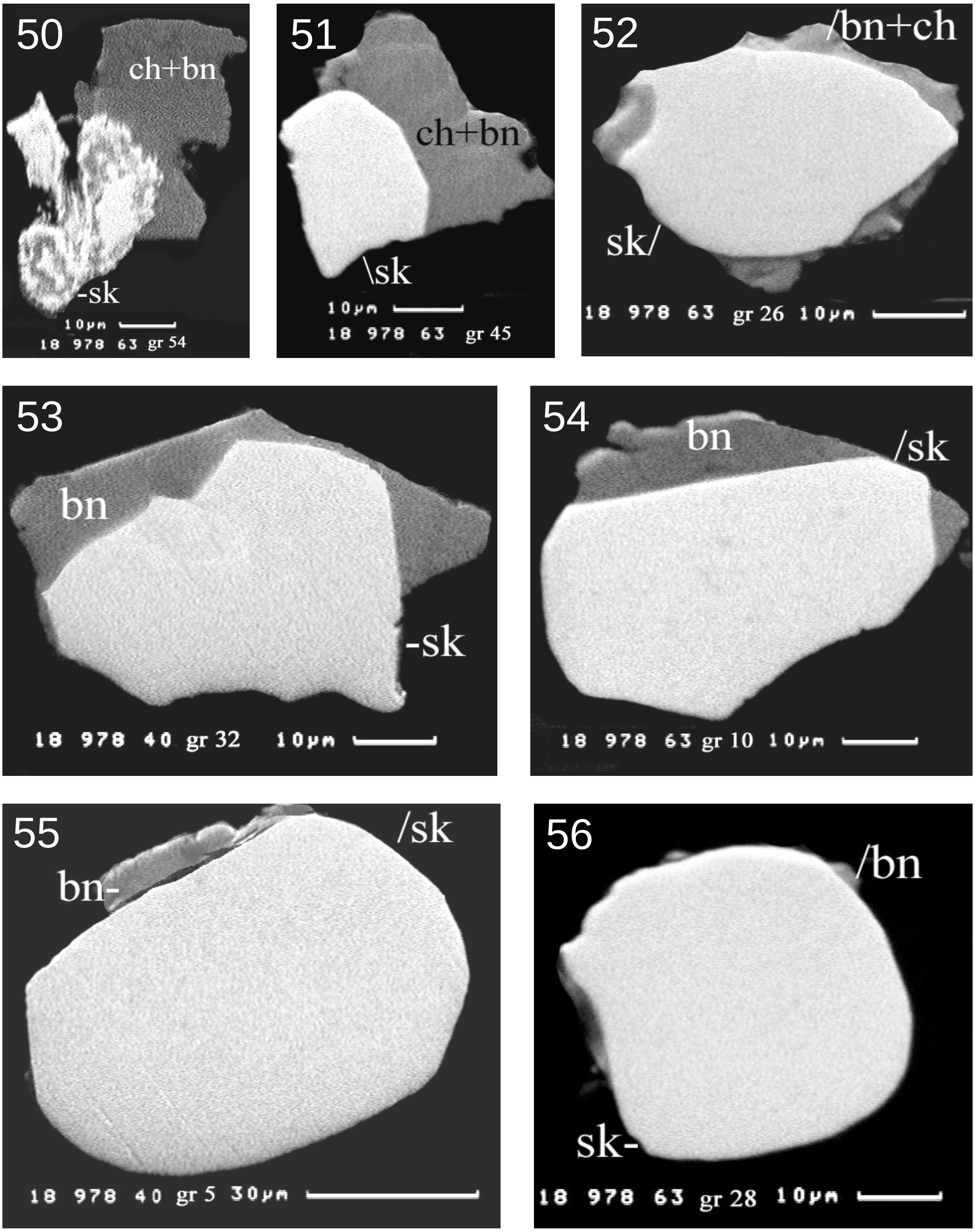

45
bn
sk/
10μm
18 978 63 gr 84

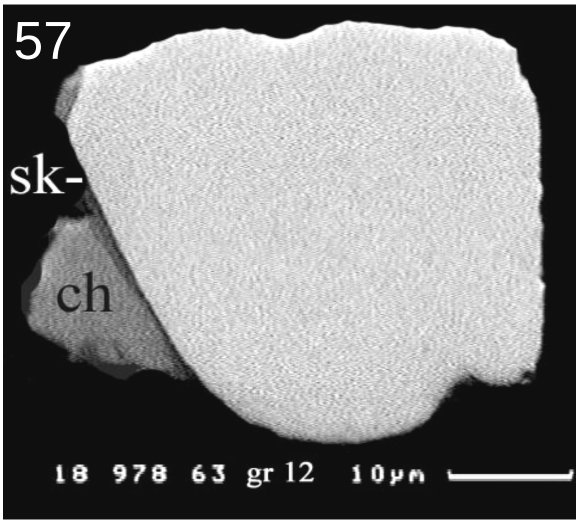

46
/sk
dg
18 878 63 gr 16 10μm

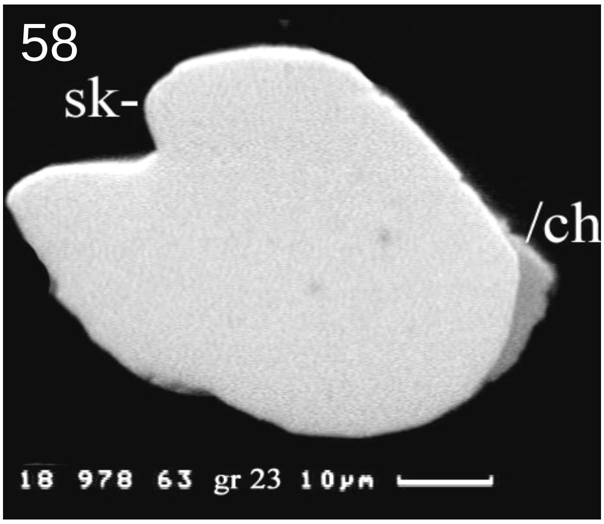

47
-sk
ch
bn
30μm
18 978 40 gr 9


48
-sk
dg
18 978 63 gr 21 10μm

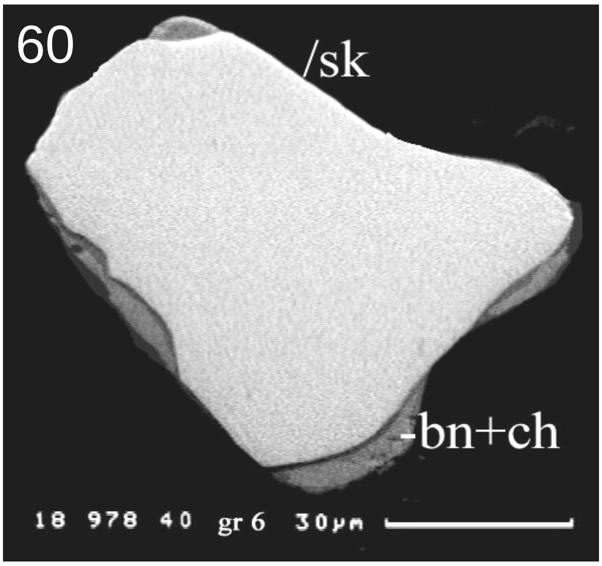

49
ch+bn
sk-
30μm
18 978 40 gr 35

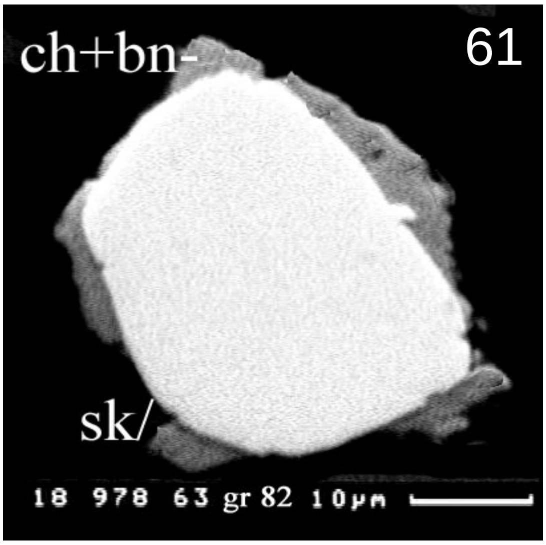

50
ch+bn
-sk
10μm
18 978 63 gr 54
51
ch+bn
\sk
10μm
18 978 63 gr 45
52
/bn+ch
sk/
18 978 63 gr 26 10μm
53
bn
-sk
18 978 40 gr 32 10μm
54
bn
/sk
18 978 63 gr 10 10μm
55
/sk
bn-
18 978 40 gr 5 30μm
56
/bn
sk-
18 978 63 gr 28 10μm

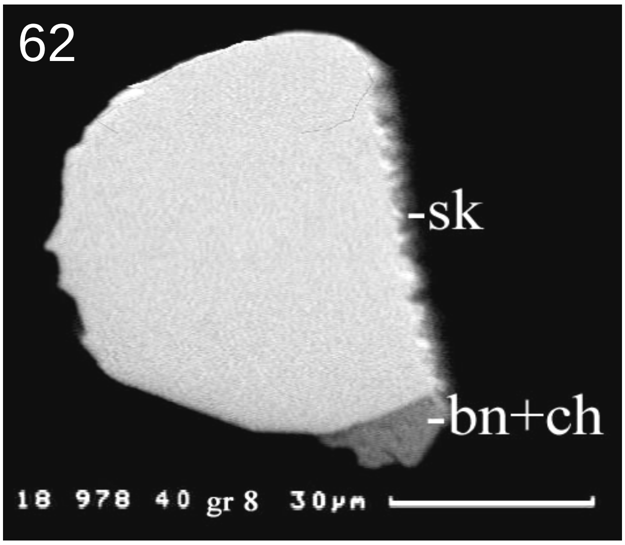

57
sk-
ch
18 978 63 gr 12 10μm

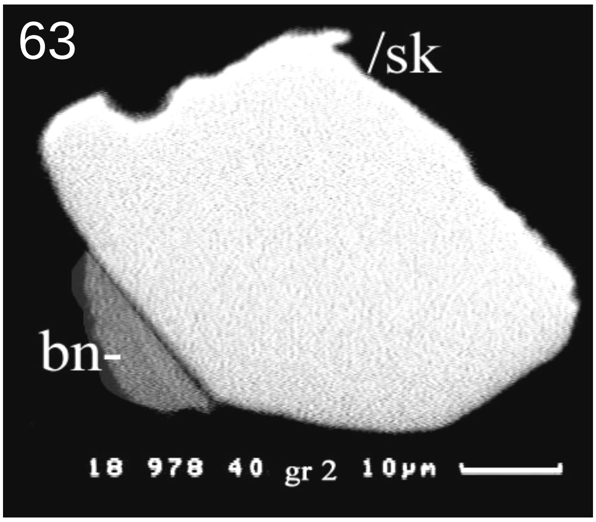

58
sk-
/ch
18 978 63 gr 23 10μm

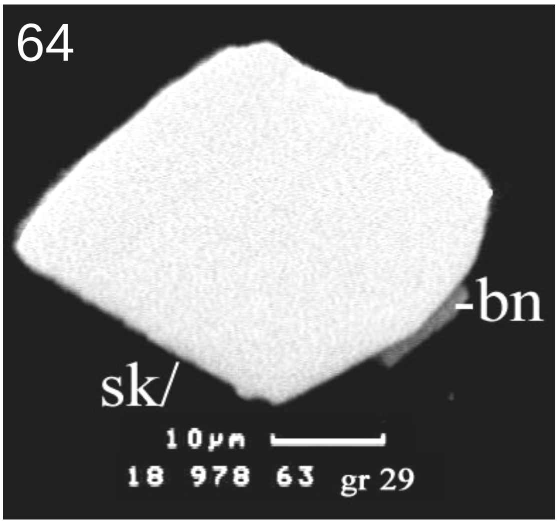

59
sk\
-ch+bn
10μm
18 978 63 gr 37

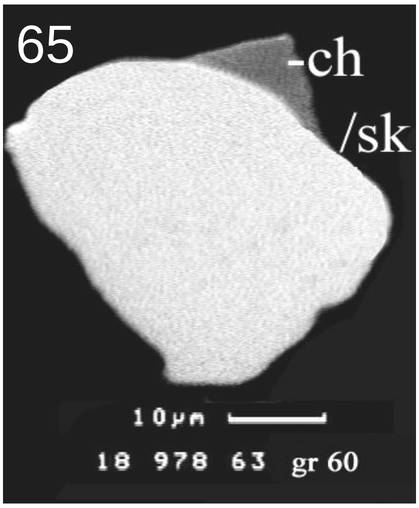

60
/sk
-bn+ch
18 978 40 gr 6 30μm

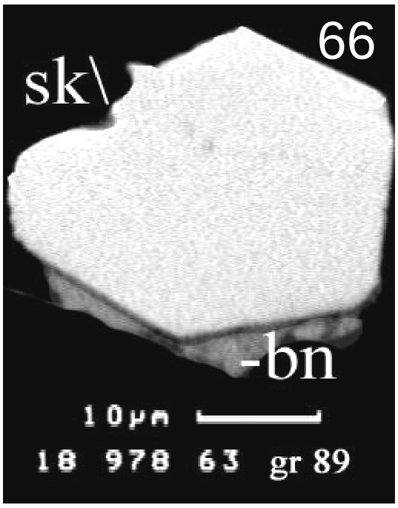

ch+bn-
61
sk/
18 978 63 gr 82 10μm

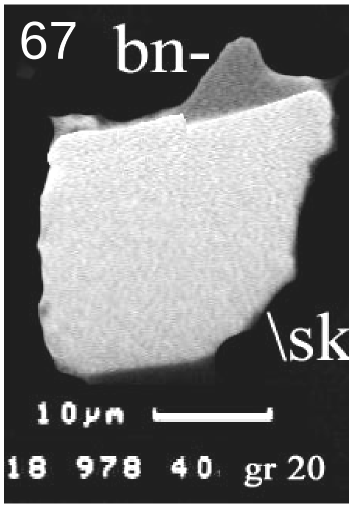

62
-sk
-bn+ch
18 978 40 gr 8 30μm

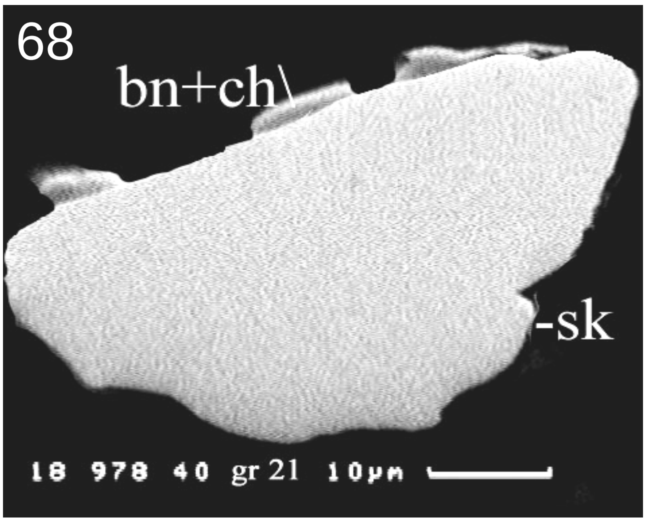

63
/sk
bn-
18 978 40 gr 2 10µm

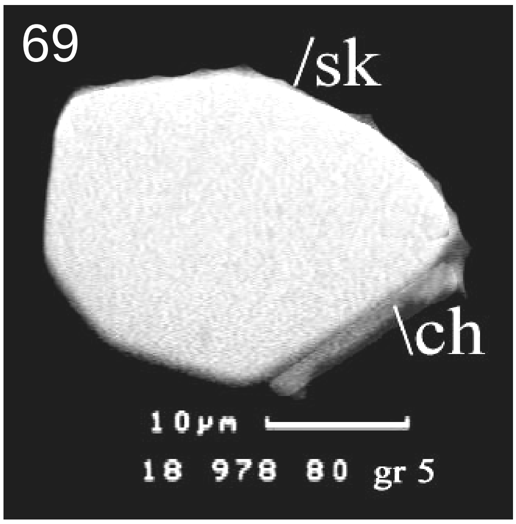

64
-bn
sk/
10µm
18 978 63 gr 29

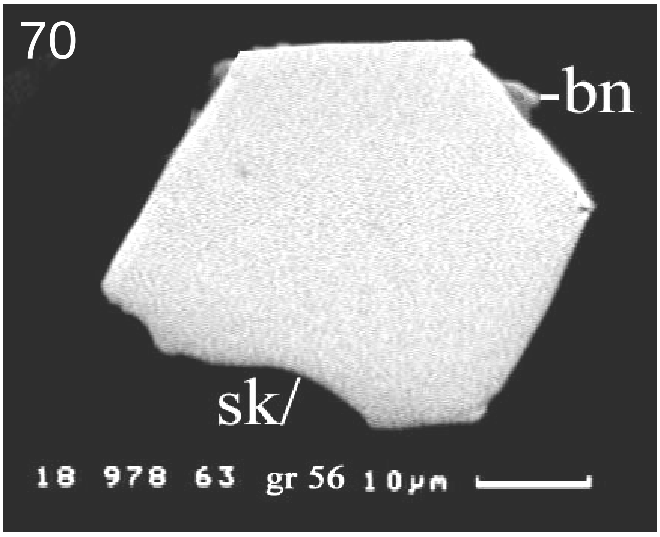

65
-ch
/sk
10µm
18 978 63 gr 60

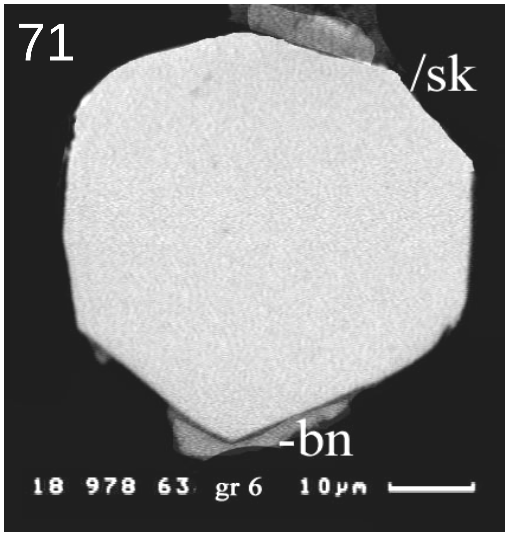

66
sk\
-bn
10µm
18 978 63 gr 89

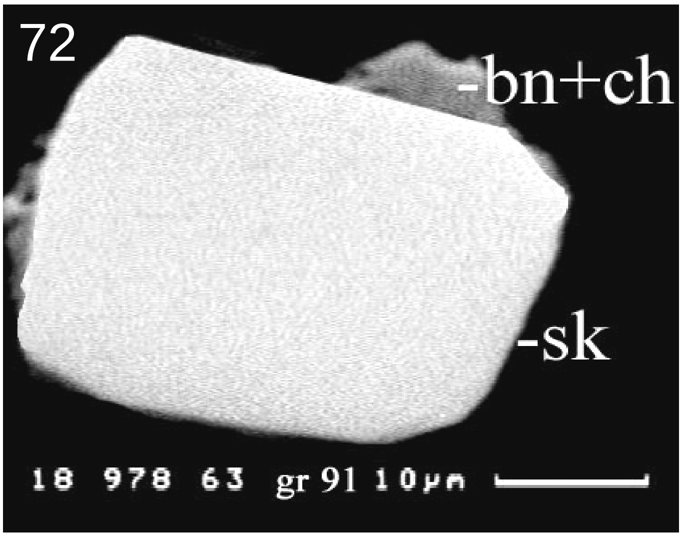

67
bn-
\sk
10µm
18 978 40 gr 20

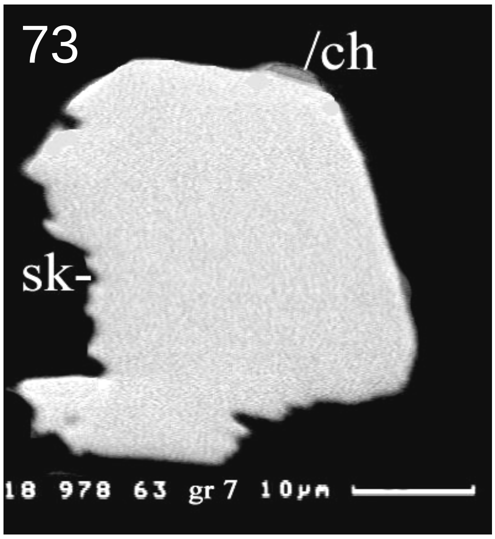

68
bn+ch\
-sk
18 978 40 gr 21 10µm

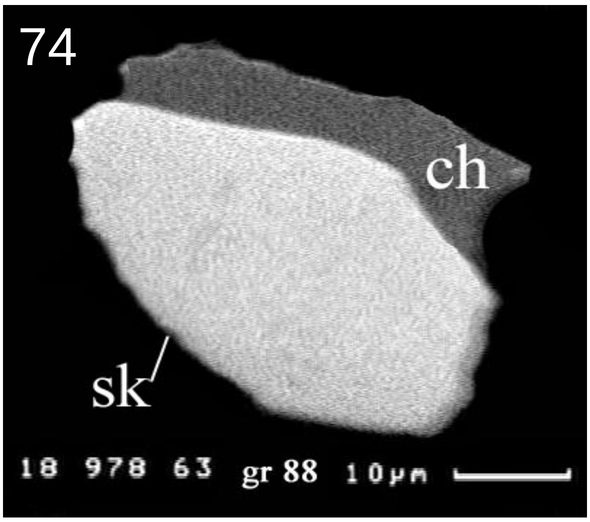

69
/sk
\ch
10µm
18 978 80 gr 5

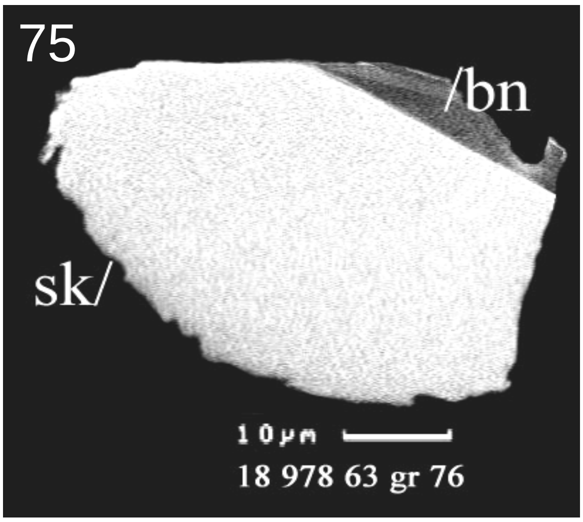

70
-bn
sk/
18 978 63 gr 56 10µm

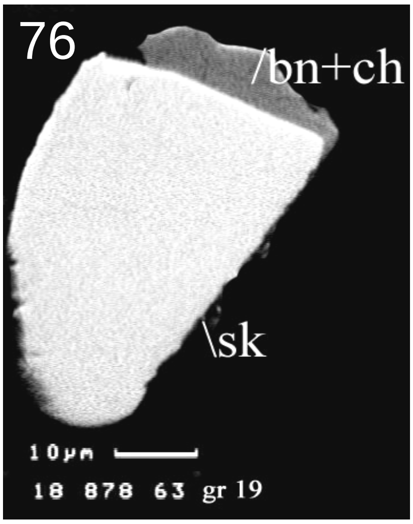

71
/sk
-bn
18 978 63 gr 6 10µm

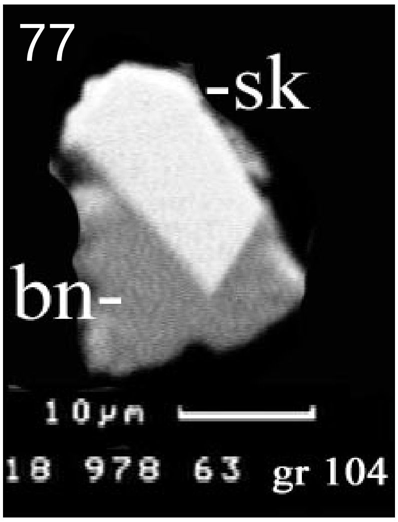

72
-bn+ch
-sk
18 978 63 gr 91 10µm

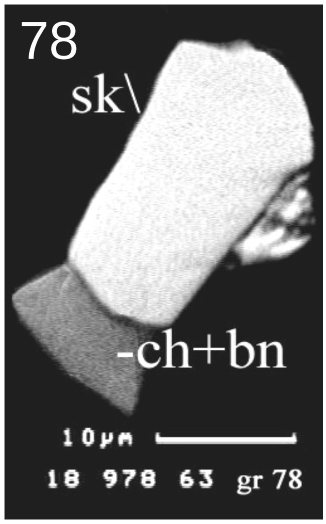

73
/ch
sk-
18 978 63 gr 7 10µm

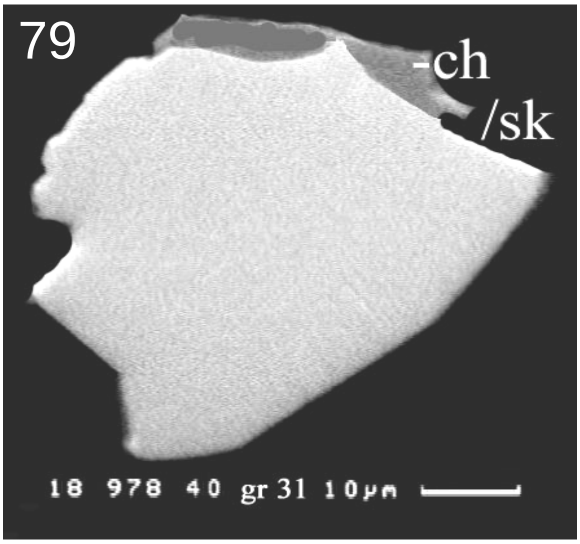

74
ch
sk/
18 978 63 gr 88 10µm

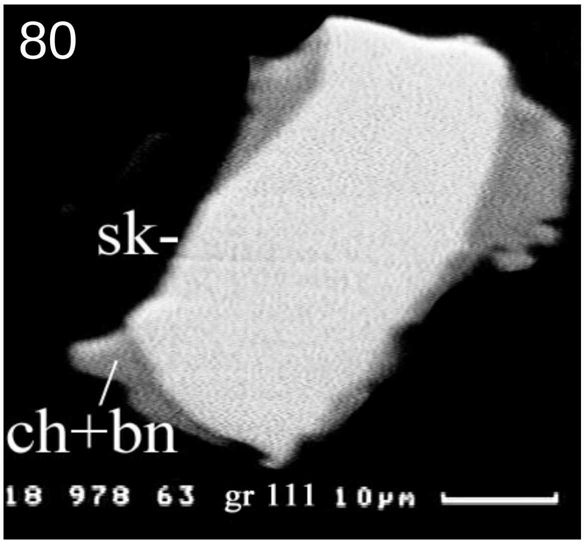

75
/bn
sk/
10µm
18 978 63 gr 76

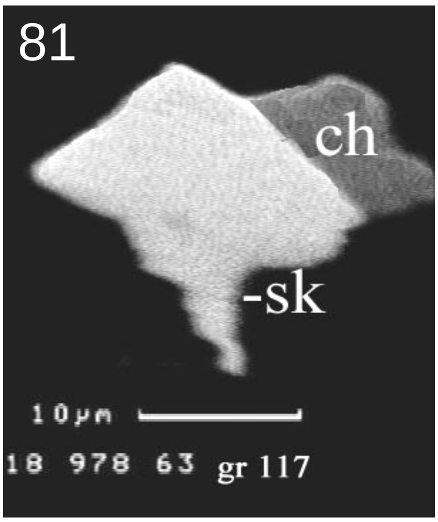

76
/bn+ch
\sk
10μm
18 878 63 gr 19

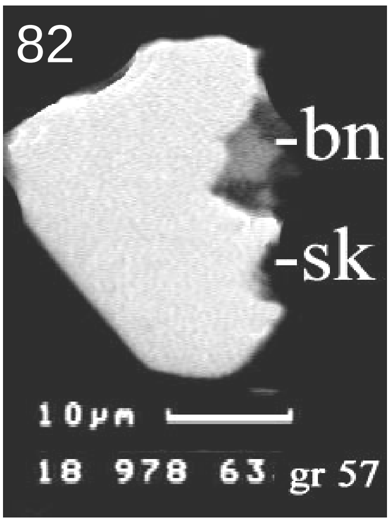

77
-sk
bn-
10μm
18 978 63 gr 104

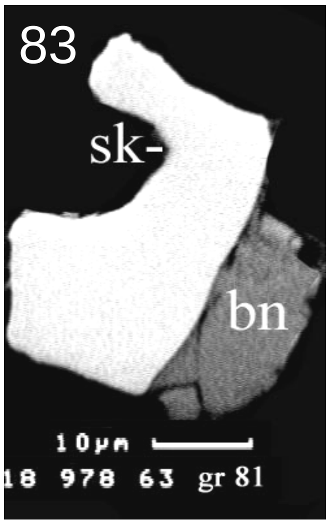

78
sk\
-ch+bn
10μm
18 978 63 gr 78

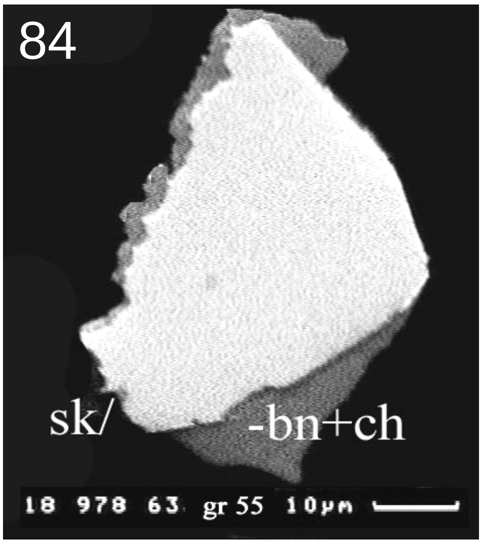

79
-ch
/sk
18 978 40 gr 31 10μm

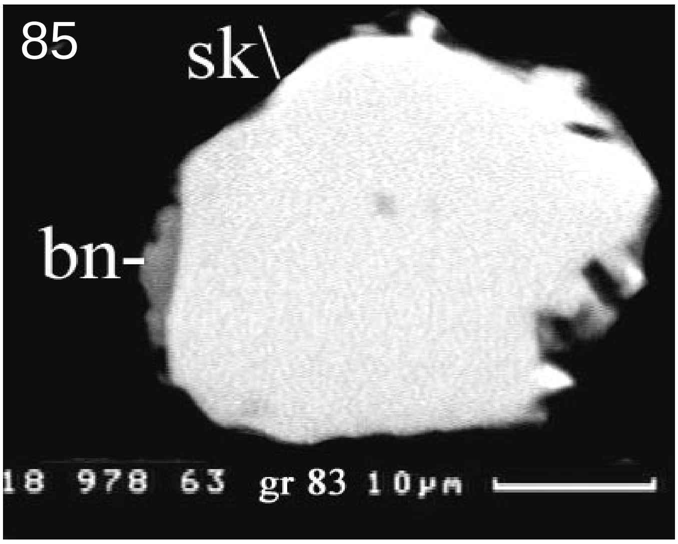

80
sk-
/
ch+bn
18 978 63 gr 111 10μm

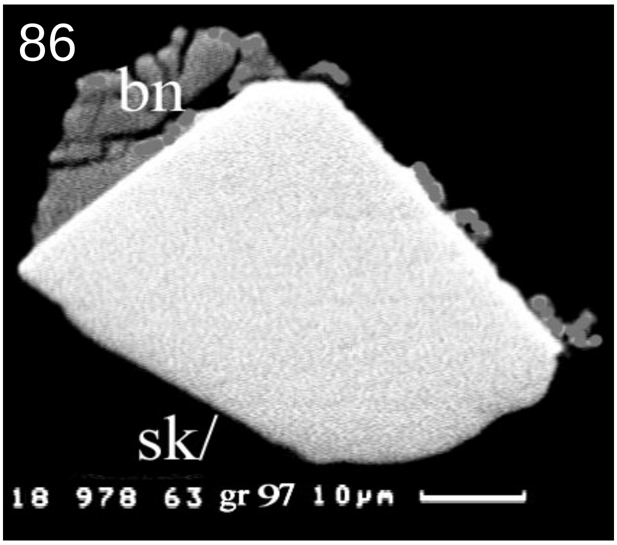

81
ch
-sk
10μm
18 978 63 gr 117

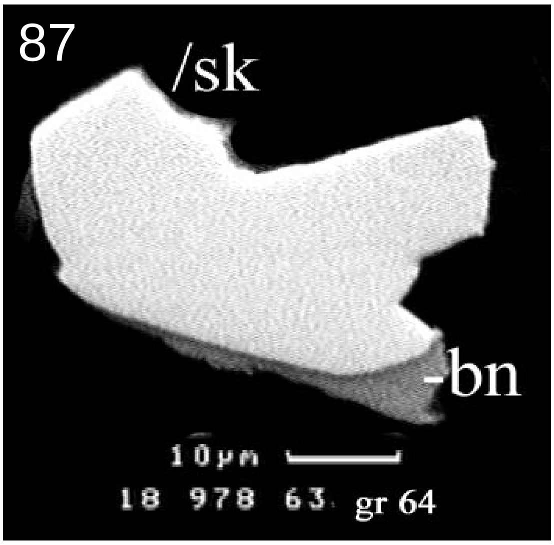

82
-bn
-sk
10μm
18 978 63 gr 57

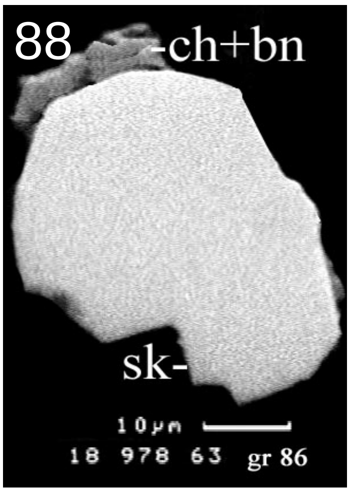

83
sk-
bn
10μm
18 978 63 gr 81

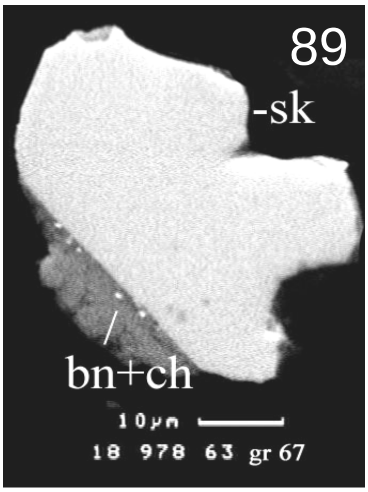

84
sk/
-bn+ch
18 978 63 gr 55 10µm

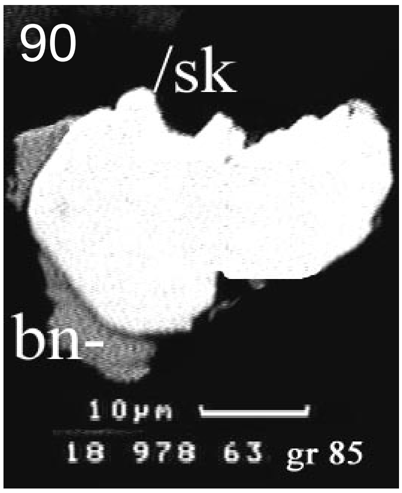

85
sk\
bn-
18 978 63 gr 83 10µm

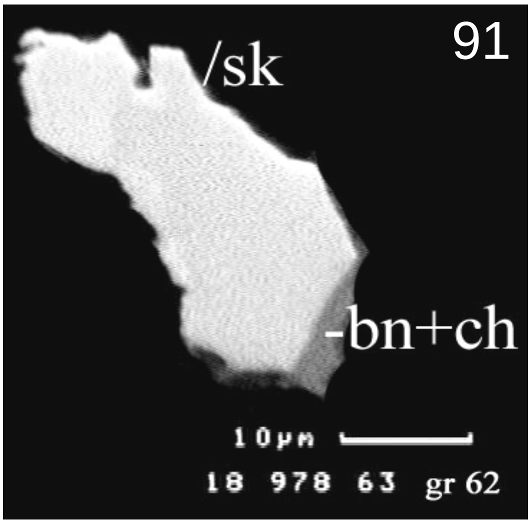

86
bn
sk/
18 978 63 gr 97 10µm

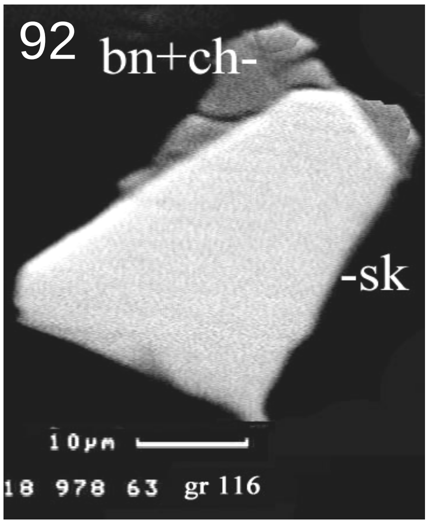

87
/sk
-bn
10µm
18 978 63 gr 64

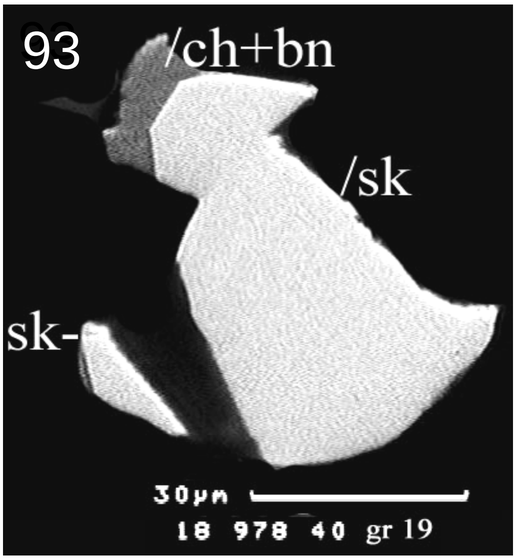

88
-ch+bn
sk-
10µm
18 978 63 gr 86


89
-sk
/
bn+ch
10µm
18 978 63 gr 67


90
/sk
bn-
10µm
18 978 63 gr 85


91
/sk
-bn+ch
10µm
18 978 63 gr 62


92
bn+ch-
-sk
10µm
18 978 63 gr 116


93
/ch+bn
/sk
sk-
30µm
18 978 40 gr 19

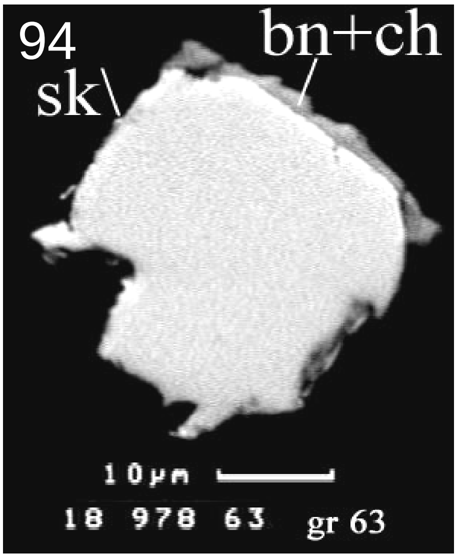
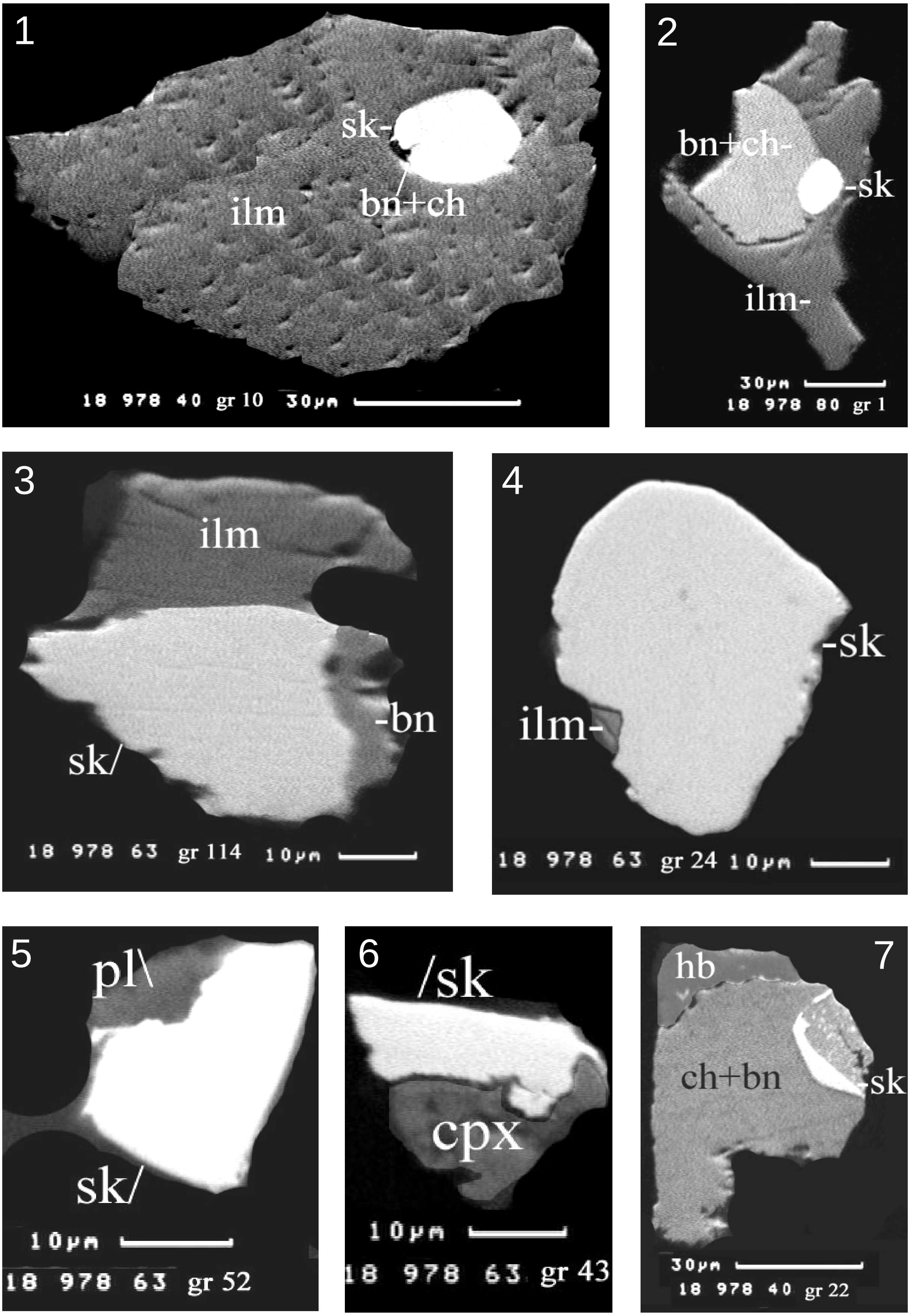
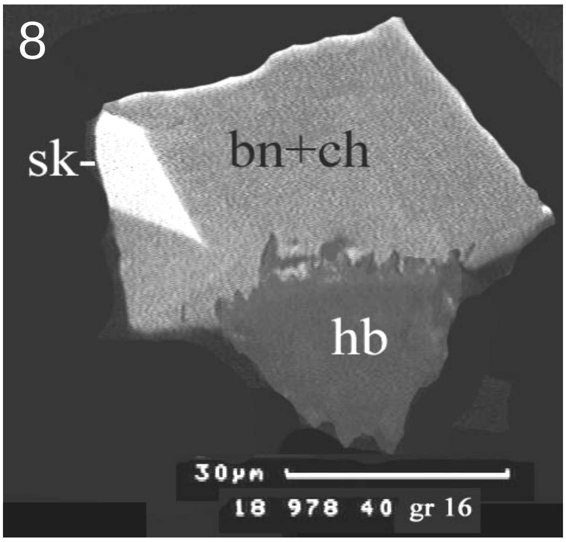
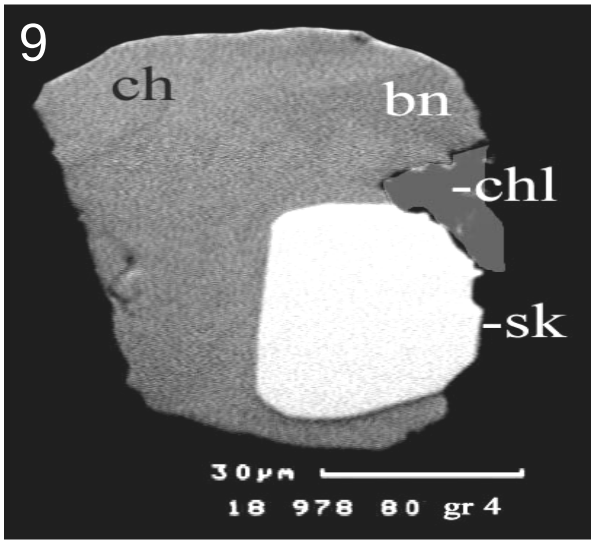

94
bn+ch
sk\
10µm
18 978 63 gr 63

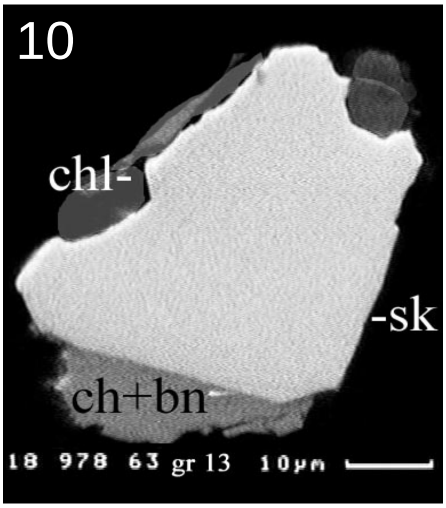
Plate 5

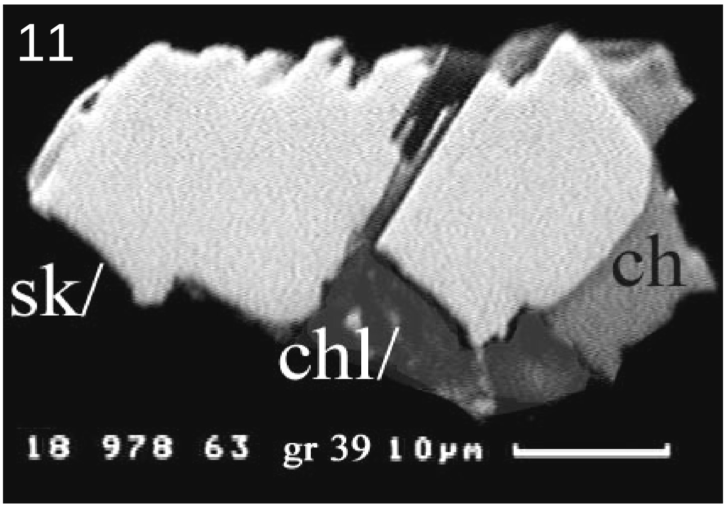
Skaergaardite particles attached base metal sulphides and gangue (**sag**) or skaergaardite attached gangue (**ag**) - in heavy concentrates of the sample 90-18, 978 (1-11); polished section, SEM-image (BIE); sk – skaergaardite, bn – bornite, ch – chalcosine, ilm – ilmenite, cpx – clinopyroxene, pl - plagioclase, chl – chlorite, hb – hornblende.


1
sk-
ilm
bn+ch
18 978 40 gr 10 30μm
2
bn+ch-
-sk
ilm-
30μm
18 978 80 gr 1
3
ilm
-bn
sk/
18 978 63 gr 114 10μm
4
-sk
ilm-
18 978 63 gr 24 10μm
5
pl\
sk/
10μm
18 978 63 gr 52
6
/sk
cpx
10μm
18 978 63 gr 43
hb
7
ch+bn
-sk
30μm
18 978 40 gr 22


8
sk-
bn+ch
hb
30μm
18 978 40 gr 16


9
ch
bn
-chl
-sk
30μm
18 978 80 gr 4


10
chl-
-sk
ch+bn
18 978 63 gr 13 10μm


11
sk/
ch
chl/
18 978 63 gr 39 10μm

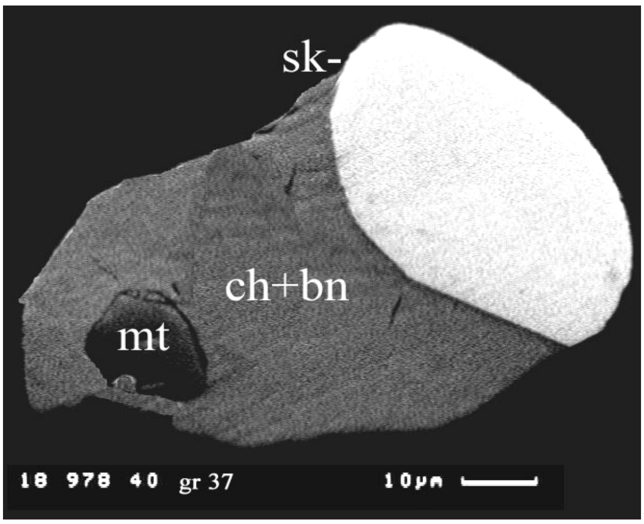
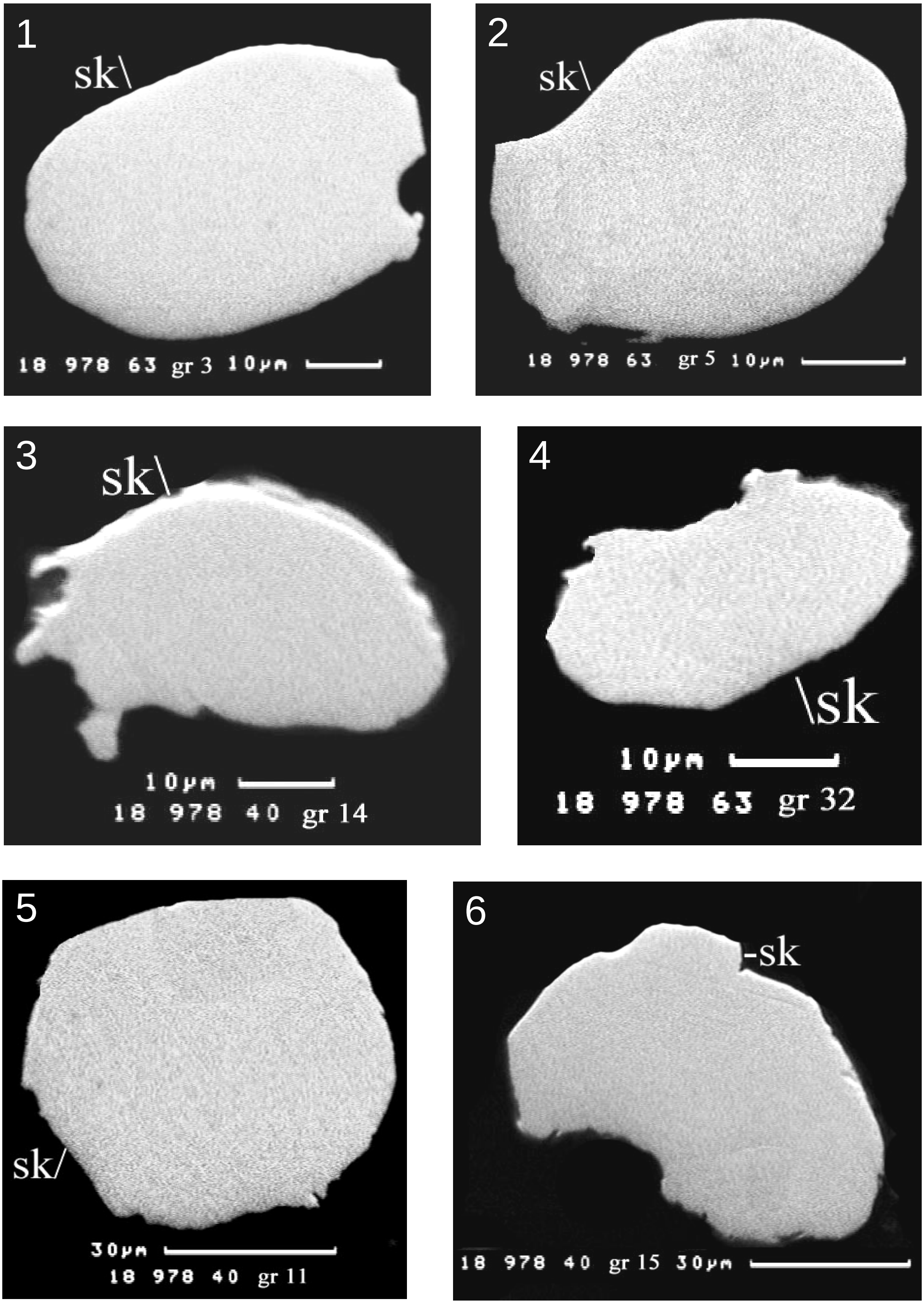
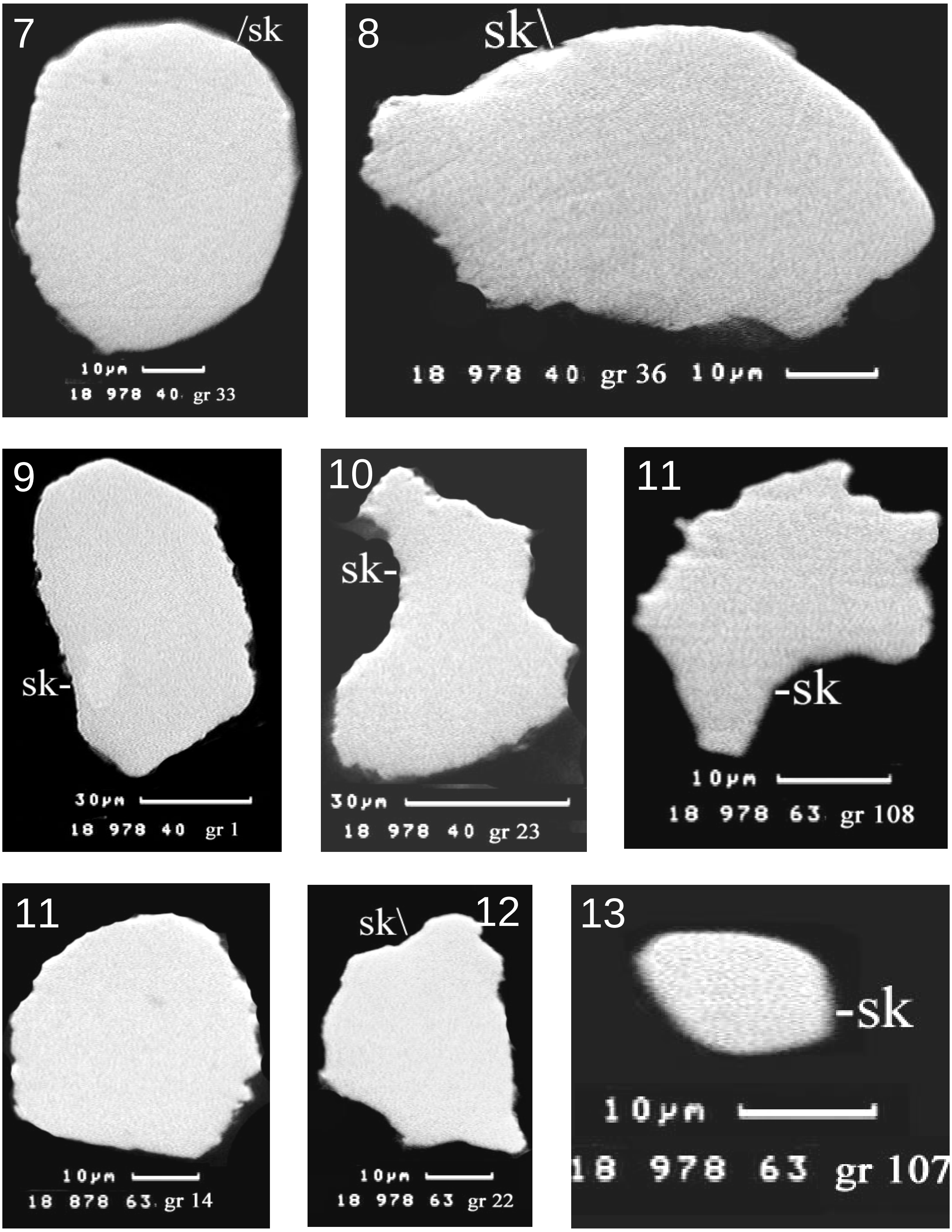
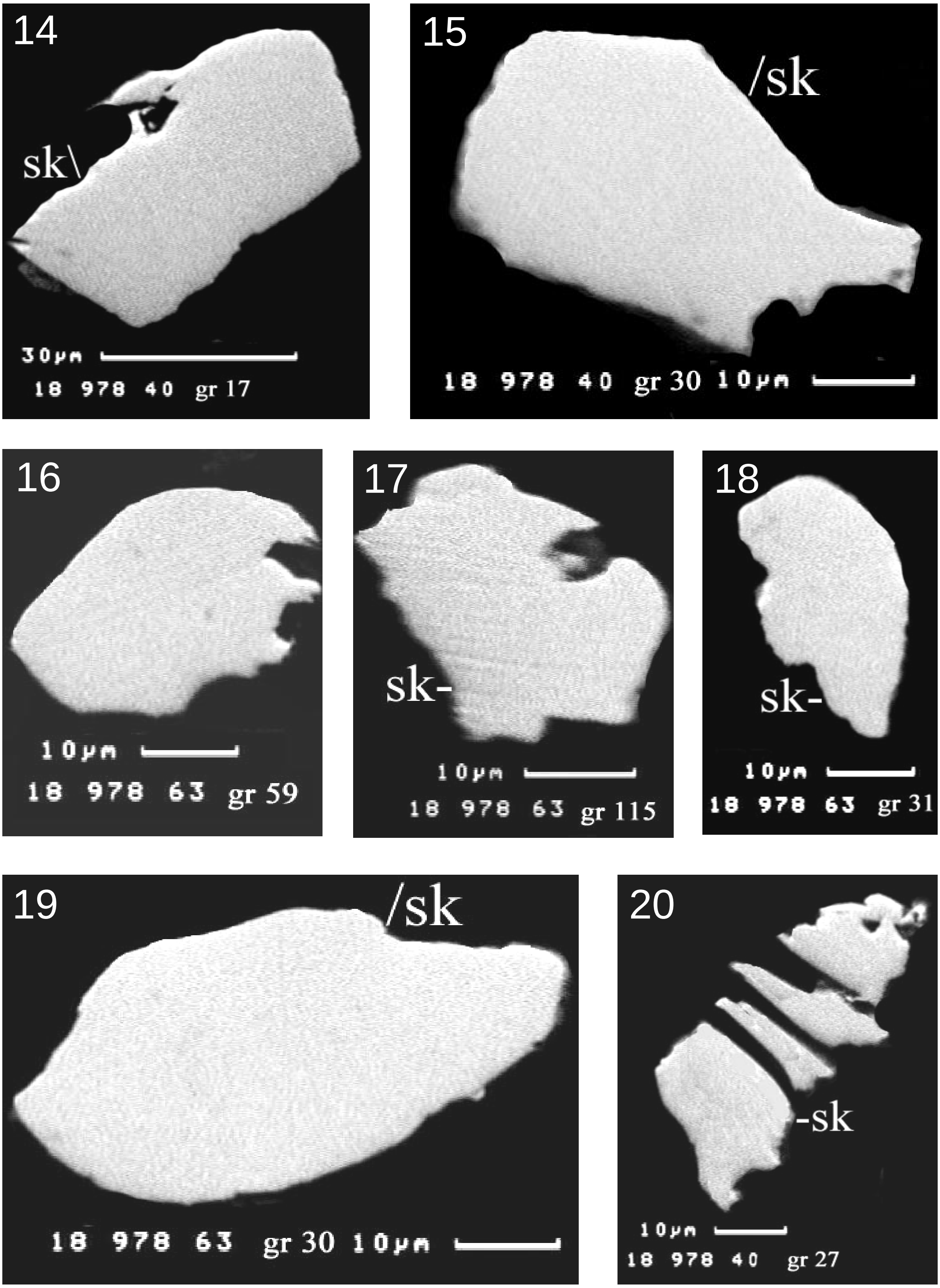

sk-
ch+bn
mt
18 978 40 gr 37
10μm

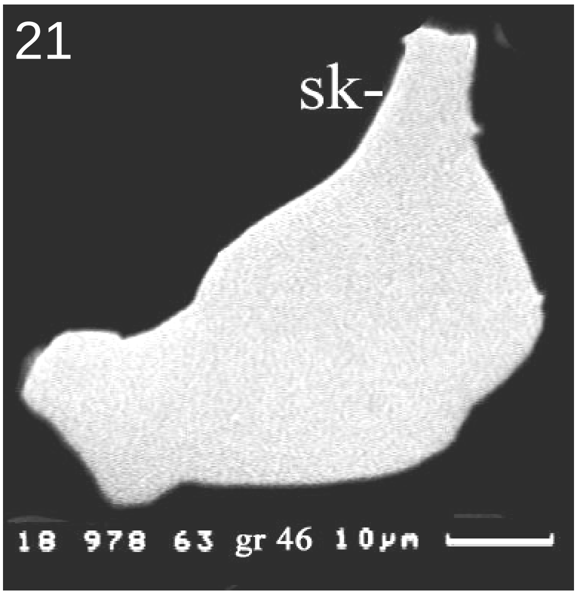
Plate 6

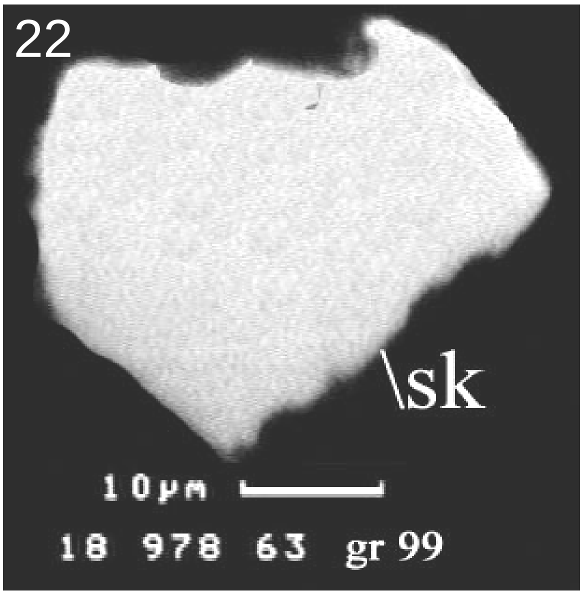
Liberated skaergaardite particles (l) - in heavy concentrates of the sample 90-18, 978 (1-28); polished section, SEM-image (BIE); sk – skaergaardite.

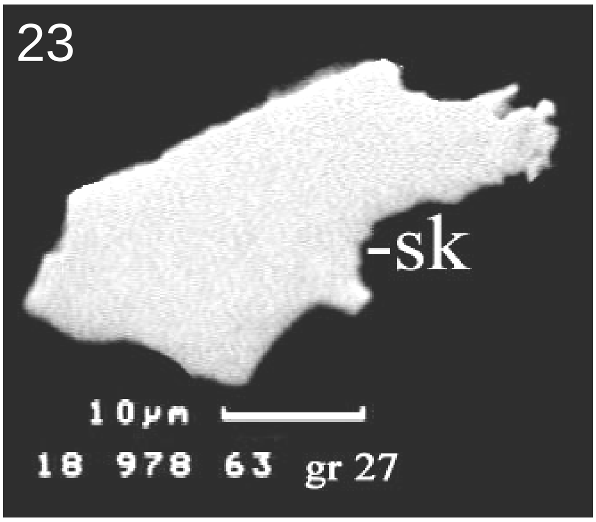

1
sk\
18 978 63 gr 3 10μm
2
sk\
18 978 63 gr 5 10μm
3
sk\
10μm
18 978 40 gr 14
4
\sk
10μm
18 978 63 gr 32
5
sk/
30μm
18 978 40 gr 11
6
-sk
18 978 40 gr 15 30μm

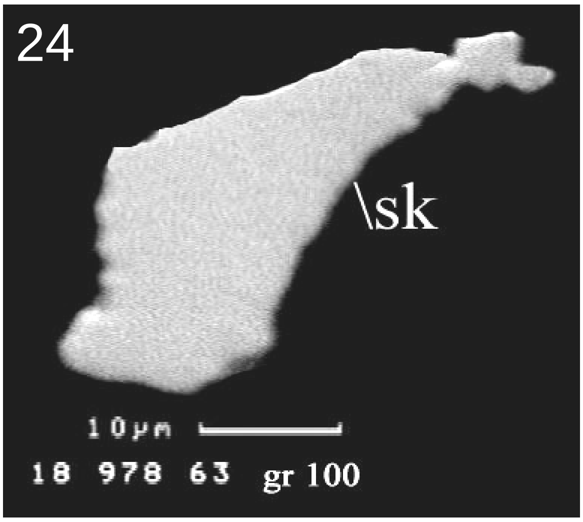

7
/sk
10μm
18 978 40 gr 33
8
sk\
18 978 40 gr 36 10μm
9
sk-
30μm
18 978 40 gr 1
10
sk-
30μm
18 978 40 gr 23
11
-sk
10μm
18 978 63 gr 108
11
10μm
18 878 63 gr 14
sk\
12
10μm
18 978 63 gr 22
13
-sk
10μm
18 978 63 gr 107

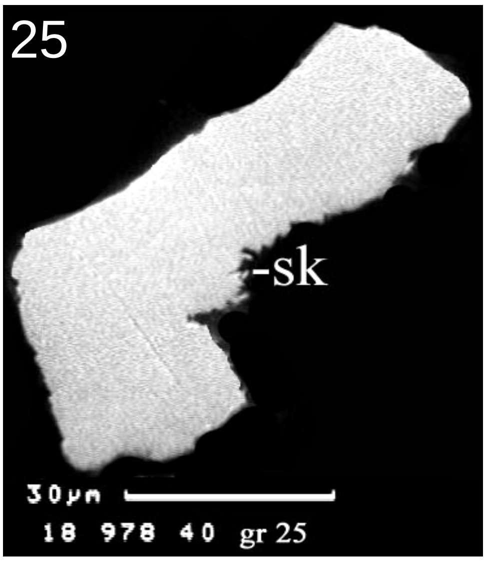

14
sk\
30µm
18 978 40 gr 17
15
/sk
18 978 40 gr 30 10µm
16
10µm
18 978 63 gr 59
17
sk-
10µm
18 978 63 gr 115
18
sk-
10µm
18 978 63 gr 31
19
/sk
18 978 63 gr 30 10µm
20
-sk
10µm
18 978 40 gr 27

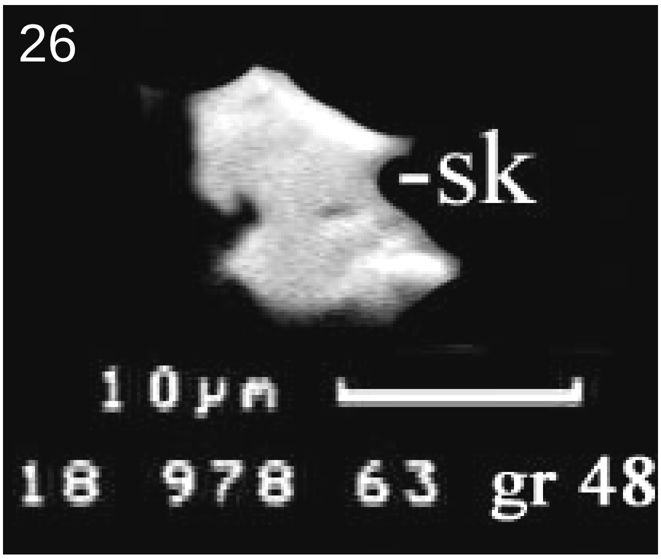

21
sk-
18 978 63 gr 46 10μm

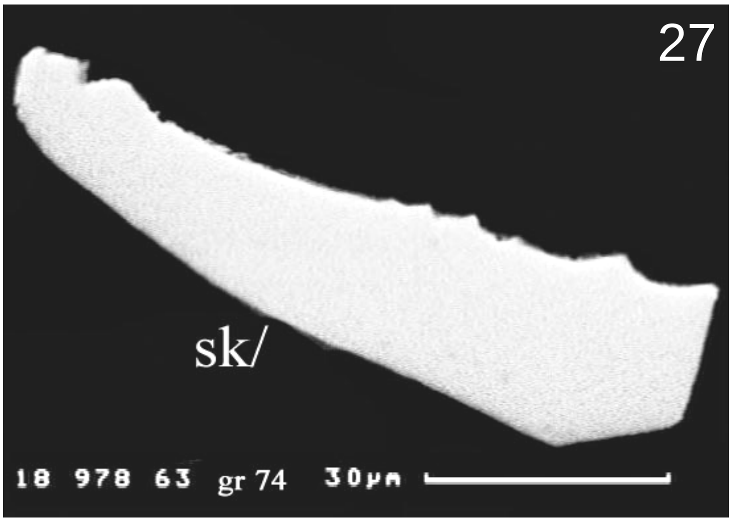

22
\sk
10μm
18 978 63 gr 99


23
-sk
10μm
18 978 63 gr 27


24
\sk
10μm
18 978 63 gr 100


25
-sk
30μm
18 978 40 gr 25


26
-sk
10μm
18 978 63 gr 48


27
sk/
18 978 63 gr 74 30μm

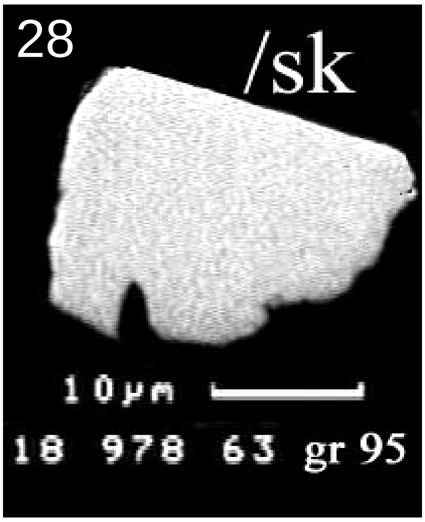
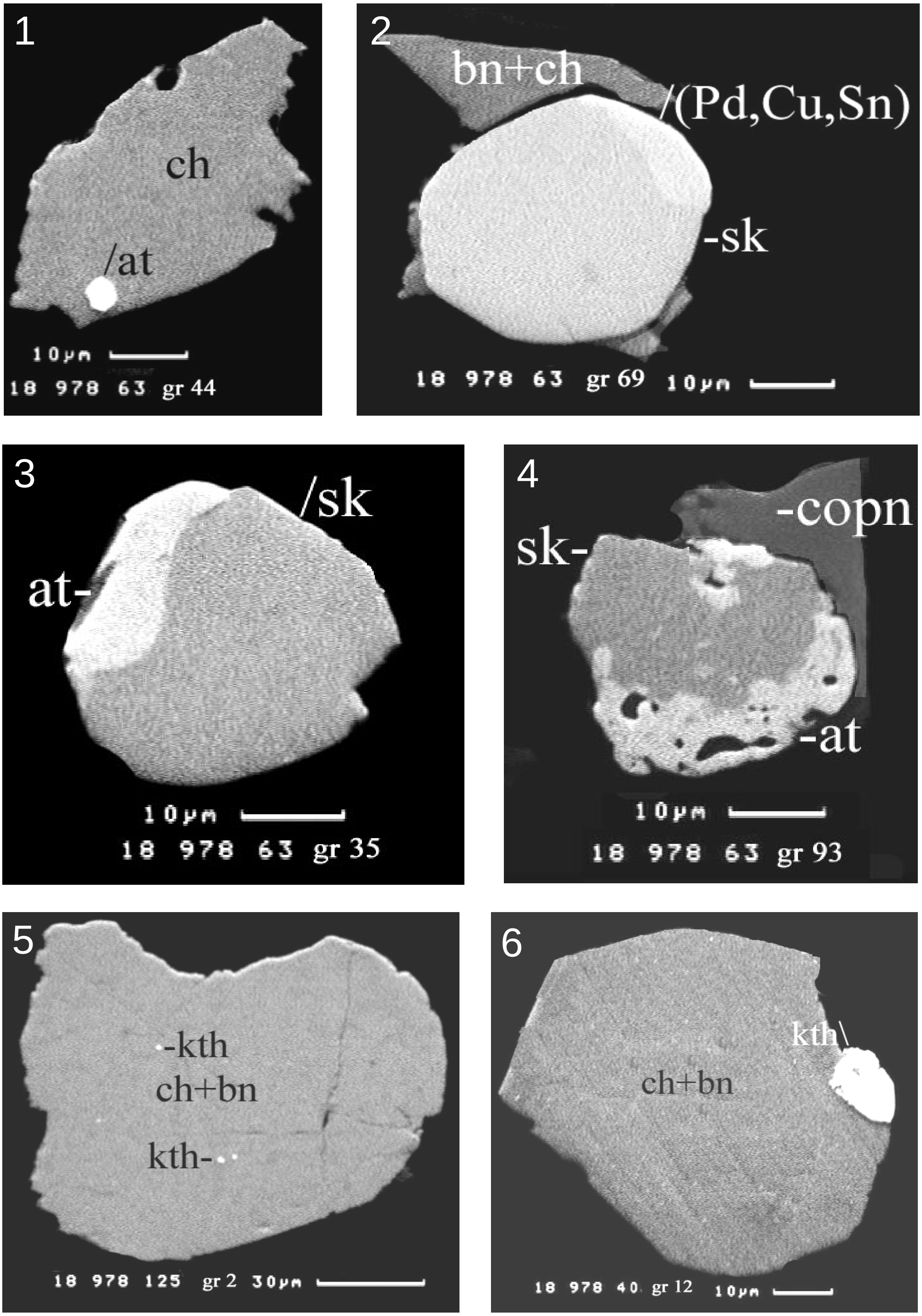
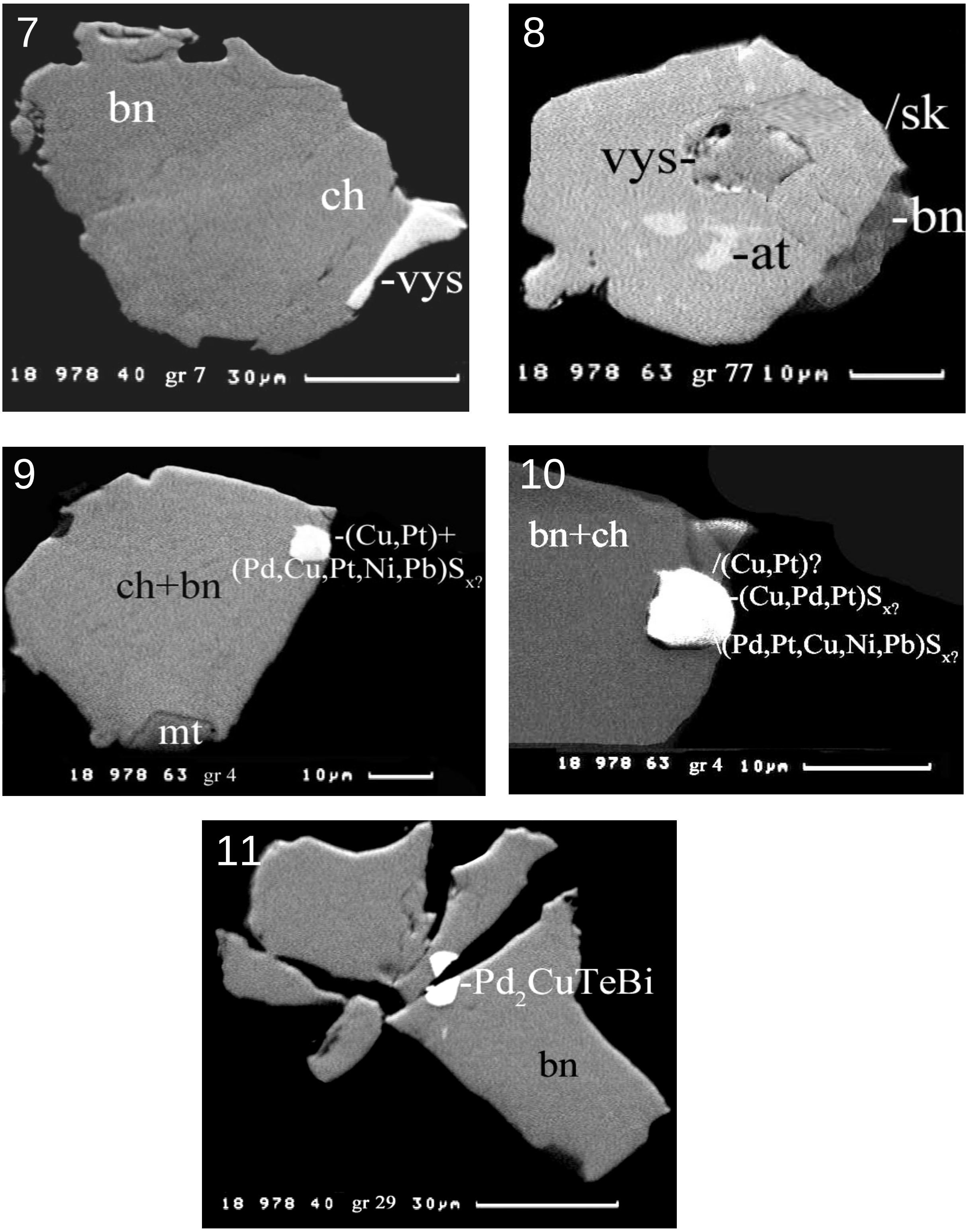

28
/sk
10μm
18 978 63 gr 95

Plate 7

PGM grains containing atokite (at, 1, 2, 4, 8), (Pd,Cu,Sn) alloy (2), keithconnite (kth, 5, 6), vysotskite (vys, 7,-8), unnamed Pd-Cu-Pt-Ni-Pb sulphides (9, 10) and $Pd_2CuTeBi$ (11) in heavy concentrates of the sample 90-18, 978; polished section, SEM-image (BIE); sk – skaergaardite, bn – bornite, ch – chalcosine, copn – cobalt pentlandite, mt – magnetite; 10 is part of 9.


1
ch
/at
10μm
18 978 63 gr 44
2
bn+ch
/(Pd,Cu,Sn)
-sk
18 978 63 gr 69 10μm
3
/sk
at-
10μm
18 978 63 gr 35
4
-copn
sk-
-at
10μm
18 978 63 gr 93
5
-kth
ch+bn
kth-
18 978 125 gr 2 30μm
6
kth\
ch+bn
18 978 40 gr 12 10μm


7
bn
ch
-vys
18 978 40 gr 7 30μm
8
/sk
vys-
-bn
-at
18 978 63 gr 77 10μm
9
-(Cu,Pt)+
(Pd,Cu,Pt,Ni,Pb)S$_{x?}$
ch+bn
mt
18 978 63 gr 4 10μm
10
bn+ch
/(Cu,Pt)?
-(Cu,Pd,Pt)S$_{x?}$
\(Pd,Pt,Cu,Ni,Pb)S$_{x?}$
18 978 63 gr 4 10μm
11
-Pd$_2$CuTeBi
bn
18 978 40 gr 29 30μm