DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2009/68

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

Part 7: Sample 90-18 958

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ABSTRACT

The report presents the results of mineralogical investigations of sample # “90-18 958” from the gold-rich upper Pd1 level in the precious metal mineralization in the Skaergaard intrusion. The bulk sample was collected between 958 and 959 meters in core “90-18” (Watts, Griffis and McOuat, 1991). Assays give 351 ppb Pd, 283 ppb Au, and 37 ppb Pt for this interval.

The gabbro in sample 90-18 958 has a characteristic structure showing reaction relationships between cumulus and inter-cumulus phases. Rinds of olivine occur at the boundaries between interstitial matrix Fe-Ti-oxides and rock-forming clinopyroxene with low-Ca pyroxene exsolution lamellae. In general, this is a “dry” rock. H_2O-bearing minerals are only locally represented in very insignificant amounts in intergrowths with Cu-Fe-sulfides.

The sample preparation included careful grinding in shatter box, sieving into fractions, wet magnetic separation of all fractions, followed by hydroseparation of non-magnetic fractions. With few exceptions, magnetic fractions do not contain precious metal phases. The concentrates were prepared as monolayer polished sections and investigated under the scanning electron microscope and the electron microprobe.

The HS concentrates contain numerous sulfide grains identified as sulfide droplets. They are formed by one or more Cu-sulfides – bornite - (83 %), more rarely by bornite and chalcopyrite (8 %), bornite and chalcosine (6 %) or chalcopyrite and chalcosine only. Several of these droplets and sulfide grains contain inclusions of a variety of PGMs in addition to liberated (free) precious metal grains.

Thirty-three particles (and 37 grains) of precious metal minerals and phases were found in the monolayer mounts. The main precious metal minerals are skaergaardite PdCu (72.3 area %) and a variety of (Au,Cu) alloys (23.4 area %). The (Au,Cu) alloys include: tetra-auricupride (Au,Pd,Pt)Cu (6.2 area %), unnamed $(Au,Pd)_3Cu$ (7.3 area %), non stoikiometric (Au,Cu) alloy (Au>Cu in atomic quantity; 9.1 area %), (Cu,Au) alloy (Cu>Au, atomic proportions, 0.8 area %). These minerals are followed by 3 less common minerals (~4 % of all precious metal minerals of the sample): nielsenite $(Pd,Au)Cu_3$ (3.3 area %), keithconnite $Pd_{3-x}(Te,Pb)$ (0.8 area %) and zvyagintsevite Pd_3Pb (0.1 area %).

The grain size of precious metal minerals (ECD) varies from 7 to 48μm, with an average of 22.5μm.

The average composition of skaergaardite (13 analyses) is (wt. %): Pd 60.3, Pt 0.2, Au 2.2, Cu 30.1, Fe 3.9, Zn 1.8, Sn 0.3, Te 0.5, Pb 0.2 Total 99.5; giving the formula :

$$(Pd_{0.98}Au_{0.02})_{1,00}(Cu_{0.82}Fe_{0.12}Zn_{0.05}Te_{0.01})_{1.00}.$$

The estimated bulk composition of the sample (assays of whole rock in brackets) is (ppb): Pd 410 (351), Au 258 (283), Pt 3 (37). Pd is concentrated in (Cu,Pd) alloys (93%) and

(Au,Cu) alloys (6 %). Pt-minerals were not found. Pt is contained in skaergaardite and tetra-auricupride. The majority of the determined precious metal minerals (PGMs and tetra-auricupride) appear to form a single paragenesis together with Cu-Fe sulfides. The paragenesis probably crystallized from late interstitial melt/fluid.

Introduction

The report describes the mineralogy of sample “90-18 958” from the Pd1 horizon in the “Platinova Reef” of the Skaergaard intrusion. The Platinova Reef is located in the lower half of the Triple Group that forms the upper 100 meters of the Middle Zone (MZ) of the Layered Series (LS) of the intrusion (see Nielsen et al., 2006 for further details). The sample was collected as a bulk sample from 958 to 959 meters in core “90-18).

This report on the PGE and Au mineralogy is based on studies of the concentrates of Au and PGM grains recovered by means of Hydroseparator CNT HS-11 (www.cnt-mc.com). The concentrates, and a polished section of the host gabbro have been studied in detail using electron microscopy and electron microprobe (Camscan-4DV, Link AN-10 000). The report gives descriptions of the analytical techniques, grain characteristics, parageneses and compositional variation within the identified groups of precious metal minerals, alloys, sulfide grains and host gabbro.

Sample 90-18 958

Sample 90-18 958 was collected from BQ drill core # “90-18” between 958 and 959 m (Watts, Griffis and McOuat, 1991) and represents the melanocratic gabbro of the Pd1 level of the Platinova Reef mineralization. Assays give 351 ppb Pd, 283 ppb Au, and 37 ppb Pt for this interval. The core has previously been sampled for other purposes and the sample does not collect all of the interval The sample includes app. 1/3 of the diameter of the preserved core.

Mineralogical investigation

Sample preparation

Small portions of the sample (971g) were crushed for short periods (0.3-0.5 min) using a shatter box with small cavities (200ml) and systematically sieved to remove the fine fraction (sieving -100µm) after each crushing session. The residual coarse fraction >100µm was re-crushed until the entire sample attained the desired maximum grain size. After complete grinding, the sample was passed through standard sieves with water (wet sieving): <40µm (424.8g) , 40-50µm (64.1g), 50-70µm (161.4g), 70-100µm (230.4g), loss 90.3 g (~9%). All fractions were subsequently passed through wet magnetic separation.

The non-magnetic parts of every fraction were then passed through hydroseparation using the computer controlled hydroseparator CNT HS-11 and a newly patented glass separation tube (GST). (Rudashevsky & Rudashevsky, 2006 and 2007) – see www.cnt-mc.com. Monolayer polished sections were produced from all the resulting non-magnetitc heavy mineral fractions. The polished sections (and one polished section of the bulk rock) were investigated under the scanning electron microprobe. No precious metal grains were found in the magnetic fractions.

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

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Results

Rock forming minerals and sulfide mineralogy

Silicates and oxides

The silicates and oxides phases related to the sulfide paragenesis include: 1) *monoclinic ferrous pyroxene*, Mg# = 0.46-0.59 (Table 1, analyses 4-6); 2) *orthorhombic ferrous pyroxene*, Mg# = 0.17-0.18 (Table 1, analyses 7 and 8); 3), *fayalite-rich olivine*, Mg# 0.43-0.45 (Table 1, analyses 9 and 10); 4) *plagioclase*, $An_{45\text{-}53}$ (Table 1, analyses 1-3); Fe-Ti oxides including 5) *ilmenite* (Table 1, analyses 11-13) and 6) *titaniferous magnetite* (Table 1, analyses 14-16). Monoclinic and orthorhombic pyroxenes form exsolution textures (Plate 1, #*5, 7, 8*).

The Fe-Ti-oxides occur as aggregates of 1-3 mm, anhedral grains. They are interstitial and fill space between grains of plagioclase and pyroxenes (see Plate 1, #*1-6, 8, 10*). Gabbro of sample 90-18 958 shows a distinct reaction relationship between cumulus and intercumulus phases. Rinds of olivine separate interstitial Fe-Ti-oxides and pyroxene-rich domains (Plate 1, #*1-3, 5*).

Two characteristic accessory phases, apatite (Plate 1, #*6*) and baddelleyite (Plate 1, #*10*), were identified in the polished section of sample 90-18 958. Several grains of baddeleyite were also identified in the heavy mineral concentrates (~40µm in size - Plate 3). They could be used for radiometric dating of the Pd1 level in the mineralization.

Sulfides

The rock forming minerals of the gabbro are relatively poor in sulfides. Grains composed of bornite-and chalcopyrite were identified only in a pyroxene aggregate characterized by exsolution (Plate 1, #*1, 5-9*).

The non-magnetic heavy mineral HS concentrates are ilmenite-rich products (> 97 %) enriched in grains of sulfides and PGMs (see Plate 2). The sulfide grains are represented by droplet-like microglobules of: (1) bornite (Plate 4, #*1-14 etc*), (2) bornite-chalcopyrite (Plate 4, #*29, 30* etc), and (3) bornite-chalcosine (Plate 4, #*37- 39* etc.), or irregular grains: (1) bornite (Plate 4, #*15-28* etc), (2) bornite-chalcopyrite (Plate 4, #*31-35* etc), (3) bornite-chalcosine (Plate 4, #*40, 41*), and (4) chalcopyrite only (Plate 4, #*36*). They are up to 0.1 mm in size.

The majority (~83 %) of thesulfide grains are composed of bornite, only, and in few cases of bornite and chalcopyrite (8 %, sometimes separated by chalcosine), or bornit and chalcosine (6 %, sometimes separated by chalcopyrite). Bornite and chalcopyrite, or bornite and chalcosine form exsolution textures inside sulphide micro globules and grains (see Plate 4, #*29, 30, 32-34, 39, 40* etc.).

Chemical compositions oshow bornite (Table 2, analyses 1-13, average: analysis 14), chalcosine (Table 2, analysis 15) and chalcopyrite (Table 2, analysis 16) to be near stoikiometric.

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

Recovery

No PGM grains were found during SEM studies of the polished bulk rock section of the gabbo. The heavy mineral HS concentrates, on the other hand, yielded many precious metal grains and 33 representative grains and particles in the <50 μm fractions of the heavy mineral HS concentrates were studied in detail. In total, 8 different PGE and Au minerals are recorded from sample 90-18 958. They include (see Table 3):

1. *skaergaardite* (Pd,Au)(Cu,Fe,Zn,Te) – 15 grains,
2. *nielsenite* $(Pd,Au)(Cu,Fe)_3$ –3 grains,
3. *(Au,Cu,Pd) alloy*– 5 grains,
4. *unnamed* $(Au,Pd)_3(Cu,Fe)$ – 5 grains,
5. *tetra-auricupride* (Au,Pd,Pt)(Cu,Fe) – 5 grains,
6. *(Cu,Au) alloy* - one grain,
7. *keithconnite* $Pd_{3-x}(Te,Pb)$ – 3 grains,
8. *zvyagintsevite* Pd_3Pb – one grain.

The volumetric proportions of these phase are calculated from the area of grains as observed in the polished mounts of the HS concentrates (Table 3 and Fig. 1).

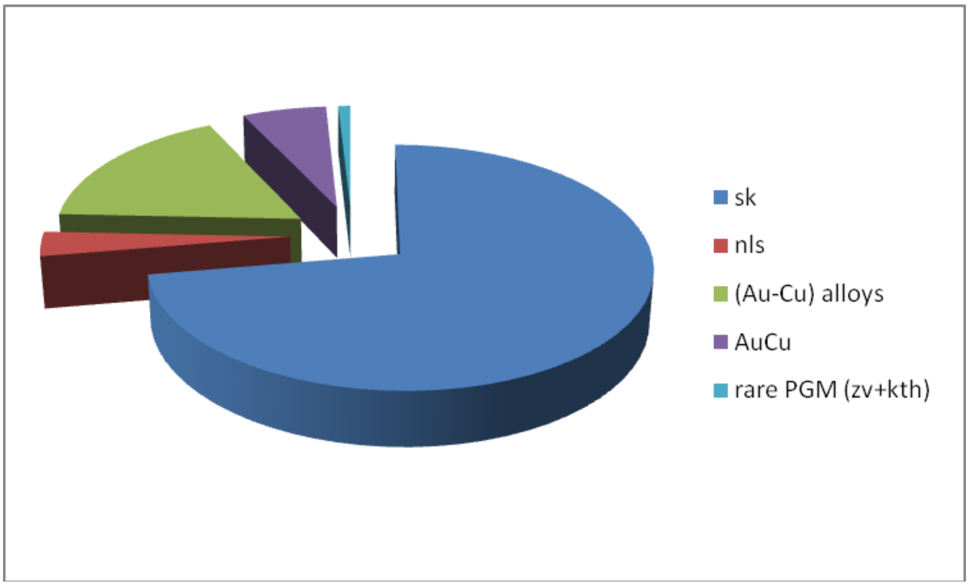

Fig.1. Precious metal minerals (area %) from the heavy mineral HS concentrates of the sample 90-18, 958; sk-skaergaardite, nls - nielsenite, AuCu – tetra-auricupride, kth – keith-connite, and zv – zvyagintsevite.

Grain size

Grain sizes were measured by their effective diameters (ECD) using imageJ software. The ECD varies from 7 to 48µm with the average of 22.5µm (Table 4; Fig. 2).

Sizes of precious metal mineral grains are distributed as follows:

Grain size, µm	Number of grains
0-10	1
10-20	18
20-30	7
30-40	6
40-50	1
Total	33

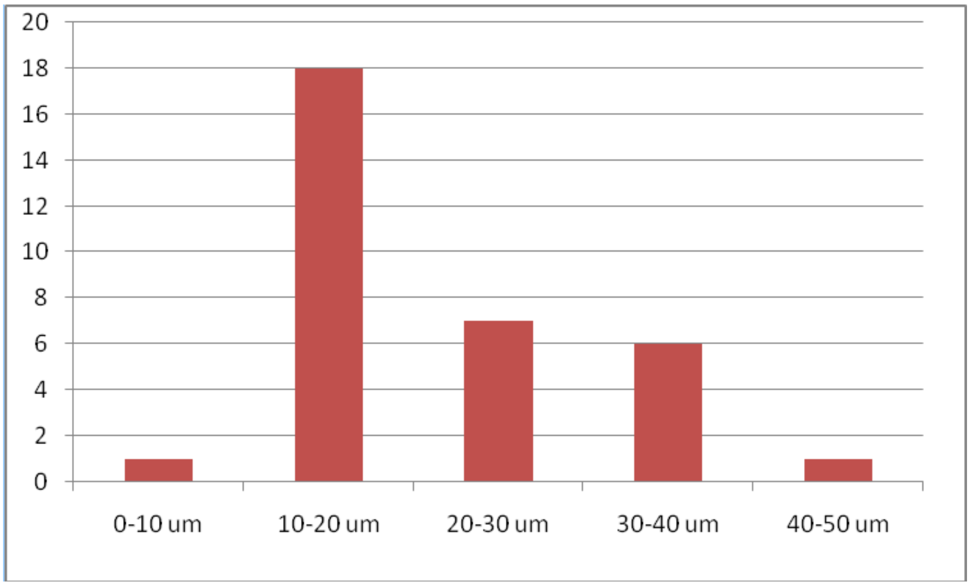

Figure 2. Grain size of precious metal mineral grains from the heavy mineral HS concentrates of the sample 90-18 958 (n=33, ECD_{avg} = 22.5µm).

The histogram of grain sizes (Fig. 2) shows lognormal distribution for the statistical selection (n=33).

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 5-7). Grains have not been broken during production of the concentrates. The largest proportion of PGM grains occur as inclusions in Cu-Fe sulfide globules and as librated grains.

Liberation

A perfect separation of accessory minerals have been achieved by the gentle crushing/disintegration of the studied sample. The method of disintegration allows preservation of primary grain size, and thus information fundamental for the development of genetic models. The concentrates provide all the necessary information for the reconstruction of the primary shapes and sizes of accessory minerals and phases, together with the parageneses and the relationships between minerals and the matrix of the rock.

In the heavy mineral HS concentrates of the sample 90-18 958 the precious metal mineral grains occur in the mineral associations shown in figure 3 (see also Table 5).

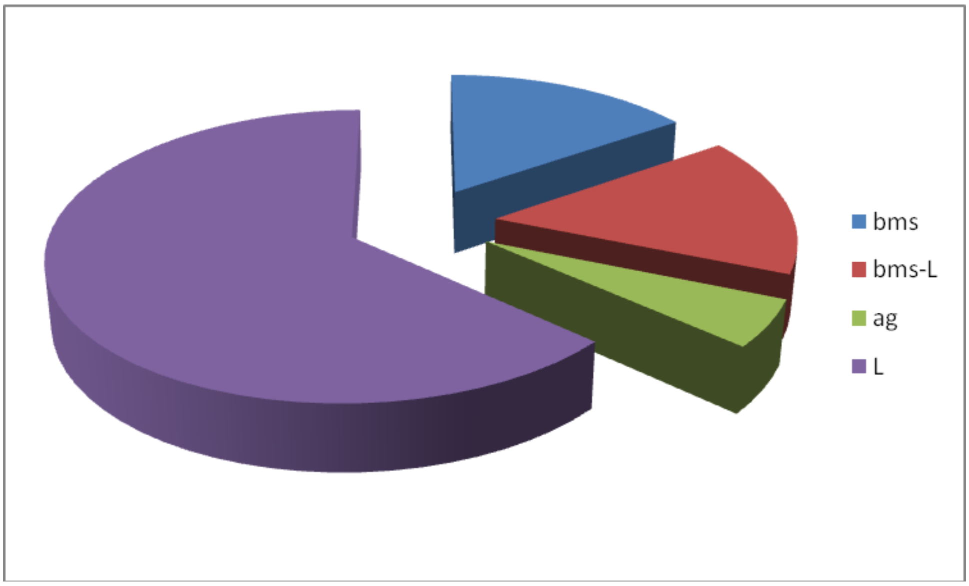

Figure. 3. Distribution of liberation for PGE- and gold minerals in the heavy mineral HS concentrates of the sample 90-18 958; bms - precious metal minerals attached to base metal sulfides; bms-L - exposed >90% precious metal minerals, attached to bms; ag - precious metal minerals attached to gangue; L – liberated (free) precious metal minerals.

Description and composition of the precious metal minerals

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

Description

Skaergaardite (Rudashevsky e.a., 2004) is one of the main precious metal mineral found in the heavy mineral HS concentrates of the sample 90-18 958 (72.3 area % of all precious metal minerals). It occurs in intergrowths with base metal sulfides (bornite and chalcopyrite - Plate 5, #*1, 3, 5*; Plate 7*, #5*), or in the form of liberated (free) grains (Plate 5, #*2, 4, 6-12*). Sometimes skaergaardite has inclusions of other PGM (for example keithconnite - see Plate 7, #*5*).

Skaergaardite grains occur both as as irregular shaped grains and aggregates, and as euhedral crystals or partially euhedral grains (see Plate 5).

The size of skaergaardite grains (#15) is from 6 to 48μm with an average of 29μm (Table 3).

Mineral chemistry

The chemical composition of skaergaardite is established in 13 analyses of 13 different grains (Table 5, analyses 1-13, and 14 average composition). The average composition is (wt. %): Pd 60.3, Pt 0.2, Au 2.2, Cu 30.1, Fe 3.9, Zn 1.8, Sn 0.3, Te 0.5, Pb 0.2 Total 99.5; the composition corresponds to the formula:

$$(Pd_{0.98}Au_{0.02})_{1.00}(Cu_{0.82}Fe_{0.12}Zn_{0.05}Te_{0.01})_{1.00}.$$

Typical substitutions in skaergaardite include: Pt up to 1.6 %, Au up to 9.9 %, Fe 2.0-5.4 %, Zn up to 3.4 %, Sn up to 2.1 %, Te up to 1.8 %, and Pb up to 1.7 %.

Nielsenite (Pd,Au)$(Cu,Fe)_3$

Two grains of nielsenite (McDonald e. a., 2008) with irregular shapes, and 7 and 25μm in size (3.3 area % of all PGE and gold minerals – see Table 3), were found in the heavy mineral HS concentrates (Plate 7, #*1-3*; Table 5, analyses 15, 16 and 17 (average). Nielsenite is found together with (Cu,Pd,Au) alloy as inclusions in bornite (Plate 7, #*1, 2*), or attached to clinopyroxene grain (Plate 7, #*3*).

Au-Cu minerals

(Au,Cu) alloys form the second most important group of precious metal minerals in sample 90-18 958 (23.4 area % of all precious metal minerals). The (Au,Cu) alloys include: tetra-auricupride (Au,Pd,Pt)Cu (6.2 area %), unnamed $(Au,Pd)_3Cu$ (7.3 area %), non stoikiometric (Au,Cu) alloy (Au>Cu in atomic proportion; 9.1 area %), (Cu,Au) alloy (Cu>Au in atomic proportion; 0.8 area %).

Tetra-auricupride (Au,Pd,Pt)Cu and (Cu,Au,Pd) alloys

Tetra-auricupride and non stokiometric (Cu,Au,Pd) alloys (Cu>Au in atomic proportion) occur as inclusions in bornite (Plate 6, #*1-4*; Plate 7, #*2*), or as liberated grains (Plate 6, #*5, 16*). Tetra-auricupride is found in intergrowths with keithconnite (Plate 6, #*4*). These alloys occur in the form of irregular shape grains (Plate 6, #*3-5*; Plate 7, #*2*), and sometimes as euhedral or partially euhedral crystals (see Plate 6, #*1, 2*).

The grain size of (Au,Cu) alloys varies between 13 and 18μm (#6) with an average of 15μm (see Table 3).

Chemical compositions of tetra-auricupride (5 analyses in 5 grains) are given in Table 6 (analyses 12-16). The average composition of tetra-auricupride (Table 6, analysis 17) is (wt. %): Pd 11.0, Pt 2.3, Au 58.7, Cu 27.2, Fe 0.7, Total 99.9. The composition corresponds to the formula

$$(Au_{0.71}Pd_{0.24}Pt_{0.03})_{0.98}(Cu_{0.98}Fe_{0.03})_{1.01}.$$

Chemical compositions of the (Cu,Au) alloys are given in the Table 6 (analyses 18, 19).

Unnamed $(Au,Pd,Pt)_3(Cu,Fe)$

Unnamed alloy with the simplified composition $(Au,Pd)_3Cu$ (7.3 area % of all precious metal minerals) is found being attached to gangue (clinopyroxene and ilmenite - Plate 6, #*6, 7*), or as liberated grains (Plate 6, #*8-10*) in the heavy mineral HS concentrates. Au_3Cu alloy occurs as irregular grains having a size from 13 to 22μm, with an average of 17μm (see Table 3).

Five analyses of this unnamed (Au,Cu) alloy have been obtained from five different grains (Table 6, analyses 6-10). The average composition of $(Au,Pd)_3Cu$ (Table 6, analysis 11) is (wt. %): Pd 6.5, Au 83.5, Cu 10.5, Fe 0.4, Total 99.8. The composition corresponds to the following formula:

$$(Au_{2.63}Pd_{0.32})_{2.95}(Cu_{1.02}Fe_{0.04})_{1.06}.$$

(Au,Cu,Pd) alloy

Non-stokiometric (Au,Cu,Pd) alloy (9.1 area % of all precious metal minerals) is found in the form of liberated grains (Plate 6, #*11-15*) in the heavy mineral HS concentrates. These alloys occur as irregular shaped grains between 13 and 24μm in size with an average of 19μm (see Table 3).

The chemical composition is established in 4 analyses from 4 different grains (Table 6, analyses 1-4). The average composition of (Au,Cu,Pd) alloy (Table 6, analysis 5) is (wt. %): Pd 7.7, Au 83.4, Cu 8.2, Fe 0.5, Total 99.8. The composition corresponds to the following formula:

$$(Au_{0.68}Cu_{0.20}Pd_{0.11}Fe_{0.02})_{1.01}.$$

The composition is close to the average of unnamed $(Au,Pd)_3Cu$ (see above).

Keithconnite $(Pd,Cu)_{3-x}(Te,Pb)$

Keithconnite (0.8 area % of all PGE and gold minerals and phases – see Table 3) is found as inclusions in matrix base metal sulfides (bornite and chalcopyrite, Plate 6, #*4;* Plate 7,

#5, 6) in the heavy mineral HS concentrates. This PGM occurs as intergrowth with tetra-auricupride (Plate 6, #4) as well as with skaergaardite (Plate 7, #5).

Keithconnite grains are irregular and from 6 to 9μm in size. The chemical composition of keithconnite is given in Table 5, analyses 18-20, and 21 (average).

Zvyagintsevite Pd_3Pb

Only one 5μm large and irregular grain of zvyagintsevite has been found (0.1 area % of all PGE and gold minerals – see Table 3). The grain was forms an inclusion in skaergaardite and bornite matrix (see Plate 7, #4; Table 5, analysis 22).

Bulk composition of PGMs of the sample 90-18 958

The relative concentrations of Pd, Au and Pt in sample 90-18 958 can be calculated from the total concentrations of precious metals (assay), the determined recovery, the modal proportions, the chemical compositions (Tables 3, 5 and 6), and the ideal densities of precious metal minerals. The estimated bulk composition of the sample (assays of whole rock in brackets) is (ppb): Pd 410 (351), Au 258 (283), Pt 3 (37). Pd is concentrated in (Cu,Pd) alloys (93%) and (Au,Cu) alloys (6 %). Pt-minerals were not found. Pt is found in skaergaardite and tetra-auricupride.

Discussion

PGM-paragenesis

The data shows that the main PGMs in the studied sample are (Cu,Pd) alloys (skaergaardite and nielsenite, 75.6 area %) and (Au,Cu) alloys (23.5 area %).

All the observations and the inter-grain relations (Plates 5-7) suggest that all PGEs and (Cu,Au) alloys (mainly tetra-auricupride) and the Cu-Fe sulfides form a single paragenesis. The Cu-Fe sulfides and the precious metal minerals are synchronous and crystallized later than rock-forming minerals: plagioclase, clinopyroxene, orthopyroxene, ilmenite and titaniferous magnetite. The Au-rich (Au,Cu) alloys (Au>>Cu in atomic proportion) are generally localized between rock-forming minerals and they probably crystallized from fluids or melt/fluid mixtures.

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Tables

Table 1 Sample 90-18-958 Rock-forming silicates and FeTi-oxides

Analysis	Plag	Plag	Plag	Cpx	Cpx	Opx	Opx	Opx	Olivine	Olivine	Ilm	Ilm	Ilm	Ti-Mt	Ti-Mt	Ti-Mt
SiO_2	56.53	55.03	54.6	49.25	48.88	49.04	47.11	47.11	33.91	33.82	nd	nd	nd	nd	nd	nd
TiO_2	nd	nd	nd	0.33	0.51	0.67	nd	nd	nd	nd	50.75	51.09	51.92	14.52	19.53	27.05
Al_2O_3	26.84	27.79	27.98	2.65	1.14	3.02	2.27	2.27	nd	nd	nd	nd	nd	11.34	3.02	4.35
V_2O_3	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.44	0.59	nd	1.32	1.47	0.88
Fe_2O_3	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	4.6	3.04	1.98	28.69	27.18	12.66
FeO	0.39	0.39	0.39	15.44	18.97	15.05	41.7	43.11	44.41	45.06	41.53	42.42	43.5	40.57	49.64	53.58
MnO	nd	nd	nd	0.41	0.39	0.39	0.78	0.78	0.9	0.78	0.52	0.52	0.78	0.26	0.52	0.65
MgO	nd	nd	nd	11.94	9.05	11.94	5.14	4.81	20.23	19.4	1.99	1.66	1.33	3.81	nd	1.99
CaO	9.37	10.35	11.05	20	20.77	19.3	2.66	1.54	nd	nd	nd	nd	nd	nd	nd	nd
Na_2O	6.33	5.53	5.53	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
K_2O	0.24	0.36	0.36	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Total	99.71	99.44	99.9	100	99.71	99.41	99.66	99.64	99.45	100.1	99.83	99.31	99.5	100.5	101.4	101.2
Cations																
Si	2.54	2.49	2.46	1.89	1.92	1.89	1.97	1.97	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Ti	0.00	0.00	0.00	0.01	0.01	0.02	0.00	0.00	0.00	0.00	0.95	0.97	0.98	3.02	4.30	5.81
Al	1.42	1.48	1.49	0.12	0.05	0.14	0.11	0.11	0.00	0.00	0.00	0.00	0.00	3.70	1.05	1.46
V	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.29	0.35	0.20
Fe^{3+}	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.09	0.06	0.04	5.97	6.00	2.72
Fe^{2+}	0.01	0.01	0.01	0.50	0.62	0.48	1.45	1.51	1.09	1.14	0.87	0.89	0.91	9.39	12.18	12.80
Mn	0.00	0.00	0.00	0.01	0.01	0.01	0.03	0.03	0.02	0.02	0.01	0.01	0.02	0.06	0.13	0.16
Mg	0.00	0.00	0.00	0.68	0.53	0.69	0.32	0.30	0.89	0.85	0.07	0.06	0.05	1.57	0.00	0.85
Ca	0.45	0.50	0.53	0.82	0.88	0.80	0.12	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Na	0.55	0.49	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.01	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
O basis	-	-	-	6	6	6	6	6	4	4	-	-	-	-	-	-
Cations	5	5	5	-	-	-	-	-	-	-	2	2	2	24	24	24

Table 2. **Chemical compositions (wt%) and formulas of sulphides from the heavy mineral HS concentrates (sample 90-18, 958)**

Analysis#	Grain#	Association	Mineral	Cu	Fe	S	Total	*Cu*	*Fe*	*S*	*Total*
Bornite				**Analysis**				***Atomic proportions***			
1	40-5g	bn*	bn	63.7	11.6	25.8	101.1	*4.98*	*1.03*	*3.99*	*10*
2	50-c	bn	bn	63.2	11.6	25.7	100.5	*4.96*	*1.04*	*4.00*	*10*
3	50-e	bn	bn	62.7	11.4	25.5	99.6	*4.97*	*1.03*	*4.00*	*10*
4	50-1	sk-bn	bn	64.1	11.1	25.5	100.7	*5.04*	*0.99*	*3.97*	*10*
5	50-3a	bn	bn	62.4	11.3	25.7	99.4	*4.95*	*1.02*	*4.03*	*10*
6	40-b	bn	bn	63.0	11.0	25.5	99.5	*4.99*	*1.00*	*4.01*	*10*
7	70-c	bn	bn	62.8	11.1	25.4	99.3	*4.99*	*1.00*	*4.00*	*10*
8	40-e	bn	bn	63.5	11.2	26.1	100.8	*4.96*	*1.00*	*4.04*	*10*
9	40-f	bn	bn	63.4	11.2	25.7	100.3	*4.99*	*1.00*	*4.01*	*10*
10	40-g	bn	bn	63.5	11.3	25.1	99.9	*5.04*	*1.02*	*3.95*	*10*
11	40-h	bn	bn	62.8	11.4	25.5	99.7	*4.97*	*1.03*	*4.00*	*10*
12	40-k	bn-cp	bn	63.2	11.1	25.4	99.7	*5.00*	*1.00*	*3.99*	*10*
13	40-m	bn	bn	63.1	10.9	25.5	99.5	*5.01*	*0.98*	*4.01*	*10*
14	aerage			63.2	11.2	25.6	100.0	*4.99*	*1.01*	*4.00*	
Chalcosine											
15	40-o	bn-chc	chc	78.1	1.1	20.1	99.3	1.97	0.03	1.00	3
Chalcopyrite											
16	40-q	cp-hb	cp	34.3	30.3	34.5	99.1	1.00	1.01	1.99	4

Abbreviations: bn: bornite; sk: skaergaardite; cp: chalcopyrite; chc: chalcosine; hb: hornblende

Table 3. Platinum group minerals and gold minerals of the heavy mineral HS concentrates (sample 90-18 958)

#	Mineral	General formula	N	Area	#%	Area%	ECDmin	ECDavg	ECDmax
1	Skaergaardite	(Pd,Au)(Cu,Fe,Zn)	15	11308	40.5	72.3	5.6	28.9	47.7
2	Nielsenite	$PdCu_3$	2	522	5.4	3.3	7.1	16	24.8
3	(Au,Cu)	(Au,Cu)	5	1429	13.5	9.1	13.2	19.1	24.3
4	Au3Cu	Au_3Cu	5	1145	13.5	7.3	13.3	16.8	21.7
5	AuCu	AuCu	5	968	13.5	6.2	12.9	15.6	18.2
6	(Cu,Au)	(Cu,Au)	1	125	2.7	0.8		12.6	
7	Keithconnite	Pd_3Te	3	122	8.1	0.8	5.6	7.1	8.4
8	Zvyagintsevite	Pd_3Pb	1	17	2.7	0.1		4.7	
Total			37	15636	100	100			

Area: total area calculated from ECD (effective circle diameter) around the grain.

Table 4. Grain sizes of precious metal mineral from the heavy mineral HS Concentrates (sample 90-18 958)

N	Grain	Association	Type	Mineral	Area, μm^2	ECD, µm
1	40-10	Au_3Cu	L	Au_3Cu	150	13.8
2	40-11	Au_3Cu-ilm	ag	Au_3Cu	138	13.3
3	40-12	(Au,Cu)	L	(Au,Cu)	288	19.2
4	40-13	sk	L	sk	1131	38.0
5	40-14	(Au,Cu)	L	(Au,Cu)	305	19.7
6	40-15	(Cu,Au)	L	(Cu,Au)	125	12.6
7	40-16	AuCu-kth-bn	bms	Total	278	18.8
8	40-16	AuCu-kth-bn	bms	kth	56	8.4
9	40-16	AuCu-kth-bn	bms	AuCu	222	16.8
10	40-17	AuCu-bn	bms	AuCu	260	18.2
11	40-18	sk	L	sk	123	12.5
12	40-19	Au_3Cu	L	Au_3Cu	371	21.7
13	40-1	sk	L	sk	643	28.6
14	40-20	AuCu-bn	bms	AuCu	131	12.9
15	40-21	(Au,Cu)	L	(Au,Cu)	137	13.2
16	40-22	nls-cpx	ag	nls	482	24.8
17	40-23	sk-bn	bms-L	sk	1788	47.7
18	40-24	sk-bn	bms-L	sk	682	29.5
19	40-25	sk	L	sk	1111	37.6
20	40-26	sk	L	sk	1231	39.6
21	40-27	sk	L	sk	360	21.4
22	40-2	sk-kth-bn-cp	bms	Total	238	17.4
23	40-2	sk-kth-bn-cp	bms	sk	213	16.5
24	40-2	sk-kth-bn-cp	bms	kth	25	5.6
25	40-3	sk-zv-bn	bms	Total	298	19.5
26	40-3	sk-zv-bn	bms	zv	17	4.7
27	40-3	sk-zv-bn	bms	sk	281	18.9
28	40-4	Au_3Cu-cpx	ag	Au_3Cu	211	16.4
29	40-5/2	AuCu	L	AuCu	219	16.7
30	40-5	kth-bn	bms	kth	41	7.2
31	40-6	Au	L	Au	235	17.3
32	40-7	Au_3Cu	L	Au_3Cu	275	18.7
33	40-8	(Au,Cu)	L	(Au,Cu)	464	24.3
34	40-9	AuCu-bn	bms	AuCu	136	13.2
35	50-1	sk-bn	bms	sk	962	35.0
36	50-2	sk	L	sk	645	28.7
37	50-3	nls-sk-bn	bms	Total	65	12.7
38	50-3	nls-sk-bn	bms	nls	40	7.1
39	50-3	nls-sk-bn	bms	sk	25	5.6
40	50-4	sk	L	sk	1227	39.5
41	50-5	sk	L	sk	886	33.6

Abbreviations: : Ilm: ilmenite; sk: skaergaardite; kth: keithconnite; bn: bornite; nls: nielsenite; cp: chalcopyrite; zv: zviagintsevite.

Association Type: L: liberated; ag: attached to gangue ; BMS: attached to base metal sulfide ; BMS-L: with less than 10% base metal sulfide.

Table 5. **Chemical compositions (wt.%) and formulas of platinum group minerals from the heavy mineral HS concentrates (sample 90-18, 958)**

Mineral	sk	sk	sk	sk	sk	sk	sk	sk	sk	sk	sk	sk	sk	sk
An#	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Grain#	40-1	40-2	40-3	40-13	40-18	40-23	40-24	40-25	40-26	50-1	50-2	50-4	50-5	sk
Association	sk	sk-kth-bn-cp	sk-zv-bn	sk	sk	sk-bn	sk-bn	sk	sk	sk-bn	sk	sk	sk	average
Analysis														
Pd	61.5	53.5	62.8	60.5	60.4	60.4	60.8	59.7	57.5	60.1	62.0	62.0	63.2	60.3
Pt	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0	0.2
Au	2.5	9.9	0.0	1.8	2.9	0.0	2.1	3.2	3.4	1.5	1.7	0.0	0.0	2.2
Cu	28.0	33.0	29.2	29.9	29.2	32.1	31.4	30.5	31.0	29.1	29.2	28.7	29.7	30.1
Fe	4.0	2.0	3.3	3.7	4.6	5.4	3.0	4.6	4.3	3.6	4.0	4.2	4.4	3.9
Zn	2.5	0.0	3.4	1.6	2.2	1.6	1.8	0.0	1.7	1.8	2.3	1.8	2.1	1.8
Sn	0.0	0.0	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.3
Te	0.8	0.9	0.6	0.0	0.0	0.0	0.0	1.2	0.6	1.8	0.0	0.0	0.0	0.5
Pb	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.0	1.4	0.0	0.2
Total	99.3	100.4	99.3	99.6	99.3	99.5	99.1	99.2	100.1	99.6	99.2	99.6	99.4	99.5
Atomic proportions														
Pd	1.0	0.9	1.0	1.0	1.0	1.0	1.0	1.0	0.9	1.0	1.0	1.0	1.0	1.0
Pt	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Au	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cu	0.8	0.9	0.8	0.8	0.8	0.9	0.9	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Fe	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Zn	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.1
Sn	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Te	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pb	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0

Abbreviations: sk: skaergaardite, kth: keithconnite, bn: bornite, cp: chalcopyrite, zv: zviagintsevite, nls: nielsenite, (Cu,Pd,Au): (Cu,Pd,Au) alloy

Table 5 continued ………

Mineral	nls	nls	nls	kth	kth	kth	kth	zv
An#	15	16	17	18	19	20	21	22
Grain#	40-22	50-3	average	40-2	40-5	40-16	average	40-3
Association	nls-cpx	nls-bn-(Cu,Pd,Au)		sk-kth-bn-cp	kth-bn	AuCu-kth-bn		sk-zv-bn
Analyses								
Pd	25.0	23.0	24.0	66.7	60.6	64.6	64.0	65.4
Pt	-	-	-	-	-	-	-	-
Au	0.0	19.5	9.8	-	-	-	-	-
Cu	73.3	54.0	63.7	1.2	1.1	1.2	1.2	1.1
Fe	0.7	1.7	1.2	0.5	1.1	0.6	0.7	1.7
Zn	-	-	-	-	-	-	-	-
Sn	-	-	-	-	-	-	-	-
Te	0.0	1.4	0.7	27.6	29.2	31.0	29.3	-
Pb	-	-	-	3.6	6.4	2.2	4.1	31.2
Total	99.0	99.7	99.4	99.6	98.4	99.6	99.2	99.4
Atomic proportions								
Pd	0.7	0.7	0.7	2.8	2.6	2.7	2.7	3.0
Pt	-	-	-	-	-	-	-	-
Au	0.0	0.3	0.2	-	-	-	-	-
Cu	3.3	2.8	3.1	0.1	0.1	0.1	0.1	0.1
Fe	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.2
Zn	-	-	-	-	-	-	-	-
Sn	-	-	-	-	-	-	-	-
Te	0.0	0.0	0.0	1.0	1.1	1.1	1.0	-
Pb	-	-	-	0.0	0.1	0.1	0.1	0.7
Total	4.0	4.0	-	4.0	4.0	4.0	-	4.0

Abbreviations: sk: skaergaardite, kth: keithconnite, bn: bornite, cp: chalcopyrite, zv: zviagintsevite, nls: nielsenite, (Cu,Pd,Au): (Cu,Pd,Au) alloy

Table 6. Chemical compositions (wt.%) and formulas of Au-Cu minerals from the heavy mineral HS concentrates (sample 90-18 958)

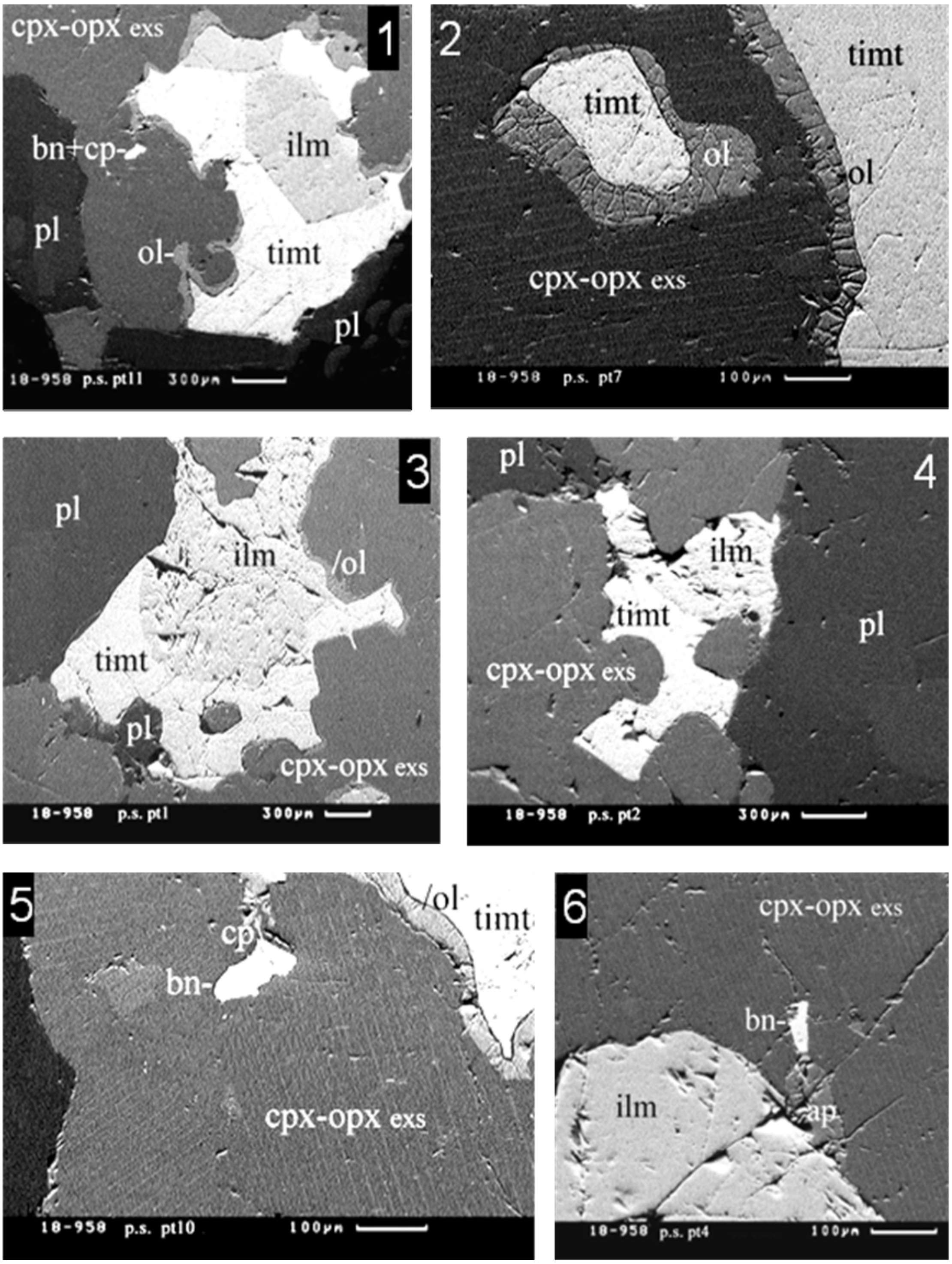
An #	Grain #	Association	Mineral	Pd	Pt	Au	Cu	Fe	Te	Total	Pd	Pt	Au	Cu	Fe	Te	Total
(Au,Cu) alloy																	
1	40-8	(Au,Cu)	(Au,Cu)	8.4	nd	74.4	16.2	0.6	nd	99.6	0.1	nd	0.5	0.4	0.0	nd	1.0
2	40-12	(Au,Cu)	(Au,Cu)	4.6	nd	90.9	4.0	0.5	nd	100.0	0.1	nd	0.8	0.1	0.0	nd	1.0
3	40-14	(Au,Cu)	(Au,Cu)	9.1	nd	82.9	7.5	0.0	nd	99.5	0.1	nd	0.7	0.2	0.0	nd	1.0
4	40-21	(Au,Cu)	(Au,Cu)	8.6	nd	85.4	5.0	1.0	nd	100.0	0.1	nd	0.7	0.1	0.0	nd	1.0
5	average			7.7	nd	83.4	8.2	0.5	nd	99.8	0.1	nd	0.7	0.2	0.0	nd	
Au3Cu																	
6	40-4	Au_3Cu-cpx	Au_3Cu	2.5	nd	88.1	8.8	0.6	nd	100.0	0.2	nd	2.9	0.9	0.1	nd	4.0
7	40-7	Au_3Cu	Au_3Cu	5.8	nd	82.0	12.3	0.0	nd	100.1	0.3	nd	2.5	1.2	0.0	nd	4.0
8	40-10	Au_3Cu	Au_3Cu	9.8	nd	83.1	11.7	0.4	nd	100.0	0.3	nd	2.6	1.1	0.0	nd	4.0
9	40-11	Au_3Cu-ilm	Au_3Cu	6.5	nd	82.0	10.0	0.8	nd	99.3	0.4	nd	2.6	1.0	0.1	nd	4.0
10	40-19	Au_3Cu	Au_3Cu	7.9	nd	82.3	9.6	0.0	nd	99.8	0.5	nd	2.6	0.9	0.0	nd	4.0
11	average			6.5	nd	83.5	10.5	0.4	nd	99.8	0.3	nd	2.6	1.0	0.0	nd	
Tetra-auricupride																	
12	40-5/2	AuCu	AuCu	3.1	1.4	70.0	25.4	0.8	nd	100.7	0.1	0.0	0.9	1.0	0.0	nd	2.0
13	40-9	AuCu-bn	AuCu	10.2	4.6	57.8	26.6	0.7	nd	99.9	0.2	0.1	0.7	0.9	0.0	nd	2.0
14	40-16	AuCu-kth-bn	AuCu	21.5	1.4	46.0	30.1	1.1	nd	100.0	0.4	0.0	0.5	1.0	0.0	nd	2.0
15	40-17	AuCu-bn	AuCu	9.1	0.0	63.9	26.1	0.0	nd	99.1	0.2	0.0	0.8	1.0	0.0	nd	2.0
16	40-20	AuCu-bn	AuCu	11.3	4.1	55.6	28.0	0.8	nd	99.8	0.3	0.1	0.7	1.0	0.0	nd	2.0
17	average			11.0	2.3	58.7	27.2	0.7	nd	99.9	0.2	0.0	0.7	1.0	0.0	nd	
(Cu,Au,Pd) alloy																	
18	40-15	(Cu,Au)	(Cu,Au)	nd	nd	63.1	35.3	0.9	nd	99.3	nd	nd	0.4	0.6	0.0	nd	1.0
19	50-3	nls-(Cu,Pd,Au)-bn	(Cu,Pd,Au)	28.1	nd	30.3	37.1	1.8	2.2	99.7	0.3	nd	0.2	0.6	0.0	0.0	1.0

Abbreviations: cpx: clinopyroxene, ilm: ilmenite, bn: bornite, kth: kiethconnite, nls: nielsenite

Plates

Plate 1

The relationship of rock-forming minerals, Fe-Ti oxides and sulphides in the tholeitic gabbros of the sample 90-18, 958 (1-10), polished section, SEM images (BIE); abbreviations used: pl – plagioclase, cpx – clinopyroxene, opx – orthopyroxene, cpx-opx exs – clinopyroxene-orthopyroxene exsolution texture, ilm - ilmenite, timt – titaniferous magnetite, mt – magnetite, ap – apatite, bdl – baddeleiyte, bn – bornite, cp - chalcopyrite.


1
cpx-opx exs
bn+cp-
ilm
pl
ol-
timt
pl
18-958 p.s. pt11 300µm
2
timt
timt
ol
ol
cpx-opx exs
18-958 p.s. pt7 100µm
3
pl
ilm
/ol
timt
pl
cpx-opx exs
18-958 p.s. pt1 300µm
4
pl
ilm
timt
pl
cpx-opx exs
18-958 p.s. pt2 300µm
5
/ol
timt
cp
bn-
cpx-opx exs
18-958 p.s. pt10 100µm
6
cpx-opx exs
bn-
ilm
ap
18-958 p.s. pt4 100µm

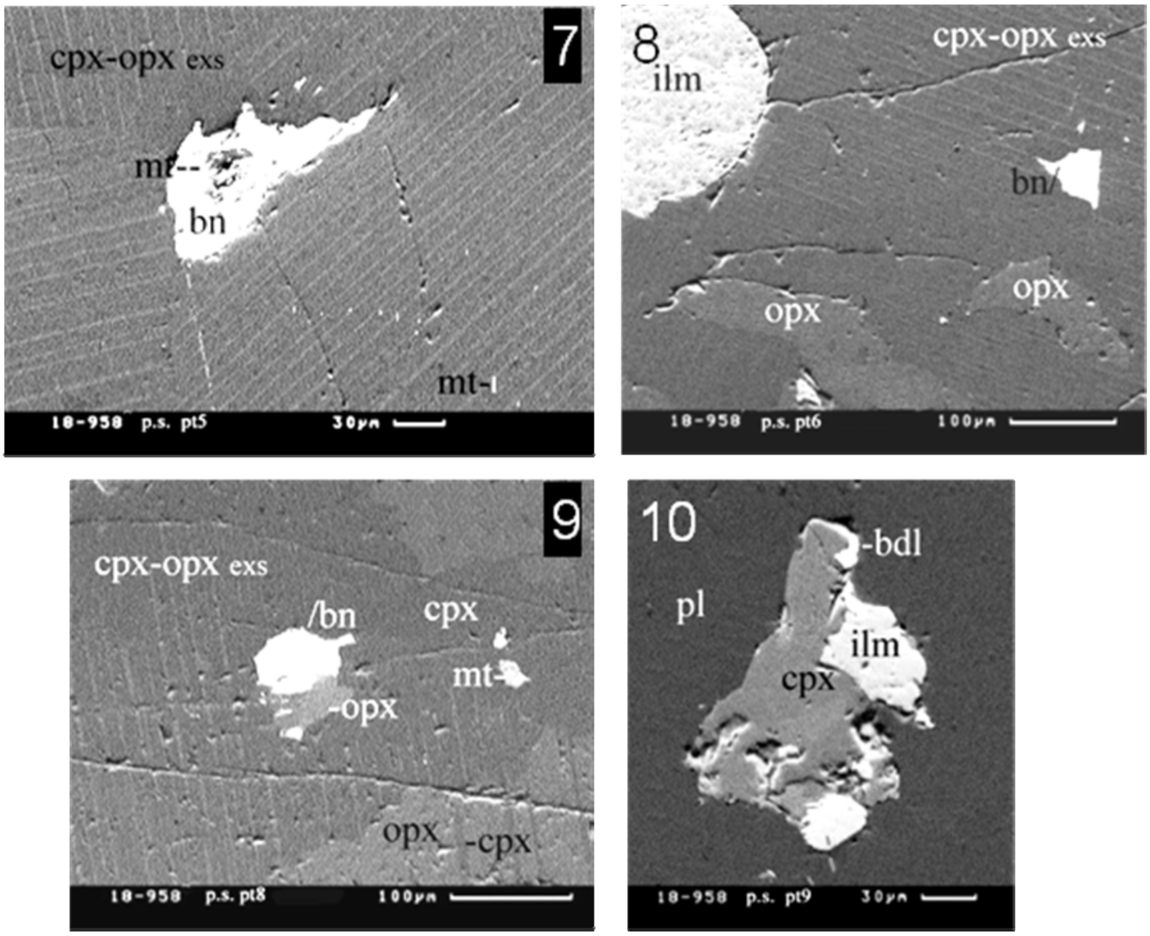

7
cpx-opx exs
mt
bn
mt
18-958 p.s. pt5 30μm
8
ilm
cpx-opx exs
bn
opx
opx
18-958 p.s. pt6 100μm
9
cpx-opx exs
/bn
cpx
mt
-opx
opx
-cpx
18-958 p.s. pt8 100μm
10
-bdl
pl
ilm
cpx
18-958 p.s. pt9 30μm

Plate 2

Polished sections of the heavy mineral HS concentrate (1- fraction <40 µm; 2 , 3 – 40-50 µm, 3 – 70-100 µm, sample 90-18, 958), SEM-images (BIE); abbreviations used: ilm – ilmenite, sk – skaergaardite, bn – bornite, opx - orthopyroxene, cpx – clinopyroxene.

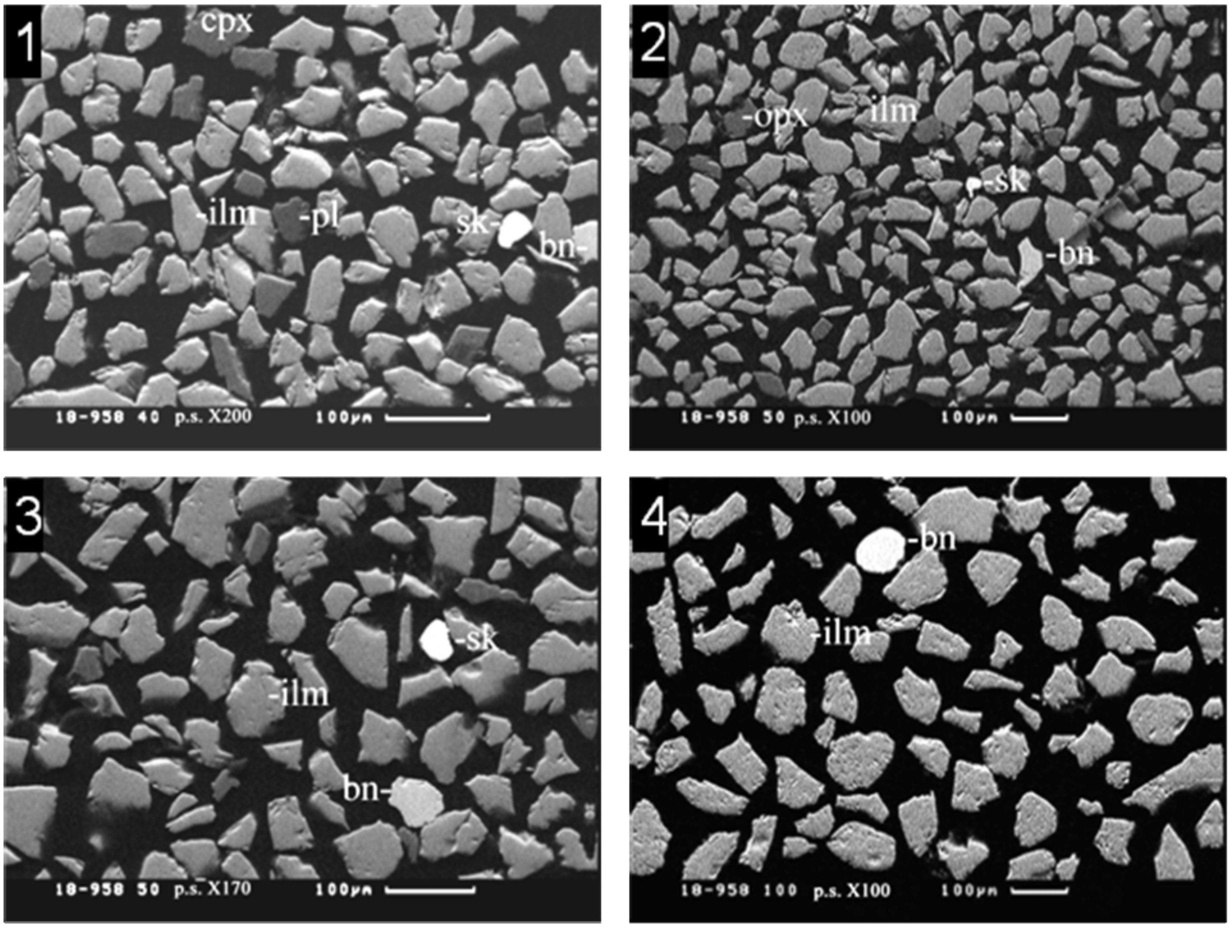
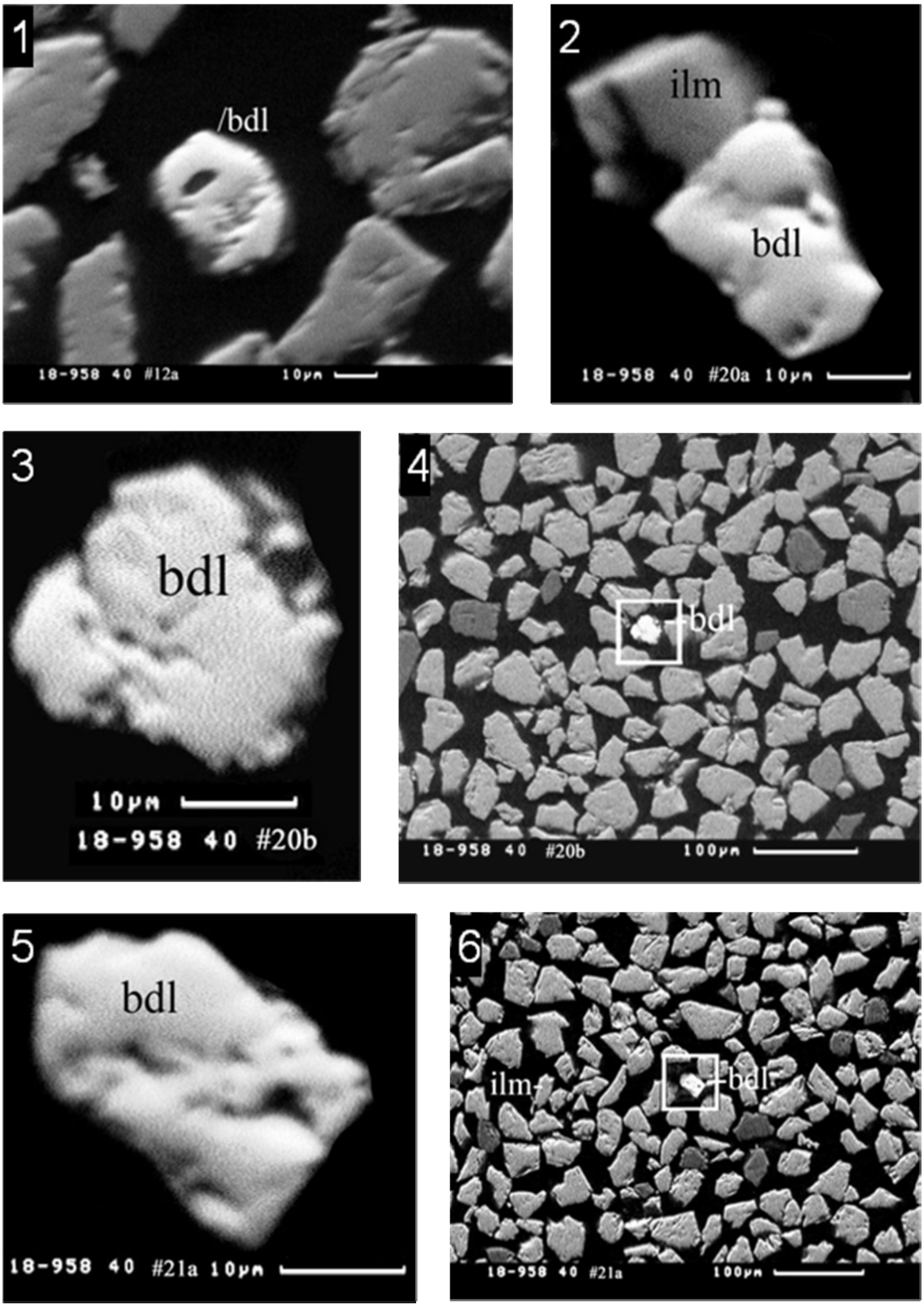

1
cpx
-ilm
-pl
sk-
bn-
18-958 40 p.s. X200
100µm
2
-opx
ilm
-sk
-bn
18-958 50 p.s. X100
100µm
3
-sk
-ilm
bn-
18-958 50 p.s. X170
100µm
4
-bn
-ilm
18-958 100 p.s. X100
100µm

Plate 3

Baddeleyite grains (for age dating), extracted into the heavy mineral HS concentrate of the sample 90-18, 958 (1-10); polished section, SEM-image (BIE); bdl – baddellyite, ilm – ilmenite.


1
/bdl
18-958 40 #12a 10μm
2
ilm
bdl
18-958 40 #20a 10μm
3
bdl
10μm
18-958 40 #20b
4
bdl
18-958 40 #20b 100μm
5
bdl
18-958 40 #21a 10μm
6
ilm
bdl
18-958 40 #21a 100μm

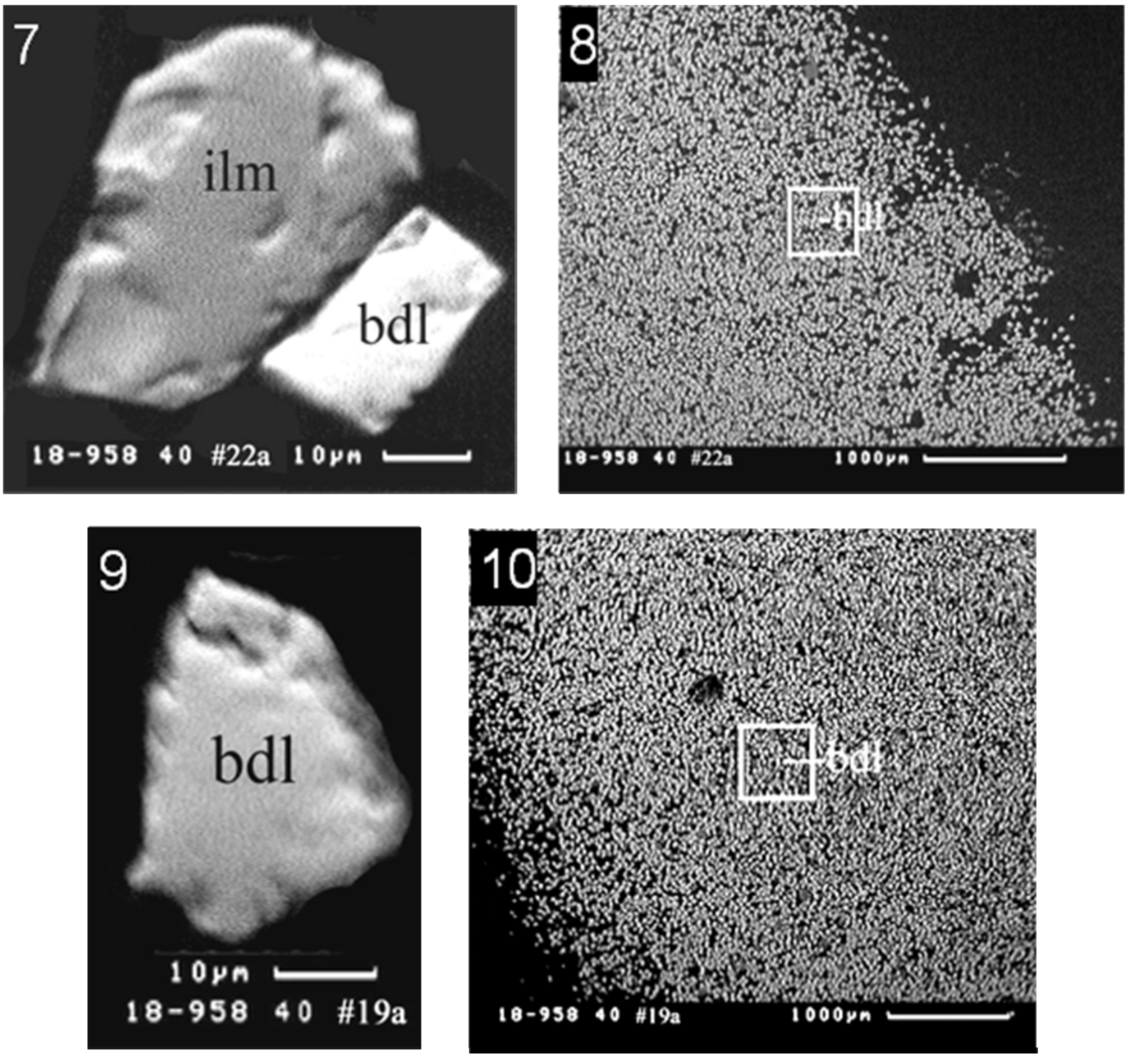
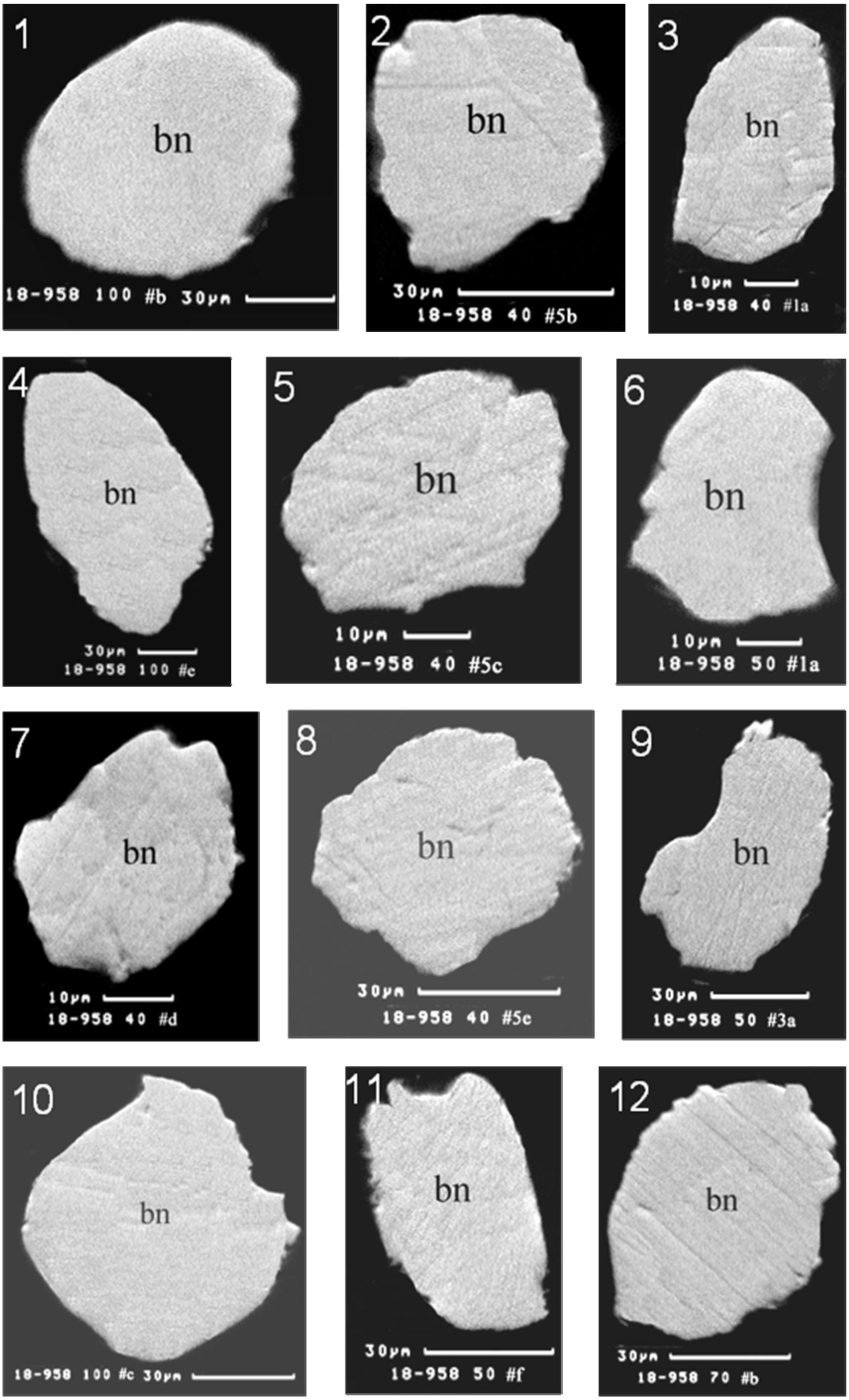
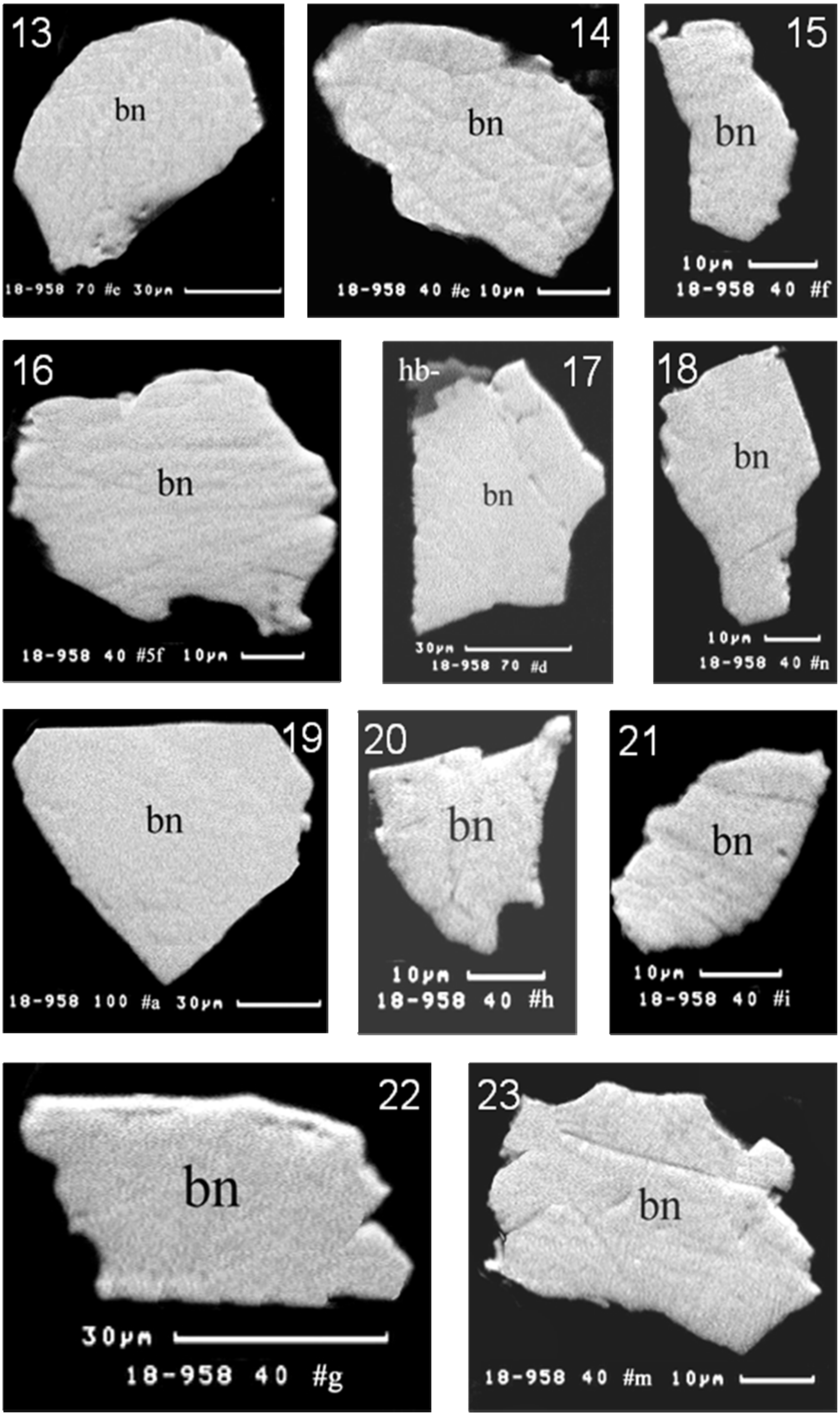
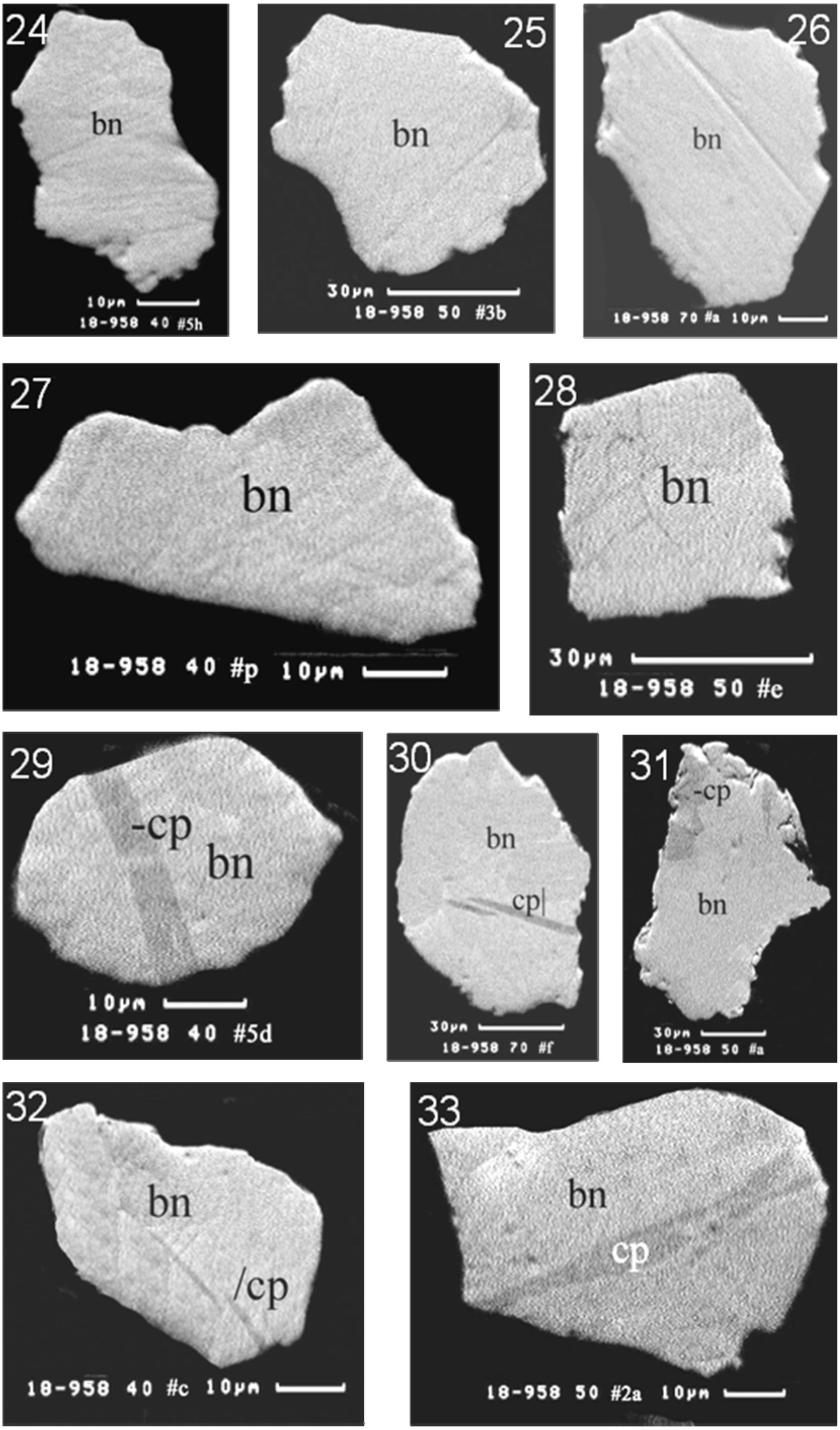

7
ilm
bdl
18-958 40 #22a 10μm
8
bdl
18-958 40 #22a 1000μm
9
bdl
10μm
18-958 40 #19a
10
bdl
18-958 40 #19a 1000μm

Plate 4

Sulphide mineralisation globules and grains of oxide rich tholeitic gabbros, sample 90-18, 958 (1-41); polished sections; SEM-images (BIE); abbreviations used: bn – bornite, cp – chalcopyrite, chc – chalcosine, hb - hornblende.


1
bn
18-958 100 #b 30μm
2
bn
30μm
18-958 40 #5b
3
bn
10μm
18-958 40 #1a
4
bn
30μm
18-958 100 #c
5
bn
10μm
18-958 40 #5c
6
bn
10μm
18-958 50 #1a
7
bn
10μm
18-958 40 #d
8
bn
30μm
18-958 40 #5c
9
bn
30μm
18-958 50 #3a
10
bn
18-958 100 #c 30μm
11
bn
30μm
18-958 50 #f
12
bn
30μm
18-958 70 #b


13
bn
18-958 70 #c 30µm
14
bn
18-958 40 #c 10µm
15
bn
10µm
18-958 40 #f
16
bn
18-958 40 #5f 10µm
hb-
17
bn
30µm
18-958 70 #d
18
bn
10µm
18-958 40 #n
19
bn
18-958 100 #a 30µm
20
bn
10µm
18-958 40 #h
21
bn
10µm
18-958 40 #i
22
bn
30µm
18-958 40 #g
23
bn
18-958 40 #m 10µm


24
bn
10μm
18-958 40 #5h
25
bn
30μm
18-958 50 #3b
26
bn
18-958 70 #a 10μm
27
bn
18-958 40 #p 10μm
28
bn
30μm
18-958 50 #e
29
-cp
bn
10μm
18-958 40 #5d
30
bn
cp|
30μm
18-958 70 #f
31
-cp
bn
30μm
18-958 50 #a
32
bn
/cp
18-958 40 #c 10μm
33
bn
cp
18-958 50 #2a 10μm

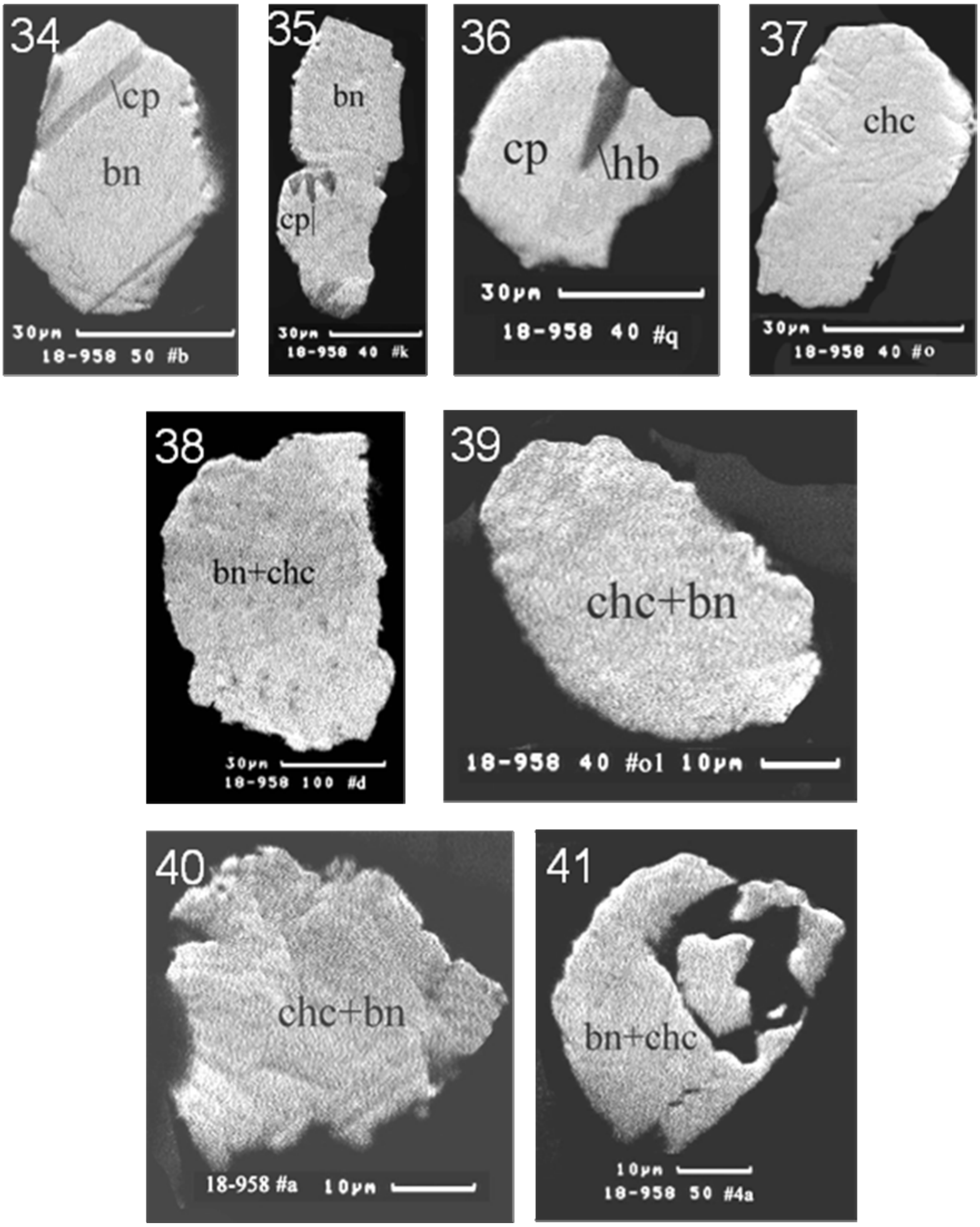
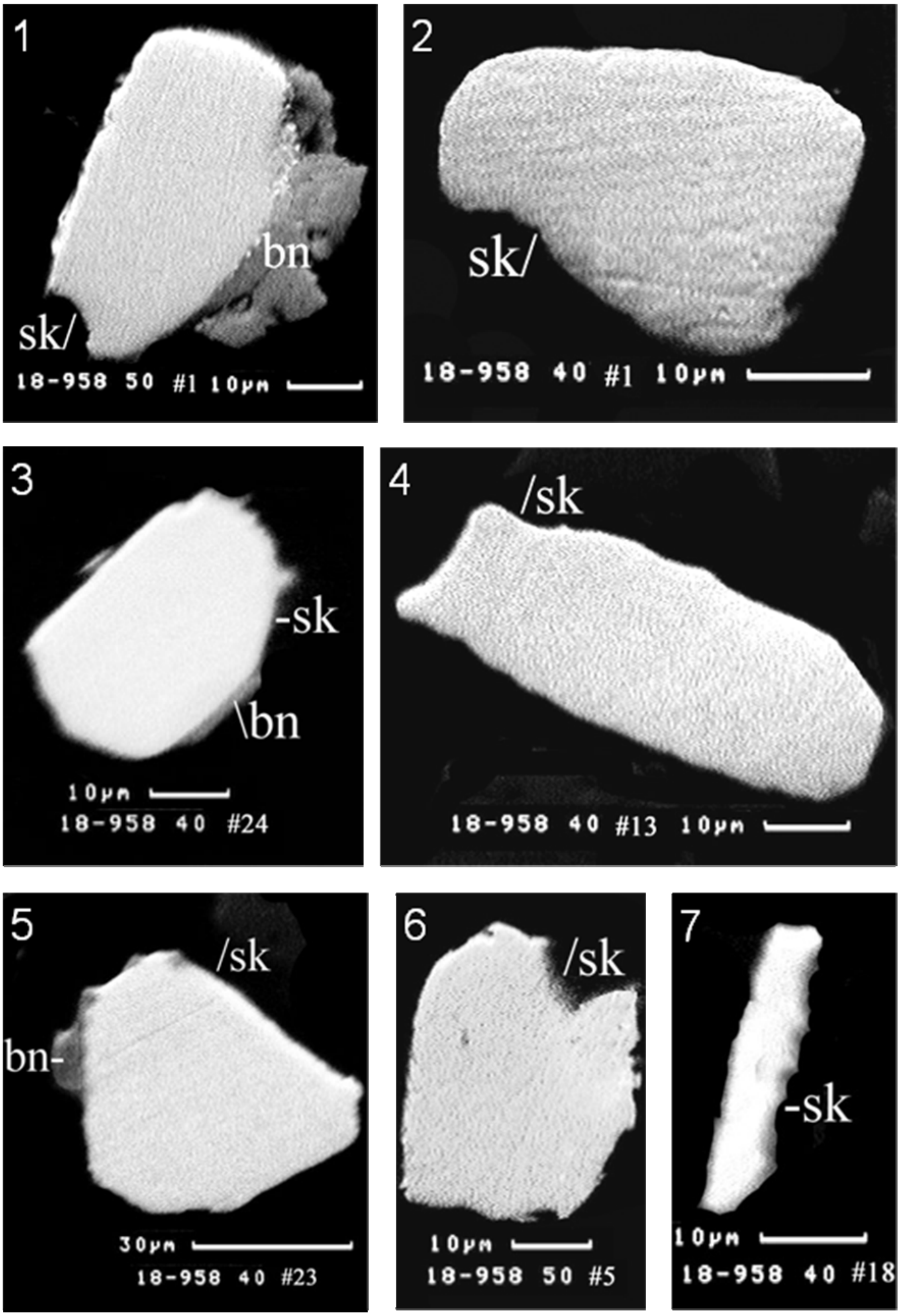

34
\cp
bn
30µm
18-958 50 #b
35
bn
cp|
30µm
18-958 40 #k
36
cp
\hb
30µm
18-958 40 #q
37
chc
30µm
18-958 40 #o
38
bn+chc
30µm
18-958 100 #d
39
chc+bn
18-958 40 #o1 10µm
40
chc+bn
18-958 #a 10µm
41
bn+chc
10µm
18-958 50 #4a

Plate 5

SEM-images (BIE) of skaergaardite (1-12) from the polished sections of the heavy mineral HS concentrates of the sample 90-18, 958; abbreviations used sk – skaergaardite, bn – bornite.


1
bn
sk/
18-958 50 #1 10μm
2
sk/
18-958 40 #1 10μm
3
-sk
\bn
10μm
18-958 40 #24
4
/sk
18-958 40 #13 10μm
5
/sk
bn-
30μm
18-958 40 #23
6
/sk
10μm
18-958 50 #5
7
-sk
10μm
18-958 40 #18

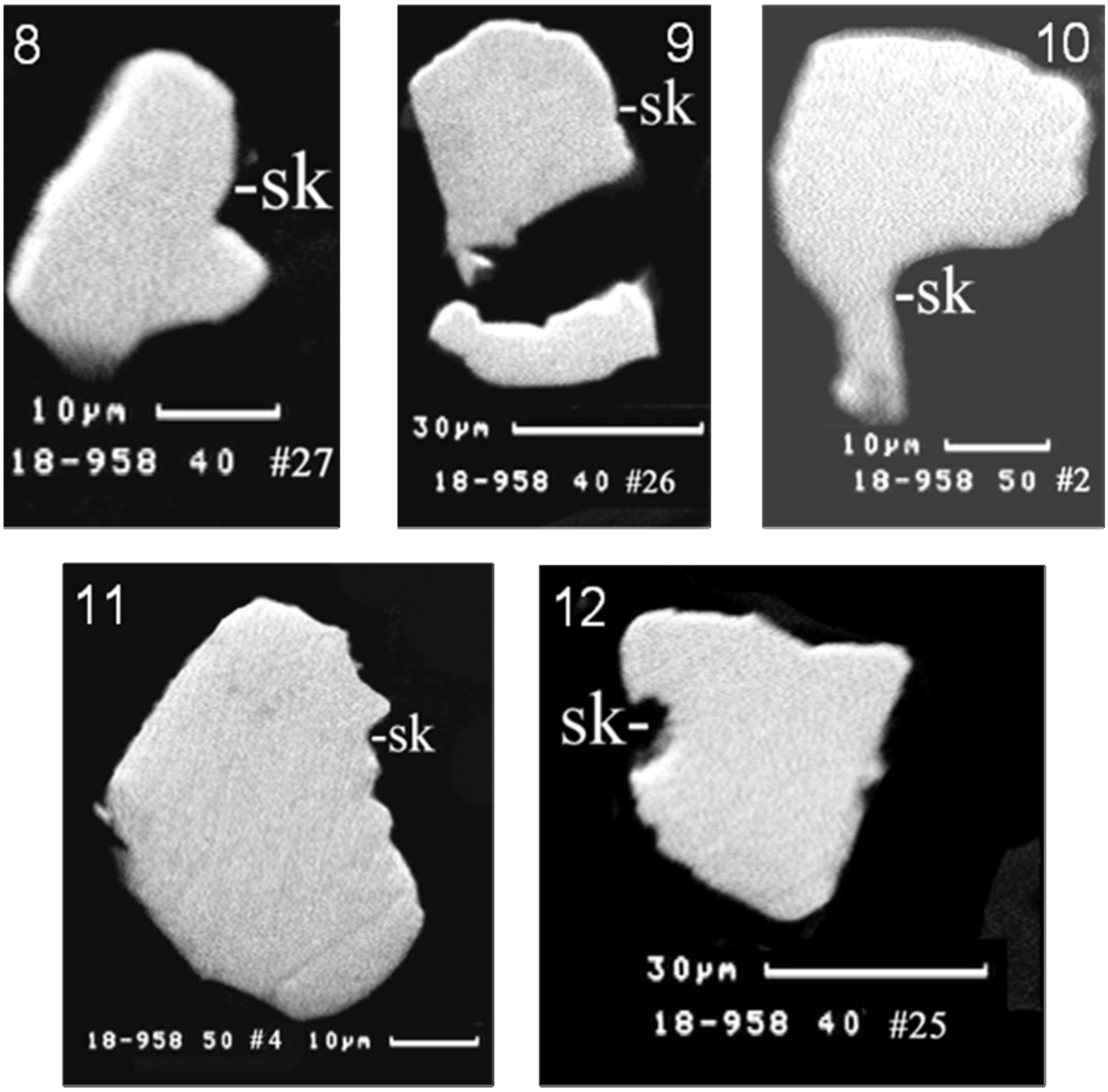
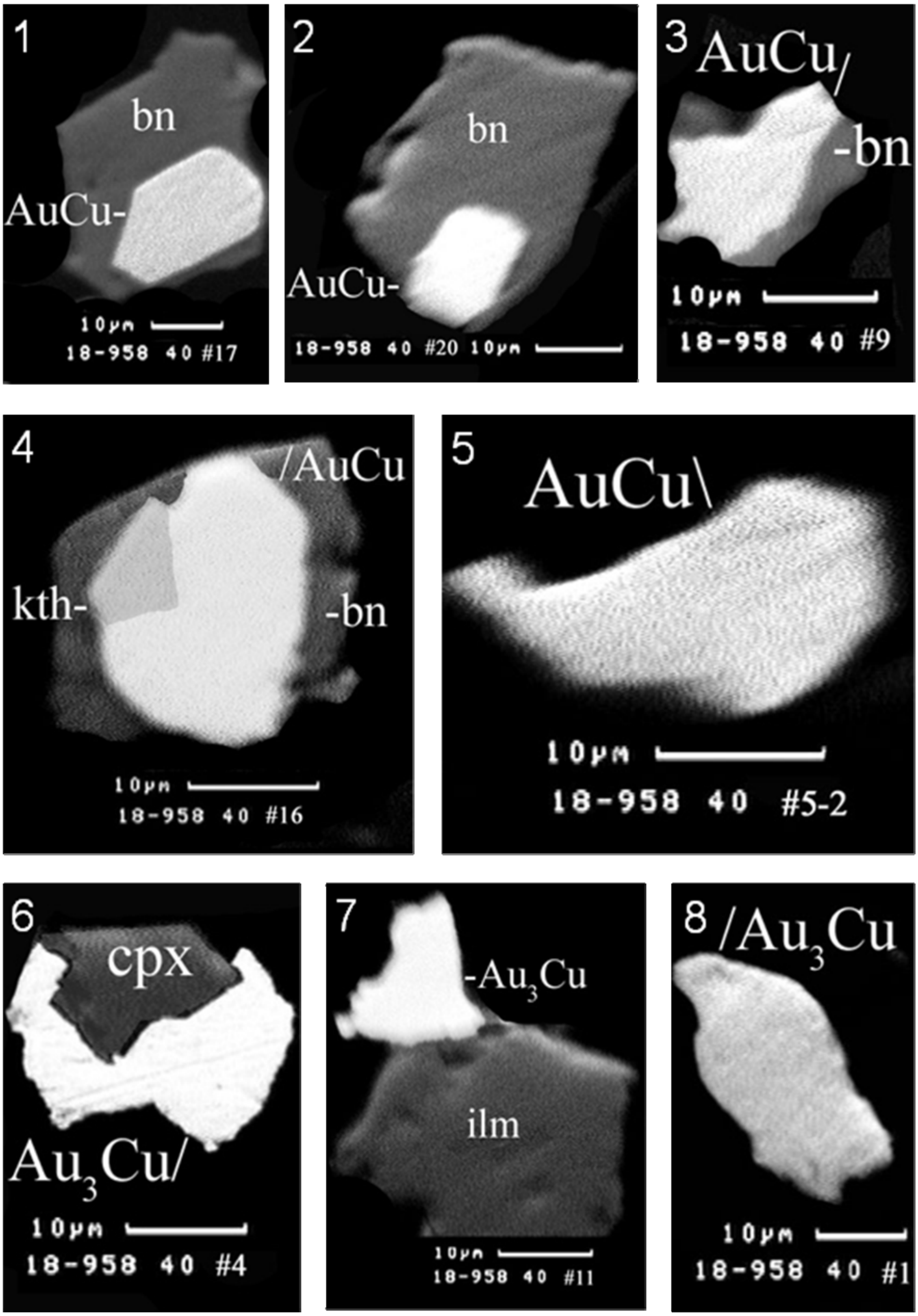

8
-sk
10μm
18-958 40 #27
9
-sk
30μm
18-958 40 #26
10
-sk
10μm
18-958 50 #2
11
-sk
18-958 50 #4 10μm
12
sk-
30μm
18-958 40 #25

Plate 6

SEM-images (BIE) of Au-Cu minerals (1-16) from the polished sections of the heavy mineral HS concentrates of the sample 90-18, 958; abbreviations used AuCu – tetra-auricupride, Au_3Cu – unnamed , kth – keithconnite, bn – bornite, .ilm – ilmenite, cpx – clinopyroxene.


1
bn
AuCu-
10μm
18-958 40 #17
2
bn
AuCu-
18-958 40 #20 10μm
3 AuCu/
-bn
10μm
18-958 40 #9
4
/AuCu
kth-
-bn
10μm
18-958 40 #16
5
AuCu\
10μm
18-958 40 #5-2
6
cpx
Au_3Cu/
10μm
18-958 40 #4
7
-Au_3Cu
ilm
10μm
18-958 40 #11
8 /Au_3Cu
10μm
18-958 40 #1

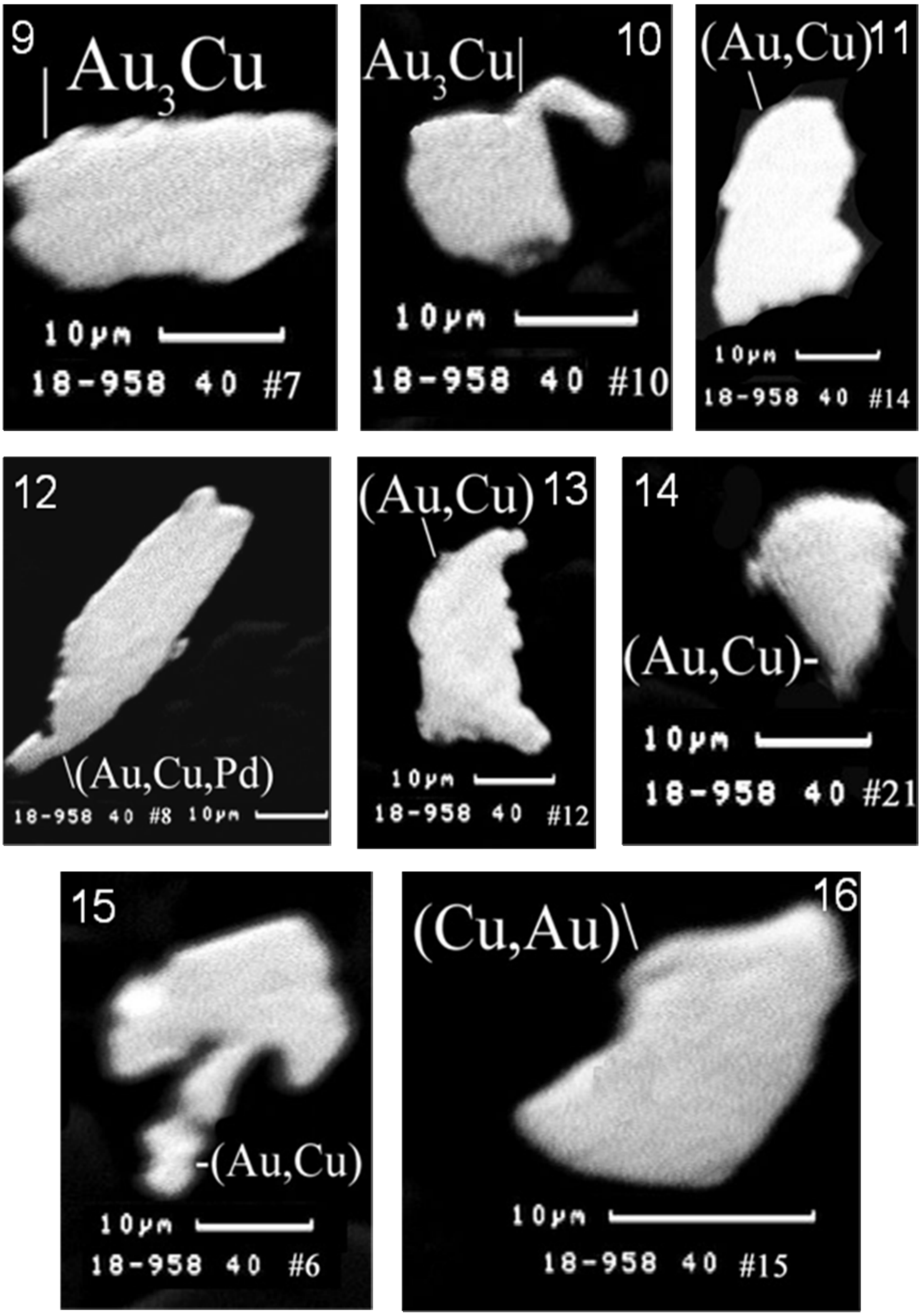
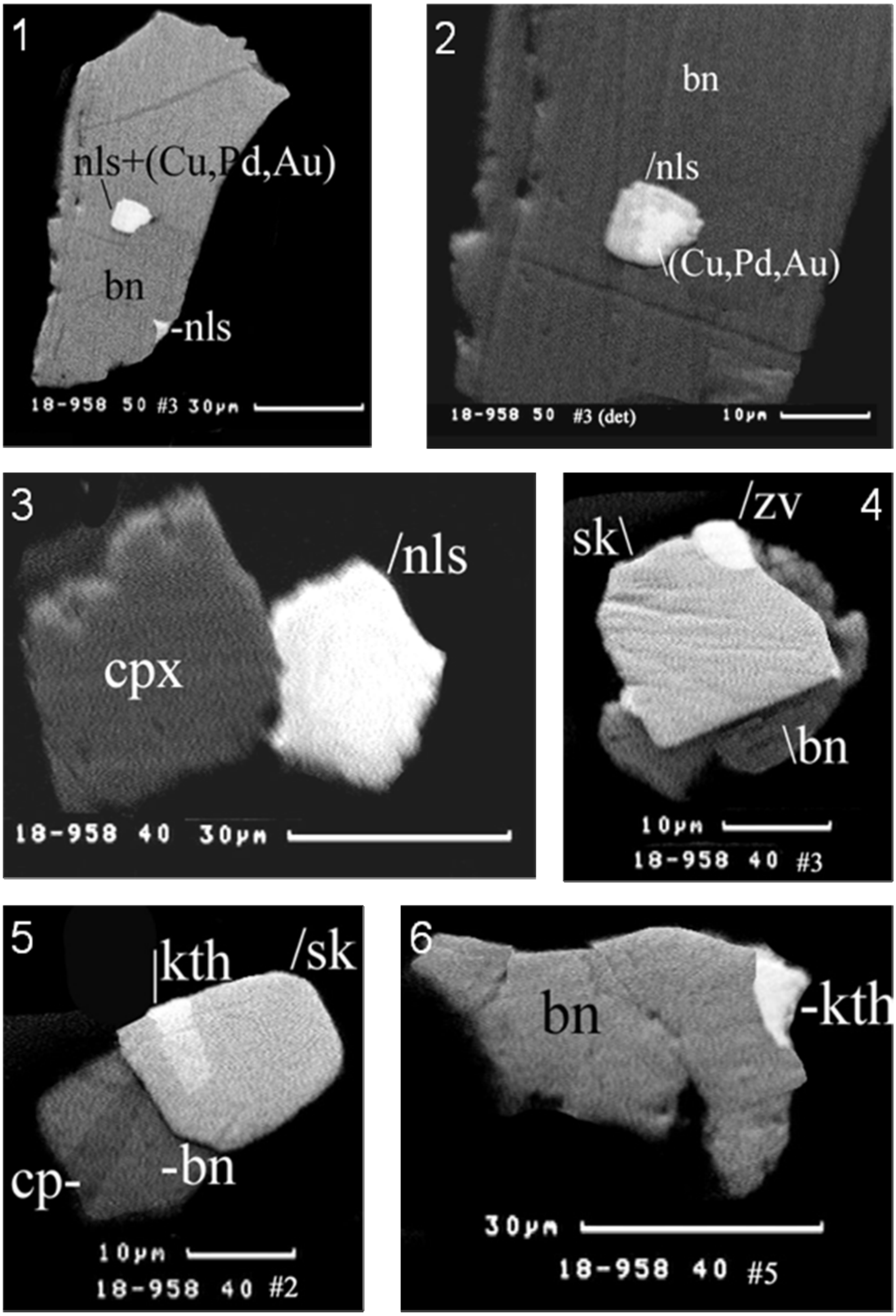

9
Au_3Cu
10μm
18-958 40 #7
10
Au_3Cu
10μm
18-958 40 #10
(Au,Cu)
11
10μm
18-958 40 #14
12
(Au,Cu,Pd)
18-958 40 #8 10μm
(Au,Cu)
13
10μm
18-958 40 #12
14
(Au,Cu)
10μm
18-958 40 #21
15
(Au,Cu)
10μm
18-958 40 #6
16
(Cu,Au)
10μm
18-958 40 #15

Plate 7

SEM-images (BIE) of nielsenite (1-3), zvyagintsevite (4) and keithconnite (5, 6) from the polished sections of the heavy mineral HS concentrates of the sample 90-18, 958; 2 is detail of 1; abbreviations used: nld – nielsenite, zv – zvyagintsevite, kth – keithconnite, sk – skaergaardite, bn – bornite, cp – chalcopyrite, cpx – clinopyroxene.


1
nls+(Cu,Pd,Au)
bn
-nls
18-958 50 #3 30µm
2
bn
/nls
\(Cu,Pd,Au)
18-958 50 #3 (det)
10µm
3
cpx
/nls
18-958 40 30µm
4
/zv
sk\
\bn
10µm
18-958 40 #3
5
|kth
/sk
cp-
-bn
10µm
18-958 40 #2
6
bn
-kth
30µm
18-958 40 #5