DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2009/54

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

Part 6: Sample 90-23A 798

Nikolay S. Rudashevsky, Yuri L. Kretser,
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Contents

Abstract

The report presents the results of mineralogical investigations of the sample # “90-23a 798” from the Platinova Reef Au-PGE mineralization in the Skaergaard intrusion. Core # “90-23A” was drilled near the eastern margin of the intrusion and the sample represents bulk gabbro from 978 to 979 meters in the core. The sample originates from the Au rich Pd4b level above the previously studied sample 90-23A 806 of palladium-rich Pd5 level. Assays give 2000 ppb Au, 360 ppb Pd and 22 ppb Pt for the sample 90-23A 798.

The sample preparation included careful grinding in shatter box, sieving into fractions, wet magnetic separation of all fractions, followed by hydroseparation of non-magnetic fraction. 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 representative selection of 179 grains of gold minerals were found in the heavy concentrates and studied in detail. They contain (as inclusions and intergrowths with Au-alloys) Pd and Pt minerals. One free grain of arsenopalladinite was also found. (Au,Cu,Ag) alloy is the absolutely dominant precious metal mineral (94.8 vol.%) followed by minor arsenopalladinute $(Pd,Cu,Au)_8(As,Sn)_3$ (4.7 %), kotulskite (0.4 vol.%), and very rare sperrylite $PtAs_2$ (0.06 vol.%). The grain size of precious metal minerals (ECD) varies between 4 and 51 µm with an average of 20.4 µm.

The host gabbro of the sample 90-23A 798 shows no signs of reaction between cumulus and inter cumulus phases and thus no reaction between early cumulus phases and residual silicate melt. However, sulfides are generally related to the interstitial domains, most commonly to a secondary paragenesis characterized by H_2O-bearing silicate phases and matrix Fe-Ti oxides.

The HS-concentrates contain numerous sulfide grains. Some of them are semi-spherical grains indentified as sulfide droplets. Sulfide grains are composed of one or more Cu-sulfides: bornite and chalcosine, minor digenite and chalcopyrite, and occasional pentlandite. Rare grains of sphalerite and galena are also observed.

Inclusions of Cu tellurides in sulfide grains are very fine (<3 µm) and rare, as compared to Au-rich samples from the interior of the intrusion (see for example the sample 90-24 1018, Rudashevsky et al, unpublished report).

Most of the identified Au-rich grains are completely liberated (free) particles or in close association with matrix Fe-Ti oxides and H_2O-bearing phases. Some rare inclusions of precious metal minerals are found also in grains of base metal sulfides (BSM).

The Au-rich paragenesis is a late, post cumulus, mineral assemblages related to the formation of a late hydrous silicate assemblage.

Introduction

The report describes mineralogy of the sample 90-23A 798 from the Au-rich Pd4 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).

This report on the PGE and Au mineralogy is based on studies of the concentrates of Au and PGM grains produced by means of Hydroseparator HS-02M (www.cnt-mc.com), using new type of Glass Separation Tube (GST), and polished section of the core rock. Mounts with concentrates, and polished section of the gabbro have been studied 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 90-23A 798

Sample 90-23A 798 was collected as a bulk sample from BQ drill core # 90-23A between 798 and 799 meters. The core was drilled with an azimuth of 35º and an inclination of –70º from top of Nunataq II. Nunataq II is located on the south side of Forbindelsesgletscher and close to the eastern contact of the intrusion.

The host gabbro is a typical, layered, mesocratic MZ gabbro composed of rock-forming plagioclase, clinopyroxene, orthorhombic pyroxene, re-equilibrated magnetite and ilmenite, and a suite of accessory, often, hydrous late phases (see below).

Sample 90-23A 798 (0.53 kg) collects Au-rich Pd4b level above the previously studied the PGE-rich samples 90-23A 806, 90-23A 807, and 90-23A 808 of the Pd5 level (Nielsen,et al., 2003a, b, c). Assays give 2000 ppb Au, 360 ppb Pd and 22 ppb Pt (Watts, Griffith & McOuat, 1991). All gabbros above sample 90-23A 798 have very low concentrations of PGE and Au and only the Pd5 and the Pd4b levels of the Platinova Reef are in mineralized in this marginal core.

Mineralogical investigation

Sample preparation and analytical techniques

The sample was ground in small portions using a shatter box with small cavities (200 ml) for short periods (0.5-1 min), sieved to remove the fine fraction (sieve -125 µm) after each grind. The residual coarse fraction >125 µm was re-ground once again until the entire sample had attained the desired maximum grain size.

After complete grinding, the sample was passed through a standard set of sieves with water. The preparation resulted in the following fractions: -40µm (287 g), 40-63 µm (72 g), 63-80µm (52 g), 80-125µm (103 g). All fractions were subsequently passed through wet magnetic separation. The magnetic concentrates contain no precious metal grains, except for rare grains intergrown with titanium-bearing magnetite.

The non-magnetic parts of every fraction from the sample # “90-23A 798” were separated using Hydroseparator HS-02M and new type of glass separation tube (GST). Monolayer polished sections were prepared from every heavy mineral concentrate. The polished sections (and one polished section of the primary rock) were investigated under the scanning electron microscope and the electron microprobe.

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

Results

Rock forming minerals and sulfides

Silicates and oxides

The rock-forming silicates and oxides of host gabbro of the sample 90-23A 798 are: 1) plagioclase, An_{44-49} (Table 1, analyses 1-2); 2) monoclinic ferrous pyroxene, Mg#=0.58-0.59 (Table 1, analyses 3-4), 3) orthorhombic ferrous pyroxene, Mg#=0.48-0.49 (Table 1, analyses 5-6), 4) Fe-Ti oxides including ilmenite (Table1, analyses 7-8) and titaniferous magnetite (Table 1, analyses 9-10); 5) secondary H_2O-bearing minerals including actinolite (Table 1, analysis 11), biotite (Table 1, analysis 12), ferrous talc (Table 1, analysis 13) and ferrosaponite (Table 1, analysis 14).

Monoclinic and orthorhombic pyroxenes form typical exsolution textures. The Fe-Ti-oxides occur as 1-3 mm large aggregates of anhedral grains. They fill the space between grains of plagioclase and pyroxenes (Plate 1, #1-3). The gabbro of the sample 90-23A 798 shows no reaction relationships between cumulus and intercumulus phases. Grains of both pyroxenes are often replaced by fine-grained aggregates of H_2O-bearing silicates (Plate 1, 3-4). Such aggregates of secondary silicates are often enriched by Cu-Fe sulfides (Plate 1). #5-8).

Sulfides

Despite of the relatively high concentration of precious metals (2-3 ppm), the gabbro is poor in sulfides and the content of Cu-Fe-sulfides is ~ 0.05 %. Grains of sulfide(s) are small in polished sections, and mostly 1-30 µm in diameter. The sulfide grains usually have irregular shapes. Most of the sulfides are related to the interstitial domains and they are generally related to a secondary paragenesis characterized by H_2O-bearing silicate phases (Plate 1, #7-8) and matrix Fe-Ti oxides (Plate 1, #6). The sectors of rock-forming pyroxenes and plagioclase that are enriched in sulfides are generally intensively replaced by finegrained aggregates of the secondary minerals including chlorite, actinolite, ferrous talc, hornblende, biotite and quartz (Plate 1, 7-8).

The non-magnetic heavy concentrates are ilmenite-rich products (> 90 %) enriched in grains of sulfide and precious metal minerals. The Cu-Fe sulfide grains in the HS-concentrates (mostly 1-30 µm, but up to 150 µm in size) include:

1. semi-spherical grains identified as sulfide droplets (Plate 2, #1-4);
2. grains of irregular shape (Plate 2, #5-13).

Sulfide grains are composed of one or more of the Cu-Fe-sulfides bornite, chalcosine, and minor digenite (Table 2, analyses 1-7), chalcopyrite, and occasionally pentlandite. Rare grains of sphalerite and galena are also observed. Bornite-and chalcosine-group minerals form exsolution textures (Plate 2). The intergrowths between Cu-Fe sulfides and H_2O-bearing minerals are commonly observed (Plate 2, #9-13).

In contrast to sulfide globules of Au-rich ores of the interior part of intrusion (for example the sample 90-24, 1018), the sulfide grains of the sample 90-23A, 798 have usually only very fine (<3 µm) and rare (see Plate 2, #4) inclusions of Cu- tellurides.

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

Recovery

No Au or PGM grains were found in the polished section of the studied sample during a search using scanning electron microprobe.

The Hydroseparation of the crushed material, however, yielded several minerals and more than 200 grains of Au-minerals and PGMs. A representative selection of 180 grains of precious metal minerals from heavy mineral concentrates of all size fractions (from –40 µm to 80-125 µm) was studied in detail. The PGM and Au-mineral paragenesis includes at least 5 precious metal:

1. **(Au,Cu,Ag) alloy**, which includes **(Au,Cu) alloy** in composition close to Au_3Cu - 179 grains,
2. **arsenopalladinite $(Pd,Cu,Au)_8(As,Sn)_3$** – 1 individual grain and 37 grains as intergrowths with (Au,Cu,Ag) alloy and kotulskite;
3. **kotulskite Pd(Te,Bi)** - as intergrowths with (Au,Cu,Ag) alloy and arsenopalladinite in 7 grains;
4. **sperrylite $PtAs_2$** – inclusions as intergrowth between arsenopalladinite and (Au,Cu,Ag) in 4 grains..

Taking into account the size of the grains, the volume ratios of precious metal minerals are calculated as follows (see also Table 3 and Fig.1):

Mineral	**Volume %**
(Au,Cu,Ag) alloy + unnamed Au_3Cu	94.8
Arsenopalladinite	4.7
Kotulskite	0.4
Sperrylite	0.1

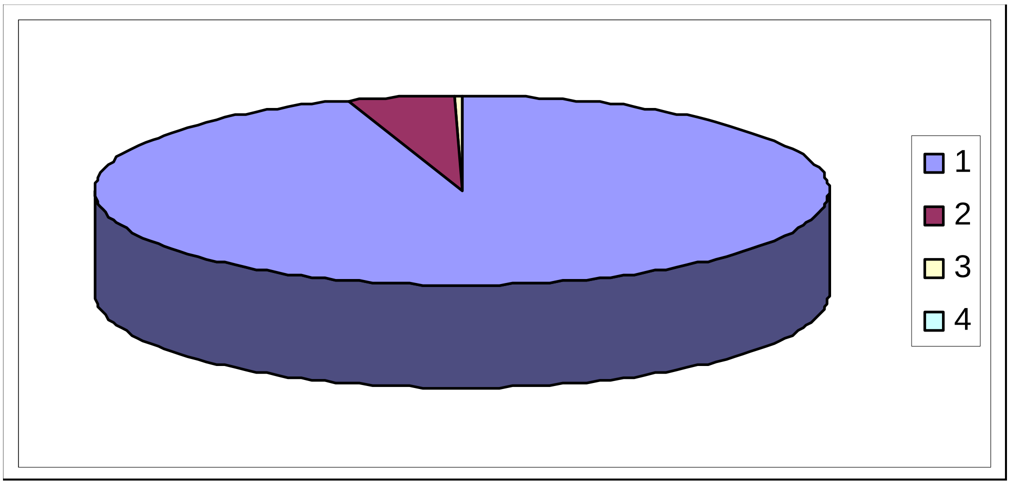


Figure 1: Distribution of precious metal minerals in sample 90-23A 798 (vol%). (1) 94.8 vol.% (Au,Cu,Ag) alloy and alloy of Au_3Cu composition; (2) 4.7 vol.% arsenopalladinite $(Pd,Cu,Au)_8(As,Sn)_3$; (3)- 0.4 vol.% Kotulskite Pd(Te,Bi); (4) – 0.06 vol.% sperrylite $PtAs_2$

Grain size of Au-minerals and PGMs

Grain sizes, as measured by the effective diameter of the grains (ECD, measured using software ImageJ), vary from 2 to 51 µm with an average of 20.4 µm (Table 3, Fig. 2). As shown in the histogram (Fig. 2), the precious metal minerals have the following distribution:

Grain size, µm	Number of grains
0-5	3
5-10	17
10-15	30
15-20	46
20-25	40
25-30	16
30-35	14
35-40	10
40-45	2
45-50	1
50-55	1

The SEIs (scanning electron images) show that the majority of these grains are well preserved, but irregular. They are believed to have preserved their primary irregular interstitial grains shapes (Plate 3-6). The grains have not been broken during the production of the concentrates. The largest proportion of grains of precious metal minerals are concentrated in the <40µm fraction. The histogram in figure 2 shows the grain size of Au minerals (n=180, including one arsenopalladinite grain) as a normal statistical distribution.

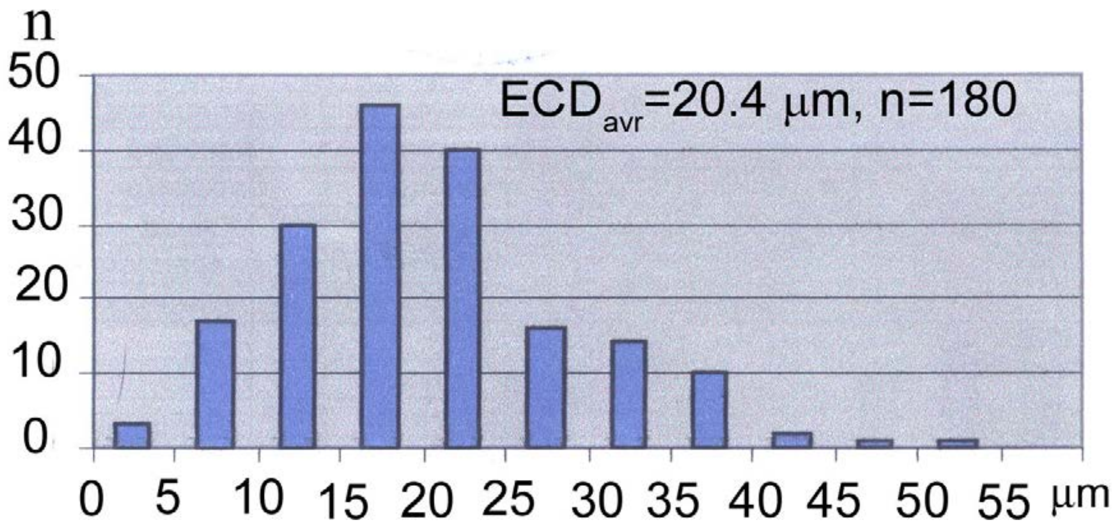


Figure 2: Grain size of gold and PGM grains in the heavy concentrates of sample 90-23A 798. 0-5 µm: 3 grains; 5-10 µm: 17; 10-15µm: 30; 15-20µm: 46; 20-25µm: 40; 25-30µm: 16; 30-35µm : 14; 35-40µm : 10; 40-45µm : 1; 50-55µm: 1.

Petrographic observations

In general, perfect separation of accessory minerals has been achieved by the gentle crushing of the sample. The gentle method of disintegration allows almost perfect preservation of the grains, which saves important information for the interpretation of the genesis of the minerals and the mineralization. The concentrates provide full information for the reconstruction of the primary shapes and sizes of accessory minerals, the parageneses, and relationships between the host rocks and the paragenesis of the mineralization.

The grains of Au-minerals and their intergrowths in the heavy mineral concentrates are divided into the following groups and mineral associations (see also Fig. 3):

1. completely liberated (free) particles –L (47.3 %);
2. two or more precious metal minerals completely liberated (free) particles –LP (15.1 %);
3. intergrowths with base metal sulfides (bornite, chalcosine, digenite, chalcopyrite, sometimes pentlandite) – BMS (1.4 %);
4. liberated particles with <10 % attached to base metal sulfides – BSM-L (3.6 %);
5. sulfide and gangue attached to gold minerals –SAG (3.1 %);
6. sulfide and gangue attached to gold minerals, but with < 10 % - SAG-L (2.7 %);
7. attached to gangue (ilmenite, magnetite, actinolite, chlorite, talc, calcite, biotite, ferrosaponite, hornblende, plagioclase, monoclinic and orthorhombic pyroxenes) – AG (2 %);
8. attached to gangue, but <10 % - AG-L (24.8 %).

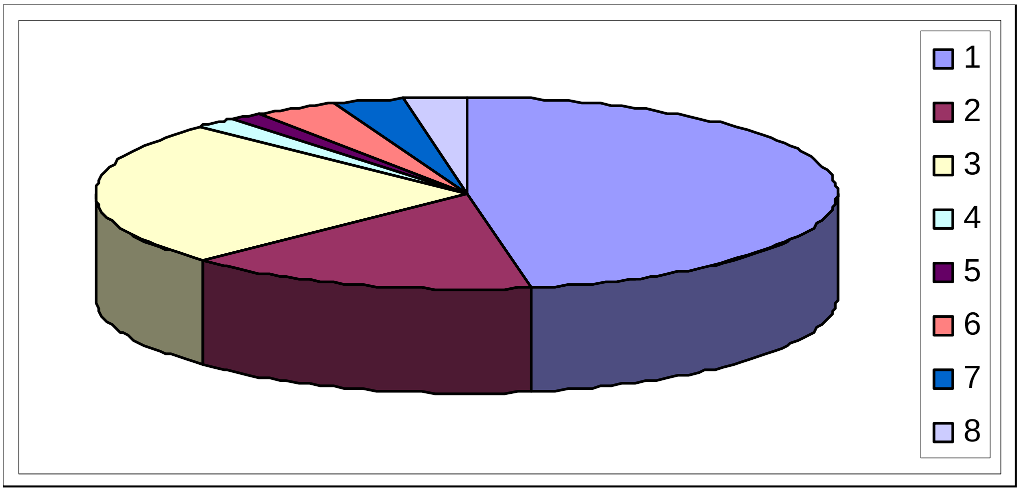


Figure 3. Gold minerals and PGMs grouped by association (sample 90-23a 798, vol. %). 1 – 47.3 % completely liberated (free) particles (L); 2 – 15.1 % two or more precious metal minerals completely liberated (free) particle (LP); 3 – 24.8 % precious metal minerals attached to gangue, but with<10 % (AG-L); 4 – 2 % precious metal minerals attached to gangue (AG); 5 – 1.4 % with base metal sulfides (BMS), 6 – 3.6 % liberated particles with <10 % attached base metal sulfides (BMS-L); 7- 3.1 % sulfide and gangue attached to precious metal minerals (SAG); 8 – 2.7 % sulfide and gangue attached to precious metal minerals, but with <10 % (SAG-L).

According to the SEIs, images of precious metal minerals from the heavy mineral concentrates could be divided on to the following different groups:

1. (Au,Cu,Ag) alloys associated with base metal sulfides (BSM+BSM-L+SAG+SAG-L) - Plate 3;
2. (Au,Cu,Pd) alloys attached to gangue (AG+AG-L) - Plate 4;
3. completely liberated grains of gold minerals (L) – Plate 5;
4. PGM and precious metal grains with PGM (LP) - Plate 6.

Description and chemistry of Au-minerals and PGMs

(Au,Cu,Ag) alloy

Description

The (Au,Cu,Ag) alloy is the absolutely dominant precious metal mineral (94.8 vol.%) in the heavy mineral concentrates of the sample 90-23A 798. It is in the concentrates found as:

1. liberated (free) grains – 47.3 % (Plate 5);
2. intergrown with base metal sulfides (BMS- 1.4 %, BMS-L – 3.6 %) (Plate 3);
3. intergrown with sulfide and gangue (SAG – 3.1 %, SAG-L –2.7 %) (Plate 3);
4. intergrown with gangue (AG – 2 %, AG-L – 24.8 %) (Plate 4);
5. intergrown with PGMs: arsenopalladinite (Plate 6, #1, 3-35, 37-42), kotulskite (Plate 6, #38-45) and sperrylite (Plate 6, #32-37).

Beside the main liberated form of (Au,Cu,Ag) alloy, the grains are commonly attached to gangue (AG, AG-L – Plate 5). In contrast, grains of (Au,Cu,Ag) alloy attached to base metal sulfides are quite uncommon (BMS, BSM-L, Plate 3, #4, 5, 9, 10, 12, 14, 15; Plate 6, #8). More often intergrowths of (Au,Cu,Ag) alloy with Cu-Fe sulfides and gangue (SAG and SAS-L - Plate 3, #1-3, 6-8, 11, 13; Plate 6, #18, 26, 30, 43) are recorded.

Intergrowths of (Au,Cu,Ag) alloy with gangue are divided into: (1) grains related to secondary minerals, and (2) grains related to primary rock-forming minerals. The former type is more common. The observed associations are:

1. (Au,Cu,Ag) alloy with secondary H_2O-bearing silicates:
2. actinolite (Plate 3, #3, 7, 8; Plate 4, #12-15, 20-31; Plate 6, #14, 23, 28, 29, 43);
3. chlorite (Plate 3, #1, 6, 8; Plate 4, #21, 32; Plate 6, #17, 18, 25, 41, 44);
4. biotite (Plate 6, #25, 39, 41);
5. ferrous talc (Plate 3, #2);
6. hornblende (Plate 3, #11);

(Au,Cu,Ag) alloy with primary rock-forming minerals:

1. as a rule, Fe-Ti oxides – ilmenite (Plate 3, #8; Plate 4, #1-15; Plate 6, #19, 21, 25, 30, 42) and titanic magnetite (Plate 3, #13; Plate 4, #5, 16, 17);
2. less commonly - plagioclase (Plate 4, #18, 19; Plate 6, #26);
3. occasionally - pyroxenes (Plate 6, #19, 24).

Recorded sizes of (Au,Cu,Pd) alloy grains are from 2 to 51 µm with an average of 20.4 µm (Table 3). The shape of (Au,Cu,Ag) alloy grains is in general irregular (Plate 3-6). 3 particles out of the 179 grains have droplet-like shapes (Plate 5, # 1-3).

Mineral chemistry

The chemical composition of (Au,Cu,Ag) alloy is established on the basis of 89 analyses from 89 different grains (Table 4). Average composition of (Au,Cu,Ag) alloy is (wt. %):
Au: 89.0, Pd: 0.4, Ag: 1.8, Cu: 7.5, Fe: 0.5, and Total: 99.2. The composition corresponds to the formulae:

$$\mathbf{(Au_{0.76}\,Cu_{0.20}\,Ag_{0.03}\,Fe_{0.01})_{1.00}}$$

Substitutions in this alloy include (wt%): up to 2.3 Pd, up to 5.8 Ag, and up to 2.0 Fe. When possible substitutions are taken into account (Au ← Ag, Pd and Cu ← Fe), many grains of (Au,Cu,Ag) alloy have compositions that are close to the stoichiometric composition of Au_3Cu (Table 4, analyses 2, 9, 11, 16, 18, 24, 26-30, 33, 37, 39, 42, 45-47, 50, 55, 63, 75-77, 79 and 81-89).

Arsenopalladinite $(Pd,Cu,Au)_8(As,Sn)_3$

Description

Arsenopalladinite is the dominating Pd mineral in the sample 90-23A 798 (4.7 vol. % of precious metal minerals). Arsenopalladinite is identified in 39 grains in the heavy concentrates.arsenopalladinite (Plate 6, #2), but 38 grains are in intergrowths. Only one grain of arsenopalladinite only was found. The 38 intergrowths are with:

1. (Au,Cu,Ag) alloy (Plate 6, #1, 3-35, 37-42),
2. (Au,Cu,Ag) alloy + sperrylite (Plate 6, #32-35, 37) +kotulskite (Plate 6, #38-42)

The size of arsenopalladinite grains varies from 3 to 27 µm, with an average size of 9 µm (Table 3). It forms anhedral grains only (see Plate 6). As a rule, arsenopalladinite grains are located in the marginal part of grains of (Au,Cu,Ag) alloy (see Plate 6).

Mineral chemistry

Twenty microprobe analyses of twenty different grains show different degrees of substitution such as Cu, and/or Au, and /or Fe for Pd and Sn for As (Table 5). The average composition of arsenopalladinite (wt.%) is: Pd: 70.8, Au: 4.2, Cu: 1.6, Fe: 0.8 Ni: 0.1 As 18.7 Sn 3.4 Total 99.5. The composition corresponds to the formulae:

$$\mathbf{(Pd_{7.27}Cu_{0.\,27}Au_{0.23}Fe_{0.15}Ni_{0.02})_{7.94}(As_{2.74}Sn_{0.31})_{3.05}}$$

Substitutions in arsenopalladinite include (wt%): up to 6.9 Au, up to 2.4 Cu, up to 1.8 Fe, and up to 0.9 Ni (see Table 5).

Rare PGMs of the studied sample include:

1. kotulskite - 0.4 vol. % (Plate 6, #38-45; Table 6);
2. sperrylite – 0.1 vol. % (Plate 6, #35-37).

Both minerals are found as fine inclusions (2-9 µm in size, see Table 3) and occur as a rule together with arsenopalladinite in the marginal part of grains of (Au,Cu,Ag) alloy.

Bulk composition of the sample 90-23A 798

The relative concentrations of Pd, Au and Pt in sample 90-23A 798 can be calculated from the total concentration of precious metals, the recovery, the modal proportions, and the chemical compositions of the minerals (Table 3-6). The estimated bulk composition of the sample (assays of whole rock in brackets) is (ppb): Au 2275 (2000), Pd 105 (360), Pt 2 (22). Au is concentrated in (Au,Cu,Ag) alloy and arsenopalladinite, Pd in arsenopalladinite, (Au,Cu) alloy and in kotulskite, and Pt is concentrated in sperrylite.

The difference between the assay and the mass balance based estimate of the bulk composition could be explained by:

1. Part of the core has been used for other investigations. Only 60% of the core is represented in the sample used for the mineralogical investigation. The assay was made prior to the extraction of core material and a bias may have been introduced.

2. The studies sample has a very heterogeneous distribution of Au-minerals and PGMs. A representative sample should have been much larger than the here studied sample.

3. The recovery of Au minerals is better than that of PGMs.

Discussion

The Au-mineral and PGM parageneses

The extensive data shows that the dominant precious metal phase in the studied sample is (Au,Cu,Ag) alloy. All observations and the inter-grain relations (Plate 3-6) suggest that Au-minerals and PGMs are part of a single paragenesis.

All PGMs (arsenopalladinite, kotulskite and sperrylite), as a rule, are located in the marginal part of gains of (Au,Cu,Ag) alloy (see Plate 6) and form rim-like aggregates around gold grains (Plate 6, 1, 5, 14-17, 32 etc.).

The petrographic characteristic of the studied sample are:

Relatively week correlation between precious metal and sulfide mineralisations: the proportion of BSM- and BSM-L associations (respectively 1.4 % and 3.6 %) is very low (see Fig. 3).

Precious metal minerals are closely associated with H_2O-bearing gangue such as actinolite, ferrous talc, biotite, hornblende (see Plate 3, #1-3, 7, 8, 11; Plate 4, #1215, 20-32; Plate 6, #14, 17, 18, 23, 25, 28, 29, 39, 41, 43, 44).

The observations in polished section (Plate 1, #5-8) and the concentrates (Plate 2, #9-13; Plate 3, #1-3, 6-8, 11; Plate 6, #18, 26, 30, 43) suggest that Cu-Fe mineralisation is also closely associated with H_2O-bearing secondary silicates .

Order of crystallization

All above mentioned observations indicate that the Au-minerals and the PGM paragenesis are late mineral assemblages related to the crystallization of the late hydrous silicate assemblage. The precious metal mineral assemblage is apparently postdating the primary sulfide mineralisation in the gabbro, and possibly a subsolidus re-eqilibration paragenesis.

Conclusion

The distinct textural and mineralogical differences between Au-rich ores of Skaergaard intrusion in the margin (sample 90-23A 798) and interior (for example sample 90-24 1018, Rudashevsky et al. unpublished) is most likely caused by different conditions of crystallization in the interior and in the marginal zone of the intrusion.

Changed conditions of crystallization due to faster cooling, and stabilization of the structure of the host rock in the marginal zone of the intrusion (sample 90-23A 798) excluded the an effective separation of cumulus phases and intercumulus melt and the formation of a distinct intercumulus melt and paragenesis in disequilibrium with the crystallized primary phases. The crystallization conditions were probably closer to equilibrium crystallization than fractional crystallization. This is supported by the absence of rims of olivine (+anorthite) along boundary of pyroxenes and Fe-Ti oxide grains, a feature so common in many of the gabbros from the interior of the intrusion (Plate 1, #1, 2). The absence (*durante absentia, lat*) of a distinct intercumulus paragenesis crystallized from a late interstitial melt (which elsewhere is appears to be an important bearer of the precious metals) suggests that no essential accumulation of a primary sulfide melt took place in sample 90-23A 798. The indirect confirmation of this conclusion is the observation that grains of (Au,Cu,Ag) alloy are rarely attached to base metal sulfides (BMS+BSM-L= 5 %).

Another consequence of changed conditions of crystallization is an apparent accumulation of residual precious metal bearing and Au-rich late melt/fluid. The replacement of Au was in the form of Au-Te-complexes. Only little re-equilibration between primary sulfide phase and residual melt/fluid occurred. Inclusions of tellurides is not characteristic for Cu-Fe aggregates of the studied sample, and it is concluded that the precious metal mineral assemblage (first of all Au) was formed as a subsolidus re-eqilibration paragenesis. This conclusion is confirmed by the relatively wide distribution and dissemination of precious metal minerals attached to late-formed H_2O-bearing gangue (AG+AG-L=26.8 %). The observations indicate that the Au enrichment in the Pd4b level in core 90-23A was caused by enrichment in and reaction with a volatile rich residual phase.

Summary

1. 180 grains of precious metal minerals in heavy concentrates from sample 90-23A 798 (0.53 kg) were investigated.

2. The totally dominating precious metal mineral is (Au,Cu,Ag) (94.8 vol.%). In addition four other precious metal minerals were identified and include: (1) unnamed Au_3Cu, (2) arsenopalladinite $(Pd,Cu.Au)_8(As,Sn)_3$, (3) kotulskite Pd(Te,Bi), and (4) sperrylite ($PdAs_2$).

3. Many grains of (Au,Cu,Ag) alloy, taking possible substitutions into account, have a composition close to that of stoichiometric Au_3Cu, which is an unnamed new mineral.

4. The estimated bulk composition of the sample (with assay concentrations in brackets) is estimated to (ppb): Au: 2275 (2000), Pd: 105 (305), and Pt: 2 (22). Au is concentrated in (Au,Cu,Ag) alloy and (Au,Cu) alloy; Pd in arsenopalladinite and in kotulskite; and Pt is concentrated in sperrylite.

5. In the heavy concentrates the Au-mineral grains generally occur in the following mineral associations: a) completely liberated (free) particles –L (47.3 %); b) two or more precious metal minerals completely liberated (free) particles –LP (15.1 %); c) intergrowths with base metal sulfides (bornite, chalcosine, digenite, chalcopyrite and sometimes pentlandite chalcopyrite, sometimes pentlandite) – BMS (1.4 %); d) liberated particles with <10 % attached base metal sulfides – BSM-L (3.6 %); e) sulfide and gangue attached to gold minerals –SAG (3.1 %); f) sulfide and gangue attached to gold minerals, but with < 10 % - SAG-L (2.7 %); g) attached to gangue (ilmenite, magnetite, actinolite, chlorite, talc, calcite, biotite, ferrosaponite, hornblende, plagioclase, monoclinic and orthorhombic pyroxenes) – AG (2 %); i) attached to gangue, but with <10 % -AG-L (24.8%).

6. The Au-minerals and the PGM paragenesis is a late assemblages related to the crystallization of a late hydrous silicates. The precious metal mineral assemblage is clearly later than the primary sulfide mineralization in the gabbro and may represent be a subsolidus re-equilibration paragenesis.

References

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.; H. Rasmussen; Rudashevsky, N.S.; Kretser, Yu.L. & Rudashevsky, V.N.(2003a). PGE and sulfide phases of the precious metal mineralisation of the Skaergaard intrusion. Part 4: sample 90-23A, 806. GEUS report **2003/53**, 40 pp.

Nielsen, T.F.D.; H. Rasmussen; Rudashevsky, N.S.; Kretser, Yu.L. & Rudashevsky, V.N. (2003b). PGE and sulfide phases of the precious metal mineralisation of the Skaergaard intrusion. Part 1: sample 90-23A, 807. GEUS report **2003/47**, 46 pp.

Nielsen, T.F.D.; H. Rasmussen; Rudashevsky, N.S.; Kretser, Yu.L. & Rudashevsky, V.N. (2003c). PGE and sulfide phases of the precious metal mineralisation of the Skaergaard intrusion. Part 5: sample 90-23A, 808. GEUS report **2003/54**, 37 pp.

Rudashevsky N.S, Kretser, Yu. L. and Rudashevsky, V.N. 2005: Gold, PGE and sulfide phases of the precious metal mineralisation of the Skaergaard intrusion. Sample 90-24 1018. Unpublished report CNT, St. Petersbourg, Russia.

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. Compositions of silicates and Fe-Ti oxides in sample 90-23A 798

Analysis	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Mineral	PL	PL	CPX	CPX	OPX	OPX	ILM	ILM	TIMT	TIMT	ACT	BT	TLC	FSPN
SiO_2	56.76	56.96	50.54	51.39	50.54	50.96	nd	nd	nd	nd	53.53	43.90	57.60	40.04
TiO_2	nd	nd	1.00	nd	0.50	nd	53.76	53.76	9.18	8.35	nd	nd	nd	nd
Al_2O_3	26.65	26.28	1.32	nd	nd	nd	nd	nd	3.40	3.21	nd	10.59	1.13	10.59
V_2O_3	nd	nd	nd	nd	nd	nd	0.59	0.44	1.77	1.47	nd	nd	nd	nd
Fe_2O_3	nd	nd	1.68	2.35	1.94	0.71	*nd*	*nd*	47.14	47.59	0.27	nd	nd	nd
FeO	0.39	0.39	14.31	13.71	27.84	30.36	43.89	44.53	40.95	39.38	16.48	22.78	17.89	23.94
MnO	nd	nd	0.52	nd	0.65	0.52	0.78	0.79	nd	nd	nd	nd	nd	nd
MgO	nd	nd	12.27	12.77	15.92	15.92	nd	nd	nd	nd	17.91	13.76	20.73	14.76
CaO	10.21	9.23	19.16	19.44	3.08	1.26	nd	nd	nd	nd	5.87	nd	0.42	1.54
Na_2O	5.39	6.47	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
K_2O	0.6	0.48	nd	nd	nd	nd	nd	nd	nd	nd	nd	8.31	nd	0.96
Total	99.99	99.81	100.80	99.66	100.46	99.74	99.01	99.51	102.44	100.01	94.07	99.34	97.77	91.83
Cations														
Si	2.56	2.56	1.92	1.97	1.96	1.99	nd	nd	nd	nd	7.98	3.29	3.83	2.88
Ti	nd	nd	0.03	nd	0.01	nd	1.03	1.03	2.02	1.88	nd	nd	nd	nd
Al	1.42	1.39	0.06	nd	nd	nd	nd	nd	1.17	1.14	nd	0.94	0.09	0.90
V	nd	nd	nd	nd	nd	nd	0.01	0.01	0.41	0.35	nd	nd	nd	nd
Fe^{3+}	nd	nd	0.05	0.07	0.06	0.02	nd	nd	10.38	10.75	0.03	nd	nd	nd
Fe^{2+}	0.01	0.01	0.45	0.44	0.90	0.99	0.94	0.95	10.02	9.88	2.06	1.43	1.00	1.44
Mn	nd	nd	0.02	nd	0.02	0.02	0.02	0.02	nd	nd	nd	nd	nd	nd
Mg	nd	nd	0.70	0.73	0.92	0.93	nd	nd	nd	nd	3.99	1.54	2.06	1.58
Ca	0.49	0.44	0.78	0.80	0.13	0.05	nd	nd	nd	nd	0.94	nd	0.02	0.12
Na	0.47	0.56	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
K	0.03	0.03	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.8	nd	0.09
# of O	5.00	5.00	4.00	4.00	4.00	4.00	2.00	2.00	24.00	24.00	15.00	8.00	7.00	7.00

Table 2. **Chemical composition and formulas of sulphides in sulphide globules of the heavy concentrates (sample 90-23a, 798)**

Analysis	Grain	Mineral	Cu	Fe	Ni	Co	S	Total
1	80, 1a	BN	61.5	12.1	nd		25.0	98.6
			4.93	*1.11*	*nd*	*nd*	*3.96*	*10.0*
2	125, 5a	BN	62.6	11.9	nd	nd	24.6	98.6
			5.02	*1.09*	*nd*	*nd*	*3.90*	*10.0*
3	125, 5d	BN	65.5	11.8	nd	nd	25.5	99.4
			4.94	*1.06*	*nd*	*nd*	*4.00*	*10.0*
4	80, 3e	CC	76.7	2.1	nd	nd	20.4	99.2
			1.93	*0.06*	*nd*	*nd*	*1.02*	*3.0*
5	125, 5d	CC	77.6	1.5	nd	nd	20.0	99.1
			1.96	*0.04*	*nd*	*nd*	*1.00*	*3.0*
6	125, 5a	CC	78.4	0.6	nd	nd	20.3	99.3
			1.97	*0.02*	*nd*	*nd*	*1.01*	*3.0*
7	80, 1a	DGN	75.8	1.9	nd	nd	21.7	99.4
			8.78	*0.25*	*nd*	*nd*	*4.97*	*14.0*

Table 3. Precious metal minerals of heavy concentrates (sample 90-23a, 798)

N	Mineral	General formula	Number of grains	Grin size, mm			Vol. %
				min	max	average	
1	(Au,Cu,Ag) alloy	(Au,Cu,Fe,Ag,Pd)	179	4	51	20.4	94.8
2	Arsenopalladinite	(Pd,Cu,Au,Fe)8(As,Sn)3	1, 38*	3	27	9	4.7
3	Kotulskite	Pd(Te,Bi)	7*	2	9	6	0.4
4	Sperrylite	PtAs2	4*	2	4	3	0.06

*As inclusions in grain of other precious metal minerals

Table 4 **Chemical composition and formuli of (Au,Cu,Pd,Ag)-alloys in the heavy concentrates of the sample 90-23a, 798**

An	Grain	Association of minerals	Au	Pd	Ag	Cu	Fe	Total	Au	Pd	Ag	Cu	Fe
1	40, 1	(Au,Cu)	89.3	nd	1.5	7.3	0.0	98.1	0.78	nd	0.02	0.20	0.00
2	40, 2	(Au,Cu)+APD+PL	86.2	1.0	1.9	8.8	0.8	98.7	0.71	0.02	0.03	0.22	0.02
3	40, 3	(Au,Cu)+APD+BN+CHL	79.0	2.3	1.5	14.7	2.0	99.4	0.57	0.03	0.02	0.33	0.05
5	40, 5	(Au,Cu)+ACT+BN	87.5	1.1	1.8	7.2	0.7	98.3	0.74	0.02	0.03	0.19	0.02
6	40, 8	(Au,Cu)+ILM	90.1	nd	2.4	7.4	0.0	99.9	0.77	nd	0.04	0.20	0.00
7	40, 9	(Au,Cu)	91.9	nd	2.3	4.8	0.0	99.0	0.83	nd	0.04	0.13	0.00
8	40, 11	(Au,Cu)+ACT	91.4	nd	1.2	6.5	0.0	99.1	0.80	nd	0.02	0.18	0.00
9	40, 12	(Au,Cu)	88.4	nd	0.9	8.6	0.7	98.6	0.74	nd	0.01	0.22	0.02
10	40, 13	(Au,Cu)+APD	91.3	nd	2.9	5.1	0.0	99.3	0.81	nd	0.05	0.14	0.00
11	40, 14	(Au,Cu)	89.6	nd	1.5	8.0	0.7	99.8	0.75	nd	0.02	0.21	0.02
12	40, 15	(Au,Cu)+APD	90.1	1.0	1.0	7.5	0.0	99.7	0.77	0.02	0.02	0.20	0.00
13	40, 16	(Au,Cu)+ACT+ILM	91.7	nd	0.0	6.5	0.9	99.1	0.80	nd	0.00	0.18	0.02
14	40, 18	(Au,Cu)+APD+KT	90.7	nd	0.0	7.8	0.0	98.5	0.79	nd	0.00	0.21	0.00
15	40, 19	(Au,Cu)+APD	90.8	nd	0.0	7.7	0.0	98.5	0.79	nd	0.00	0.21	0.00
16	40, 20	(Au,Cu)	88.6	nd	1.4	9.5	0.5	100.0	0.72	nd	0.02	0.24	0.02
17	40, 21	(Au,Cu)+SP	90.4	nd	3.1	5.4	0.6	99.5	0.79	nd	0.05	0.14	0.02
18	40, 22	(Au,Cu)+BN	89.8	nd	1.4	9.6	0.0	100.8	0.74	nd	0.02	0.24	0.00
19	40, 23	(Au,Cu)+KT+BT+CHL	90.4	nd	1.8	6.5	0.0	98.7	0.79	nd	0.03	0.18	0.00
20	40, 25	(Au,Cu)	91.2	nd	1.9	5.5	0.5	99.1	0.80	nd	0.03	0.15	0.02
21	40, 26	(Au,Cu)+BN	88.7	nd	1.9	8.0	0.4	99.0	0.75	nd	0.03	0.21	0.01
22	40, 27	(Au,Cu)+APD	91.9	nd	1.1	7.3	0.0	100.3	0.79	nd	0.02	0.19	0.00
23	40, 29	(Au,Cu)+APD+SP	90.0	1.1	2.6	4.8	0.0	98.5	0.81	0.02	0.04	0.13	0.00
24	40, 30	(Au,Cu)+APD+ILM+BT+CHL	90.7	nd	0.9	8.9	0.0	100.5	0.76	nd	0.01	0.23	0.00
25	40, 32	(Au,Cu)+ILM	86.9	1.2	0.9	9.5	1.3	99.8	0.70	0.02	0.01	0.24	0.04
26	40, 33	(Au,Cu)	90.6	nd	0.0	8.0	1.2	99.8	0.76	nd	0.00	0.21	0.04
27	40, 34	(Au,Cu)+ACT	87.7	1.1	1.9	7.6	0.8	99.1	0.73	0.02	0.03	0.20	0.03
28	40, 35	(Au,Cu)	88.0	0.9	1.0	9.3	0.4	99.6	0.72	0.01	0.02	0.24	0.01
29	40, 36	(Au,Cu)+APD	86.1	2.0	0.9	9.9	0.0	98.9	0.71	0.03	0.01	0.25	0.00
30	40, 37	(Au,Cu)+PN	87.6	nd	0.9	10.2	0.0	98.7	0.73	nd	0.01	0.26	0.00
31	40, 38	(Au,Cu)+BN+TIMT	88.4	1.0	2.8	7.3	0.0	99.5	0.75	0.01	0.04	0.19	0.00
32	40, 39	(Au,Cu)+APD+TIMT+ILM	89.3	1.4	3.7	4.3	0.0	98.7	0.80	0.02	0.06	0.12	0.00

Table 4 continued

An	Grain	Association of minerals	Au	Pd	Ag	Cu	Fe	Total	Au	Pd	Ag	Cu	Fe
33	40, 40	(Au,Cu)+APD	87.0	nd	1.3	10.0	0.6	98.9	0.71	nd	0.02	0.25	0.02
34	40, 41	(Au,Cu)	90.6	nd	1.0	7.4	0.0	99.0	0.79	nd	0.02	0.20	0.00
35	40, 42	(Au,Cu)+BN+CC	88.1	nd	0.0	11.2	0.5	99.8	0.71	nd	0.00	0.28	0.01
36	40, 43	(Au,Cu)+ACT+CHL	92.3	nd	1.1	4.5	0.5	99.4	0.84	nd	0.02	0.13	0.02
37	40, 44	(Au,Cu)	88.2	1.1	1.0	7.4	0.6	98.3	0.75	0.02	0.02	0.20	0.02
38	40, 45	(Au,Cu)	92.8	nd	1.5	4.8	0.8	99.9	0.82	nd	0.02	0.13	0.03
39	40, 46	(Au,Cu)+ACT	88.1	nd	1.5	8.6	0.0	98.2	0.75	nd	0.02	0.23	0.00
40	40, 47	(Au,Cu)	91.9	nd	1.0	6.1	0.0	99.0	0.82	nd	0.02	0.17	0.00
41	40, 48	(Au,Cu)+PN	86.6	nd	0.9	10.1	1.0	98.6	0.70	nd	0.01	0.26	0.03
42	40, 49	(Au,Cu)	86.5	1.1	0.9	10.3	0.0	98.8	0.71	0.02	0.01	0.26	0.00
43	40, 50	(Au,Cu)	90.3	nd	1.1	5.7	0.9	98.0	0.80	nd	0.02	0.16	0.03
44	40, 52	(Au,Cu)+APD+ACT	91.3	nd	1.7	5.8	1.0	99.9	0.79	nd	0.03	0.16	0.03
45	40, 54	(Au,Cu)	87.4	0.9	1.4	9.4	0.0	99.1	0.72	0.01	0.02	0.24	0.00
46	40, 57	(Au,Cu)+PL	88.3	nd	1.9	8.6	0.0	98.8	0.75	nd	0.03	0.23	0.00
47	40, 58	(Au,Cu)	88.6	nd	1.3	9.0	0.4	99.3	0.74	nd	0.02	0.23	0.01
48	40, 59	(Au,Cu)	88.0	nd	2.2	8.1	0.0	98.3	0.75	nd	0.03	0.21	0.00
49	40, 60	(Au,Cu)	88.5	1.5	2.3	6.9	0.8	99.9	0.74	0.02	0.03	0.18	0.02
50	40, 61	(Au,Cu)	86.6	nd	1.6	9.5	0.8	98.5	0.71	nd	0.02	0.24	0.02
51	40, 62	(Au,Cu)	86.6	1.7	3.5	6.4	1.2	99.4	0.72	0.03	0.05	0.16	0.04
52	40, 63	(Au,Cu)	91.2	nd	2.2	6.0	0.0	99.4	0.80	nd	0.03	0.16	0.00
53	40, 64	(Au,Cu)	89.2	1.2	1.2	6.0	1.1	98.7	0.77	0.02	0.02	0.16	0.03
54	40, 72	(Au,Cu)+ILM	89.1	nd	2.3	6.1	0.9	98.4	0.77	nd	0.04	0.16	0.03
55	40, 74	(Au,Cu)	88.1	nd	2.2	9.0	0.0	99.3	0.73	nd	0.03	0.23	0.00
56	40, 75	(Au,Cu)	86.3	nd	1.3	10.5	1.4	99.5	0.68	nd	0.02	0.26	0.04
57	40, 76	(Au,Cu)	85.7	0.9	4.5	5.9	1.8	98.8	0.71	0.01	0.07	0.15	0.05
58	40, 77	(Au,Cu)	91.8	nd	2.7	4.2	0.0	98.7	0.84	nd	0.05	0.12	0.00
59	40, 78	(Au,Cu)+APD	87.8	1.5	4.7	3.8	1.4	99.2	0.76	0.02	0.07	0.10	0.04
60	40.79	(Au,Cu)+APD+SP	89.3	nd	3.4	4.5	0.8	98.0	0.80	nd	0.06	0.12	0.02
61	40, 80	(Au,Cu)	87.2	nd	5.8	4.8	1.0	98.9	0.75	nd	0.09	0.13	0.03
62	40, 82	(Au,Cu)+APD+SP	90.6	0.9	2.8	4.7	0.0	99.0	0.81	0.01	0.06	0.13	0.00
63	40, 84	(Au,Cu)+ACT	87.1	nd	1.3	9.7	0.5	98.7	0.72	nd	0.02	0.25	0.01
64	40, 86	(Au,Cu)+APD+SP+CP	87.9	nd	3.6	7.4	0.7	99.6	0.73	nd	0.05	0.19	0.02
65	40, 88	(Au,Cu)	84.8	0.9	1.7	9.9	1.4	98.7	0.68	0.01	0.02	0.24	0.04

Table 4 continued

An	Grain	Association of minerals	Au	Pd	Ag	Cu	Fe	Total	Au	Pd	Ag	Cu	Fe
66	40, 89	(Au,Cu)	88.3	2.2	2.4	5.3	0.8	99.0	0.76	0.03	0.04	0.14	0.02
67	40, 91	(Au,Cu)	91.2	nd	1.7	5.5	0.8	99.2	0.80	nd	0.03	0.15	0.02
68	40, 95	(Au,Cu)+PL	92.3	1.0	1.1	4.9	0.0	99.3	0.83	0.02	0.02	0.14	0.00
69	40, 96	(Au,Cu)	93.7	nd	1.1	4.6	0.4	99.8	0.84	nd	0.02	0.13	0.01
70	40, 97	(Au,Cu)+APD+KT	91.5	nd	2.9	5.5	0.0	99.9	0.80	nd	0.05	0.15	0.00
71	40, 103	(Au,Cu)	89.8	nd	5.8	3.4	0.5	99.5	0.80	nd	0.09	0.09	0.02
72	40, 104	(Au,Cu)	85.2	1.4	1.3	10.6	1.1	99.6	0.67	0.02	0.02	0.26	0.03
73	40, 105	(Au,Cu)+APD+OPX+ACT	91.3	nd	3.1	4.8	0.7	99.9	0.80	nd	0.05	0.13	0.02
74	63, 1	(Au,Cu)	92.8	nd	1.4	5.1	0.6	99.9	0.82	nd	0.02	0.14	0.02
75	63, 2	(Au,Cu)+KT	89.0	nd	2.0	8.4	0.0	99.4	0.75	nd	0.03	0.22	0.00
76	40-2, 1	(Au,Cu)	89.8	nd	1.3	9.0	0.6	100.7	0.73	nd	0.02	0.23	0.02
77	40-2, 3	(Au,Cu)+ACT	90.1	nd	1.0	9.7	0.5	101.3	0.73	nd	0.02	0.24	0.01
78	40-2, 4	(Au,Cu)+APD+KT+BN+BT	90.9	nd	4.1	5.6	0.0	100.6	0.79	nd	0.07	0.15	0.00
79	40-2, 6	(Au,Cu)	89.4	nd	1.7	7.9	0.5	99.5	0.75	nd	0.03	0.21	0.01
80	40-2, 9	(Au,Cu)	87.2	1.7	3.1	6.3	0.6	98.9	0.74	0.03	0.05	0.17	0.02
81	40-2, 10	(Au,Cu)	87.5	nd	1.3	9.7	0.6	99.1	0.72	nd	0.02	0.25	0.02
82	40-2, 12	(Au,Cu)+BN+ACT	86.7	nd	1.2	10.5	0.6	99.0	0.70	nd	0.02	0.26	0.02
83	40-2, 13	(Au,Cu)+APD	87.9	nd	1.6	8.9	0.3	98.7	0.74	nd	0.02	0.23	0.01
84	40-2, 14	(Au,Cu)+APD+BN	88.1	nd	1.8	8.6	0.3	98.8	0.74	nd	0.03	0.22	0.01
85	40-2, 15	(Au,Cu)	87.1	nd	1.3	10.1	0.0	98.5	0.72	nd	0.02	0.26	0.00
86	80, 1	(Au,Cu)	88.5	nd	1.1	9.2	0.0	98.8	0.74	nd	0.02	0.24	0.00
87	80, 2	(Au,Cu)	88.2	nd	1.0	9.7	0.0	98.9	0.74	nd	0.01	0.25	0.00
88	80, 3	(Au,Cu)+APD+KT	87.7	nd	2.6	7.8	0.5	98.6	0.74	nd	0.04	0.21	0.01
89	125, 1	(Au,Cu)	87.8	nd	1.3	9.5	0.7	99.3	0.72	nd	0.02	0.24	0.02
		Average, n=89	89.0	0.4	1.8	7.5	0.5	99.2	0.76	nd	0.03	0.20	0.01

Table 5 **Chemical composition and formulas of the arsenopalladinite in PGM-grains of the heavy concentrates (sample 90-23a, 798)**

			Weight %								*Atomic proportions*							
An	**Grain**	**Association of minerals**	**Pd**	**Au**	**Cu**	**Fe**	**Ni**	**As**	**Sn**	**Total**	***Pd***	***Au***	***Cu***	***Fe***	***Ni***	***As***	***Sn***	***Total***
1	40, 2	APD+(Au,Cu)+BN+PL	69.7	6.9	1.4	0.0	nd	16.8	5.1	99.9	*7.35*	*0.39*	*0.25*	*0.00*	*nd*	*2.51*	*0.49*	11.0
2	40, 3	APD+(Au,Cu)+BN	68.1	6.4	2.0	0.4	0.7	16.8	5.2	99.7	*7.10*	*0.36*	*0.35*	*0.08*	*0.13*	*2.49*	*0.49*	11.0
3	40, 13	APD+(Au,Cu)	73.2	2.3	2.1	0.0	nd	20.2	1.2	99.1	*7.47*	*0.13*	*0.36*	*0.00*	*nd*	*2.92*	*0.11*	11.0
4	40, 15	APD+(Au,Cu)	68.9	5.4	1.4	0.5	0.9	19.5	3.2	99.3	*7.04*	*0.30*	*0.24*	*0.09*	*0.18*	*2.85*	*0.29*	11.0
5	40, 18	APD+(Au,Cu)+KT	71.6	4.1	1.8	0.0	nd	20.5	1.5	99.5	*7.34*	*0.23*	*0.31*	*0.00*	*nd*	*2.98*	*0.13*	11.0
6	40.27	APD+(Au,Cu)	71.3	4.6	1.4	0.4	nd	17.8	4.0	99.5	*7.41*	*0.25*	*0.24*	*0.10*	*nd*	*2.62*	*0.38*	11.0
7	40, 29	APD+(Au,Cu)+SP	69.1	6.3	2.0	0.8	nd	18.3	3.0	99.5	*7.17*	*0.35*	*0.35*	*0.16*	*nd*	*2.69*	*0.28*	11.0
8	40, 30	APD+(Au,Cu)+ILM+BT+CHL	72.9	0.9	2.3	1.2	nd	21.1	0.0	98.4	*7.32*	*0.05*	*0.39*	*0.23*	*nd*	*3.01*	*0.00*	11.0
9	40, 40	APD+(Au,Cu)	71.8	2.5	2.4	1.0	nd	21.5	0.0	99.2	*7.20*	*0.13*	*0.41*	*0.19*	*nd*	*3.07*	*0.00*	11.0
10	40, 78	APD+(Au,Cu)	70.3	5.9	0.9	0.8	nd	17.2	4.8	99.2	*7.33*	*0.33*	*0.17*	*0.17*	*nd*	*2.55*	*0.45*	11.0
11	40, 79	APD+(Au,Cu)+SP	69.3	5.6	0.8	1.8	nd	17.5	4.5	99.5	*7.19*	*0.31*	*0.14*	*0.35*	*nd*	*2.58*	*0.42*	11.0
12	40, 81	APD+(Au,Cu)	70.1	5.0	1.0	1.0	nd	19.0	3.7	99.8	*7.22*	*0.28*	*0.18*	*0.21*	*nd*	*2.78*	*0.34*	11.0
13	40, 82	APD+(Au,Cu)+SP	72.2	1.3	2.4	1.5	nd	22.7	0.0	100.2	*7.08*	*0.07*	*0.40*	*0.29*	*nd*	*3.16*	*0.00*	11.0
14	40, 86	APD+(Au,Cu)+SP+CP	71.4	3.5	1.0	1.5	0.4	16.0	6.4	100.2	*7.22*	*0.19*	*0.18*	*0.30*	*0.08*	*2.45*	*0.58*	11.0
15	40, 92	APD+(Au,Cu)	69.7	3.5	1.9	1.1	nd	20.1	3.0	99.3	*7.10*	*0.19*	*0.32*	*0.21*	*nd*	*2.91*	*0.28*	11.0
16	40, 97	APD+(Au,Cu)+KT	70.4	4.3	1.0	1.0	nd	19.3	4.1	100.1	*7.22*	*0.24*	*0.17*	*0.19*	*nd*	*2.81*	*0.37*	11.0
17	40, 128	APD+(Au,Cu)	69.9	5.5	0.7	0.7	nd	17.1	5.2	99.2	*7.36*	*0.32*	*0.13*	*0.14*	*nd*	*2.56*	*0.49*	11.0
17	40-2, 4	APD+(Au,Cu)+KT+BN+BT	69.4	4.9	1.3	0.5	nd	18.3	4.5	98.9	*7.26*	*0.28*	*0.23*	*0.10*	*nd*	*2.71*	*0.42*	11.0
18	40-2, 13	APD+(Au,Cu)	75.0	1.2	2.2	0.5	nd	20.7	0.0	99.7	*7.51*	*0.07*	*0.38*	*0.09*	*nd*	*2.95*	*0.00*	11.0
19	40-2,14	APD+(Au,Cu)+BN	71.0	3.3	0.8	0.6	nd	16.8	6.5	99.0	*7.45*	*0.19*	*0.14*	*0.12*	*nd*	*2.50*	*0.61*	11.0
20	80, 3	APD+(Au,Cu)+KT+BN	70.9	4.7	2.1	0.7	nd	16.5	4.5	99.4	*7.37*	*0.26*	*0.36*	*0.14*	*nd*	*2.44*	*0.42*	11.0
		average	70.8	4.2	1.6	0.8	0.1	18.7	3.4	99.5	*7.27*	*0.23*	*0.27*	*0.15*	*0.02*	*2.74*	*0.31*	11.0

Table 6	Chemical composition of the kotulskite im PGM-grains in the heavy concentrates (sample 90-23a,798)											
			Weight %					***Atomic proportions***				
Analysis	**Grain**	**Association of minerals**	**Pd**	**Te**	**Bi**	**Total**		***Pd***	***Te***	***Bi***	***sum***	
1	40, 97	KT=(Au,Cu)+APD	45.5	53.5	nd	99.0		*1.01*	*0.99*	*nd*	*2.00*	
2	40-2, 4	KT+(Au,Cu)+APD+BN+BT	43.6	47.9	7.5	99.0		*1.00*	*0.91*	*0.09*	*2.00*	
3	63, 2	KT+(Au,Cu)	42.5	48.2	9.1	99.8		*1.00*	*0.92*	*0.08*	*2.00*	
nd = no data or below detection												

PLATES

Abbreviations for minerals and phases in alphabetic order

ACT	actinolite
(Au,Cu)	(Au,Cu) alloy
APD	arsenopalladinite
BN	bornite
BT	biotite
CPX	clinopyroxene
CPXexs	clinopyroxene exsolutions
CC	chalcosine
CT	Cu-telluride
CHL	chlorite
DGN	digenite
HB	hornblende
ILM	ilmenite
KT	kotulskite
OPX	orthopyroxene
PL	plagioclase
PN	pentlandite
SP	sperrylite
SPH	sphalerite
TIMT	titaniferous magnetite
TLC	talc
UN-1	undetermined phase.

Plate 1

Relationships between rock-forming minerals, Fe-Ti oxides, and sulfides in oxide-rich tholeiitic gabbros (1-8), sample 90-23a,798; polished section, SEM-image (BIE).

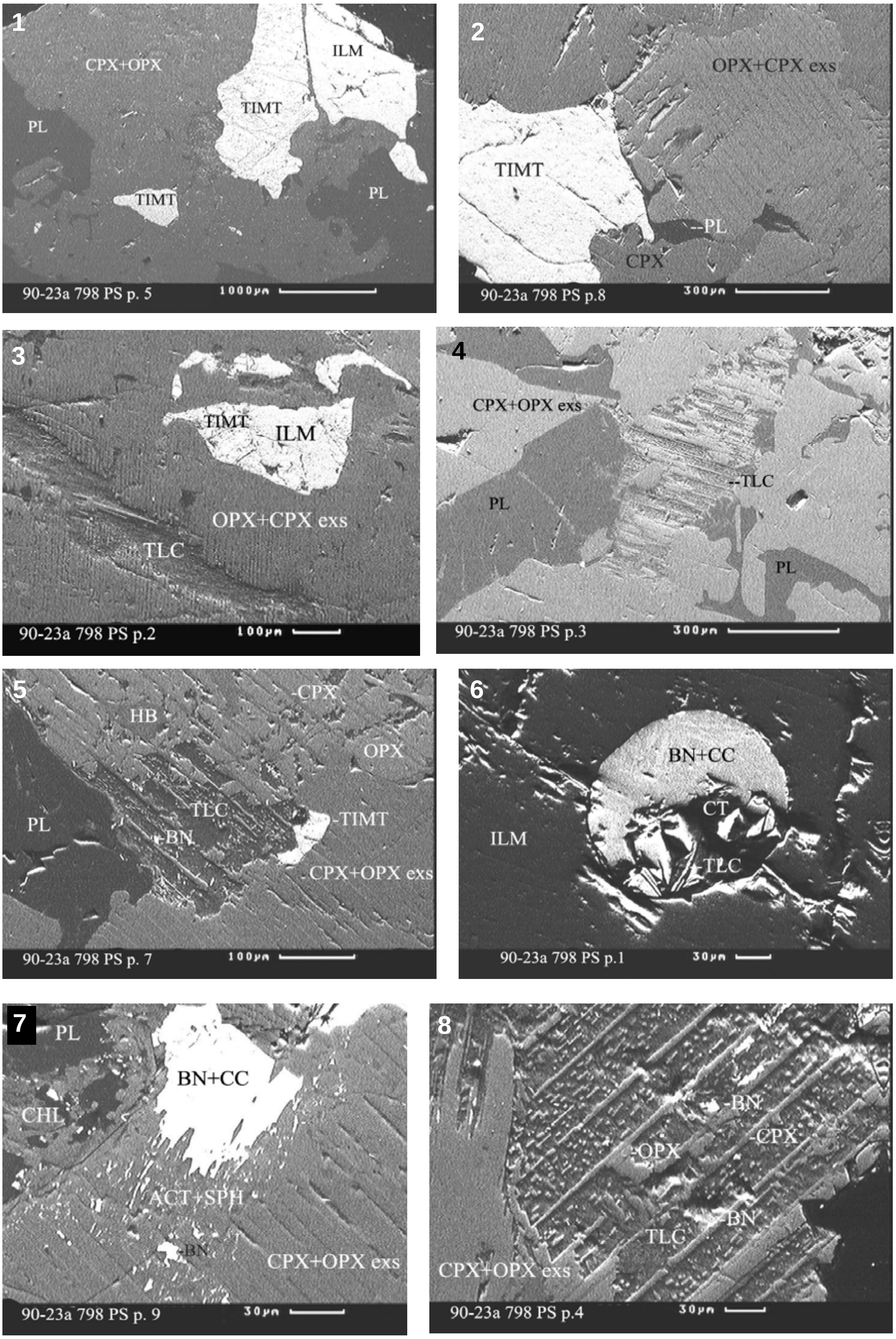
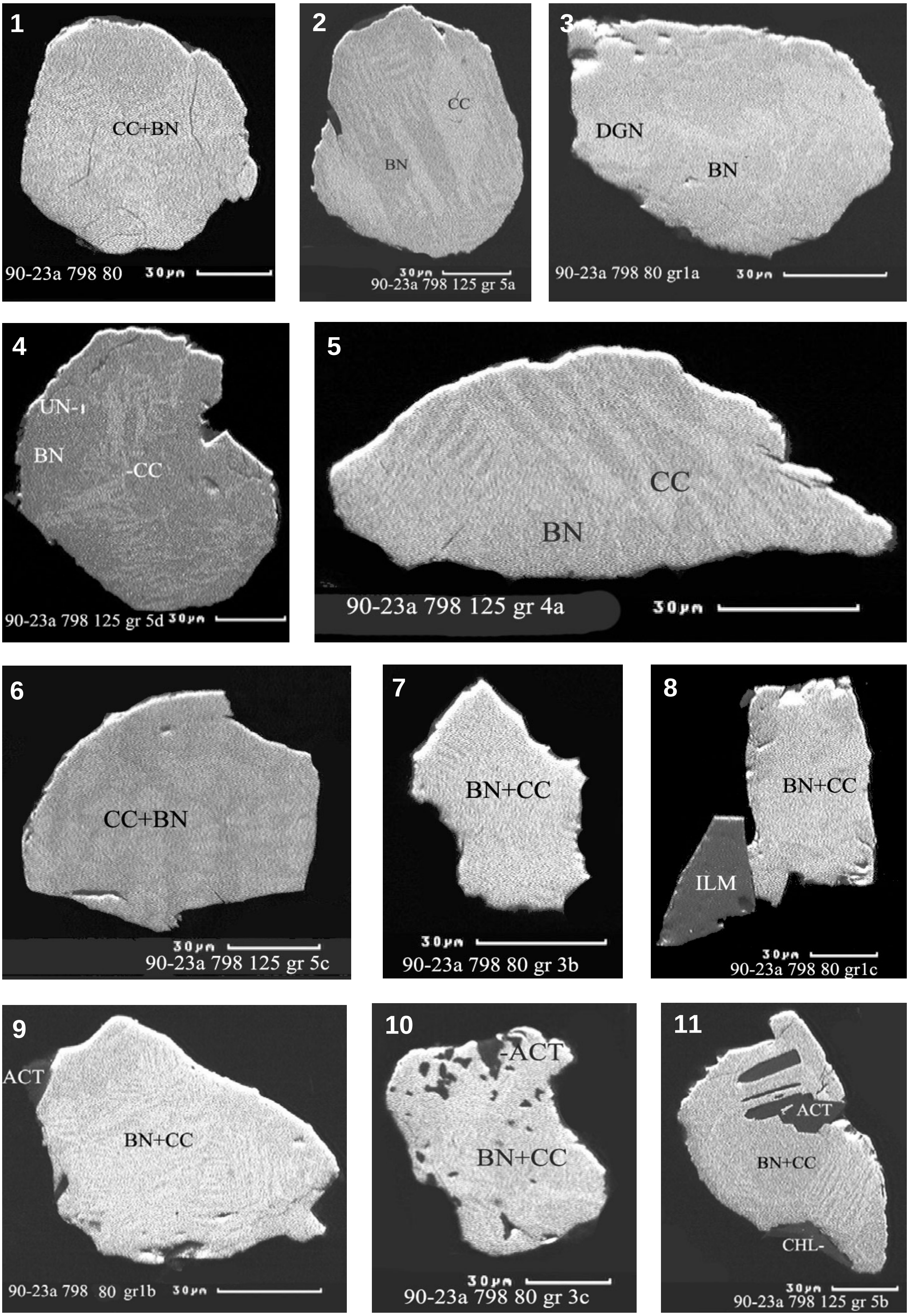
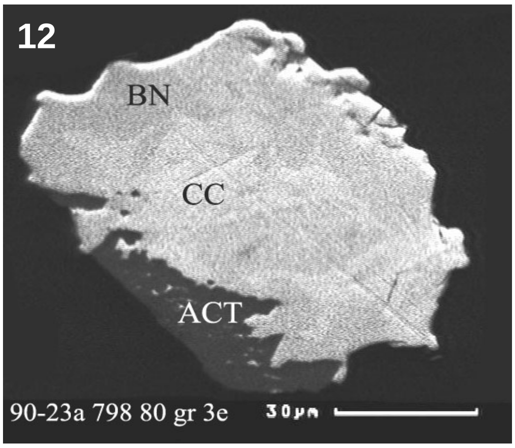

1
CPX+OPX
ILM
TIMT
PL
TIMT
PL
90-23a 798 PS p. 5
1000μm
2
OPX+CPX exs
TIMT
--PL
CPX
90-23a 798 PS p.8
300μm
3
TIMT
ILM
OPX+CPX exs
TLC
90-23a 798 PS p.2
100μm
4
CPX+OPX exs
PL
--TLC
PL
90-23a 798 PS p.3
300μm
5
-CPX
HB
OPX
TLC
PL
-BN
-TIMT
CPX+OPX exs
90-23a 798 PS p. 7
100μm
6
BN+CC
CT
ILM
-TLC
90-23a 798 PS p.1
30μm
7
PL
BN+CC
CHL
ACT+SPH
-BN
CPX+OPX exs
90-23a 798 PS p. 9
30μm
8
-BN
-OPX
-CPX
-BN
TLC
CPX+OPX exs
90-23a 798 PS p.4
30μm

Plate 2

Globuls and grains of sulfide mineralisation from oxide-rich tholeiitic gabbros (1-13), tsample 90-23a, 798. Polished sections with grains from the heavy concentrates, SEM-image (BIE).


1
CC+BN
90-23a 798 80
30μm
2
CC
BN
30μm
90-23a 798 125 gr 5a
3
DGN
BN
90-23a 798 80 gr1a
30μm
4
UN-1
BN
-CC
90-23a 798 125 gr 5d
30μm
5
CC
BN
90-23a 798 125 gr 4a
30μm
6
CC+BN
30μm
90-23a 798 125 gr 5c
7
BN+CC
30μm
90-23a 798 80 gr 3b
8
BN+CC
ILM
30μm
90-23a 798 80 gr1c
9
ACT
BN+CC
90-23a 798 80 gr1b
30μm
10
-ACT
BN+CC
30μm
90-23a 798 80 gr 3c
11
ACT
BN+CC
CHL-
30μm
90-23a 798 125 gr 5b


12
BN
CC
ACT
90-23a 798 80 gr 3e
30µm

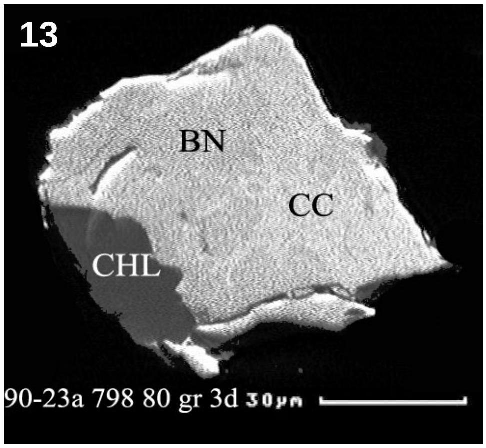
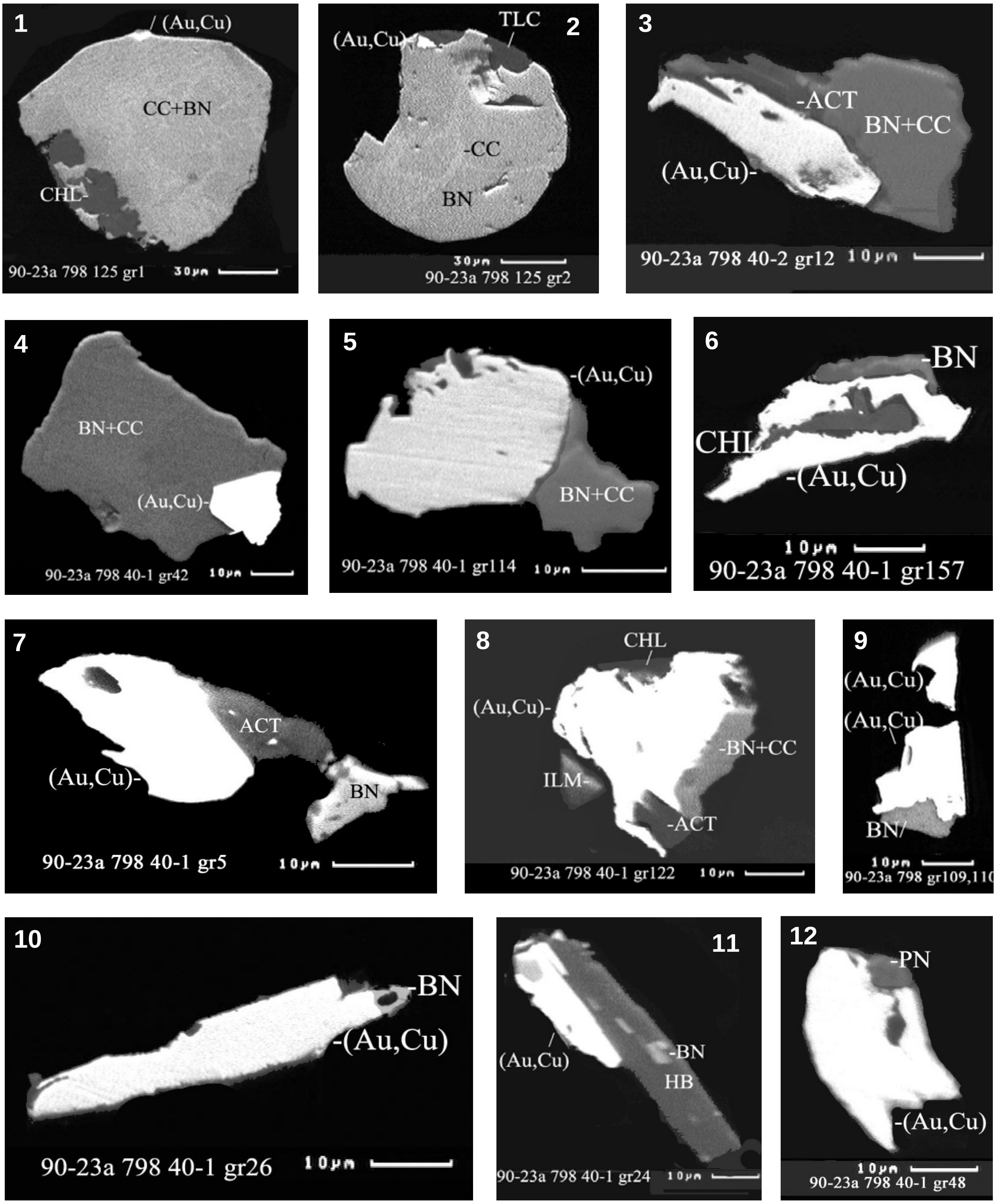

13
BN
CC
CHL
90-23a 798 80 gr 3d
30µm

Plate 3

Grains of (Au,Cu,Ag) alloy attached to base metal sulfide minerals and to sulfide and gangue (BSM, BSM-L, SAG, SAG-L) in the heavy concentrates of the sample 90-23a 798 (1-15); polished section, SEM-image (BIE).


1
/ (Au,Cu)
CC+BN
CHL-
90-23a 798 125 gr1
30μm
TLC
2
(Au,Cu)-
-CC
BN
30μm
90-23a 798 125 gr2
3
-ACT
BN+CC
(Au,Cu)-
90-23a 798 40-2 gr12
10μm
4
BN+CC
(Au,Cu)-
90-23a 798 40-1 gr42
10μm
5
-(Au,Cu)
BN+CC
90-23a 798 40-1 gr114
10μm
6
-BN
CHL
-(Au,Cu)
10μm
90-23a 798 40-1 gr157
7
ACT
(Au,Cu)-
BN
90-23a 798 40-1 gr5
10μm
8
CHL
(Au,Cu)-
-BN+CC
ILM-
-ACT
90-23a 798 40-1 gr122
10μm
9
(Au,Cu)
(Au,Cu)
BN/
10μm
90-23a 798 gr109,11
10
-BN
-(Au,Cu)
90-23a 798 40-1 gr26
10μm
11
(Au,Cu)
-BN
HB
90-23a 798 40-1 gr24
10μm
12
-PN
-(Au,Cu)
10μm
90-23a 798 40-1 gr48

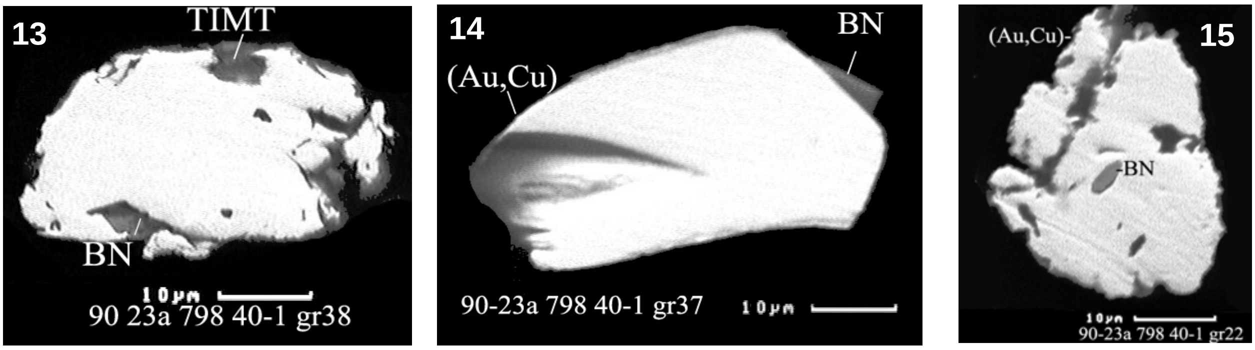
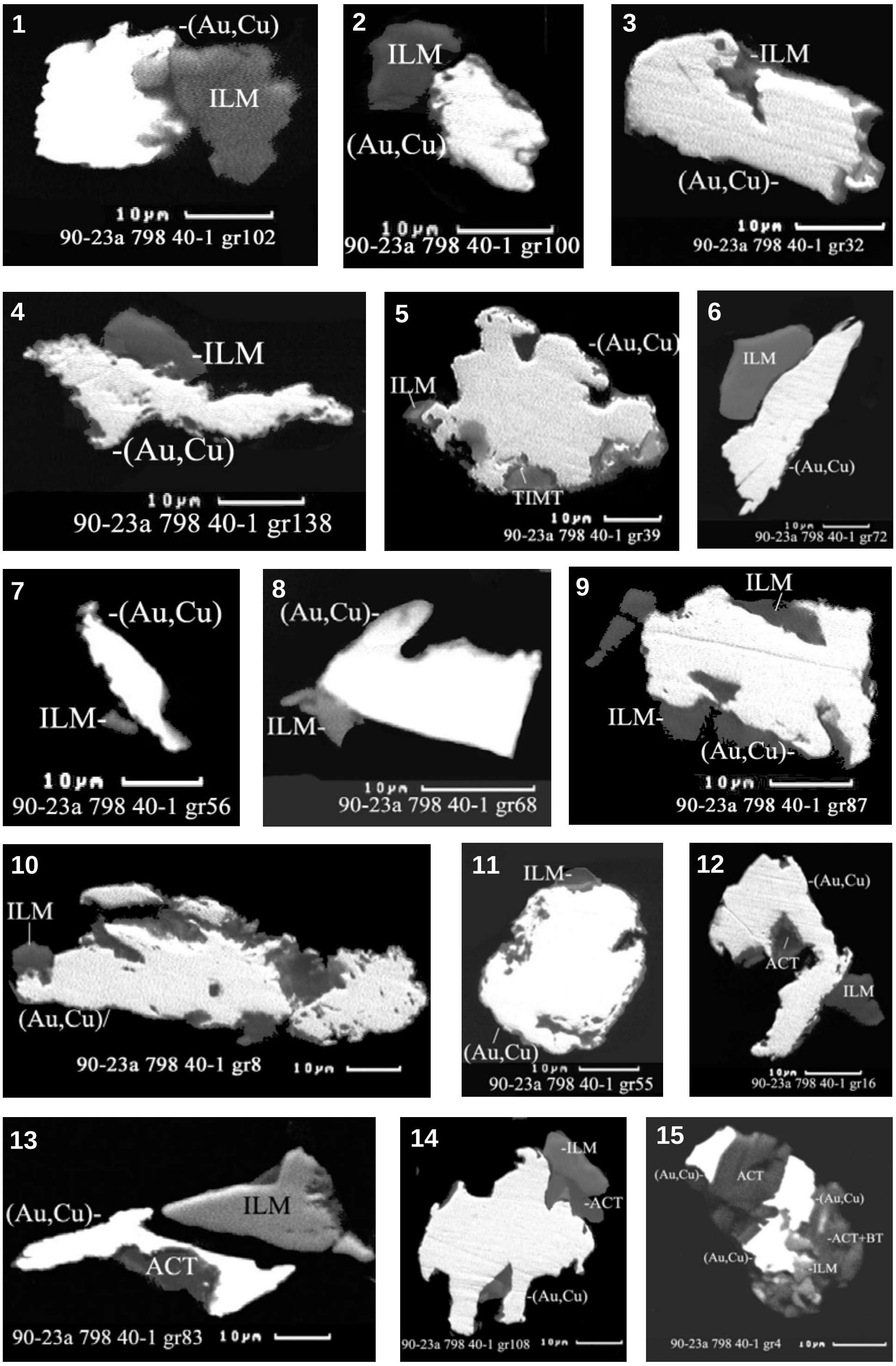

13
TIMT
BN
10μm
90 23a 798 40-1 gr38
14
(Au,Cu)
BN
90-23a 798 40-1 gr37
10μm
15
(Au,Cu)-
-BN
10μm
90-23a 798 40-1 gr22

Plate 4

(Au,Cu,Ag) alloy attached to gangue (AG, AG-L) in heavy concentrates of the sample 90-23a 798 (1-32); polished section, SEM-image (BIE).


1
-(Au,Cu)
ILM
10μm
90-23a 798 40-1 gr102
2
ILM
(Au,Cu)
10μm
90-23a 798 40-1 gr100
3
-ILM
(Au,Cu)-
10μm
90-23a 798 40-1 gr32
4
-ILM
-(Au,Cu)
10μm
90-23a 798 40-1 gr138
5
-(Au,Cu)
ILM
TIMT
10μm
90-23a 798 40-1 gr39
6
ILM
-(Au,Cu)
10μm
90-23a 798 40-1 gr72
7
-(Au,Cu)
ILM-
10μm
90-23a 798 40-1 gr56
8
(Au,Cu)-
ILM-
10μm
90-23a 798 40-1 gr68
9
ILM
ILM-
(Au,Cu)-
10μm
90-23a 798 40-1 gr87
10
ILM
(Au,Cu)/
90-23a 798 40-1 gr8
10μm
11
ILM-
(Au,Cu)
10μm
90-23a 798 40-1 gr55
12
-(Au,Cu)
ACT
ILM
10μm
90-23a 798 40-1 gr16
13
(Au,Cu)-
ILM
ACT
90-23a 798 40-1 gr83
10μm
14
-ILM
-ACT
-(Au,Cu)
90-23a 798 40-1 gr108
10μm
15
(Au,Cu)-
ACT
-(Au,Cu)
-ACT+BT
(Au,Cu)-
-ILM
90-23a 798 40-1 gr4
10μm

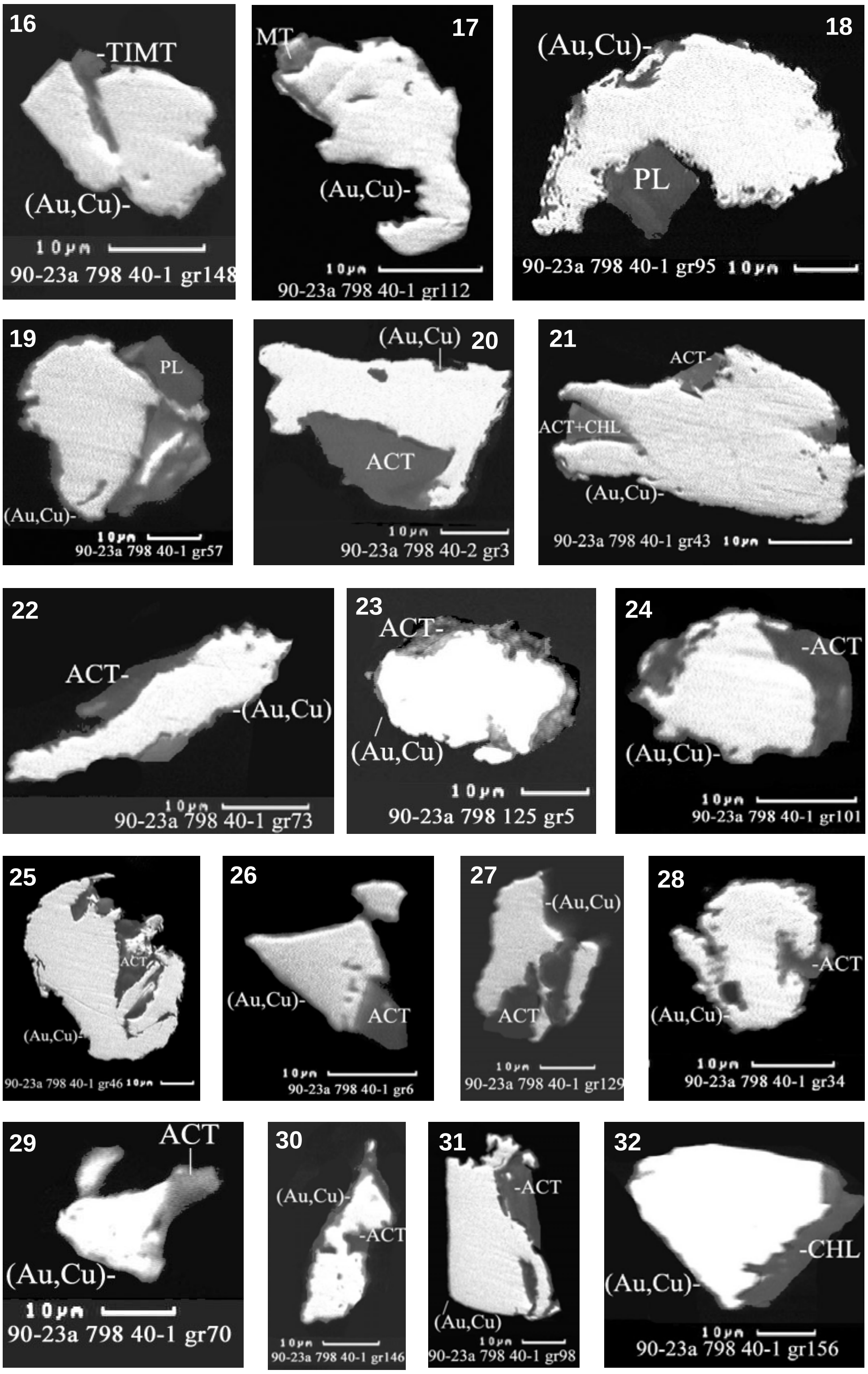
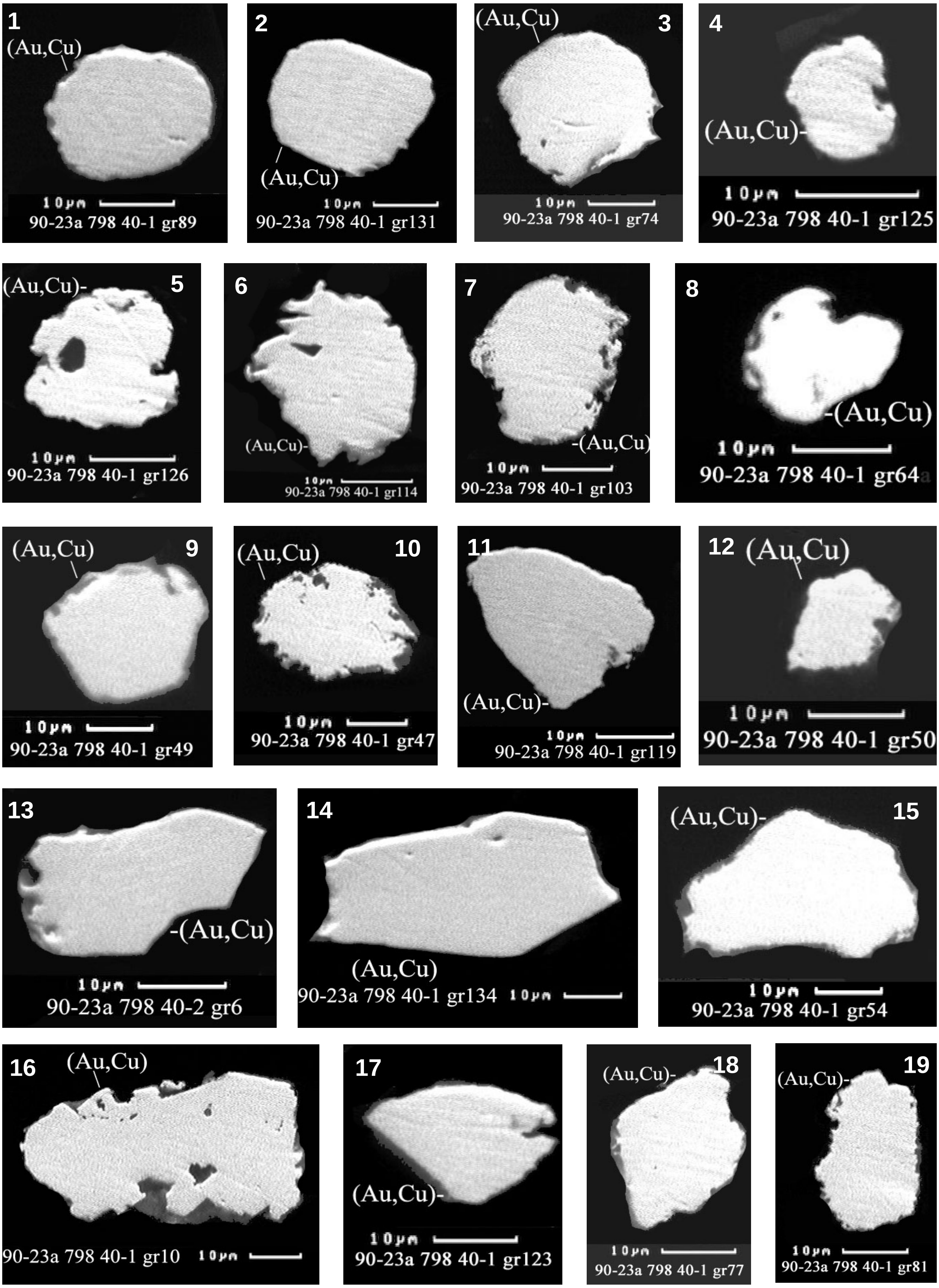
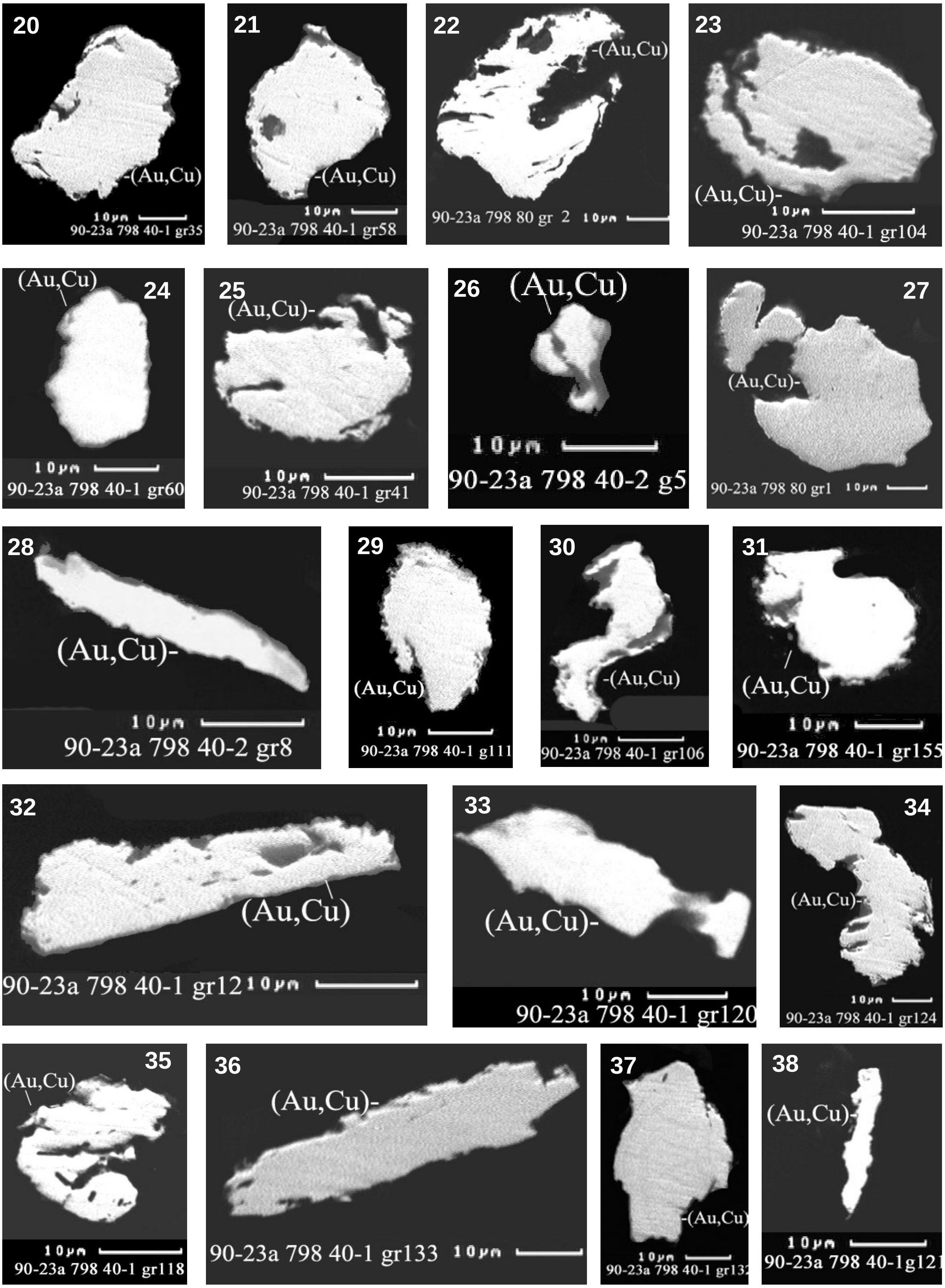
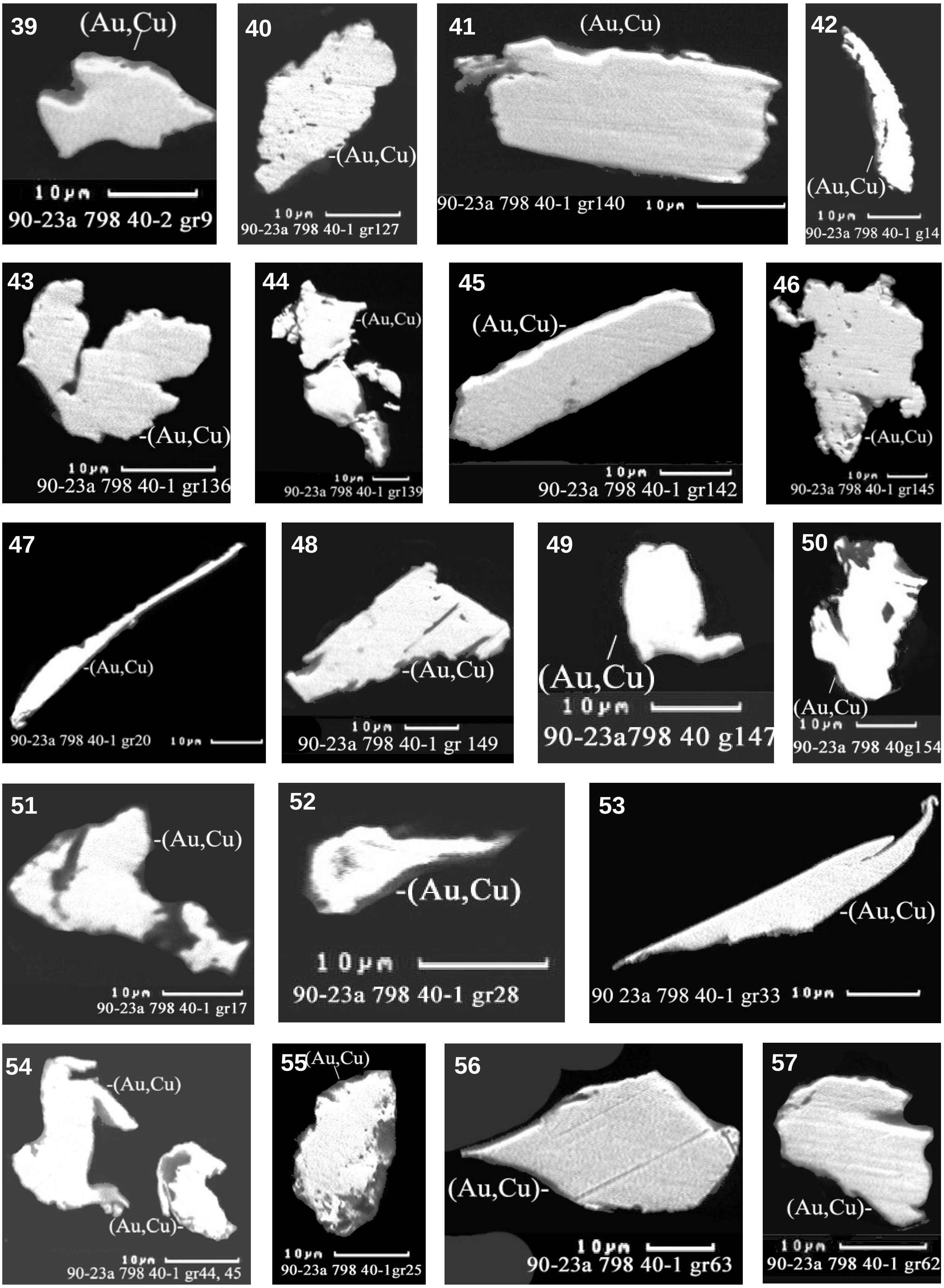

16
-TIMT
(Au,Cu)-
10 μm
90-23a 798 40-1 gr148
17
MT
(Au,Cu)-
10 μm
90-23a 798 40-1 gr112
18
(Au,Cu)-
PL
90-23a 798 40-1 gr95
10 μm
19
PL
(Au,Cu)-
10 μm
90-23a 798 40-1 gr57
20
(Au,Cu)
ACT
10 μm
90-23a 798 40-2 gr3
21
ACT-
ACT+CHL
(Au,Cu)-
90-23a 798 40-1 gr43
10 μm
22
ACT-
-(Au,Cu)
10 μm
90-23a 798 40-1 gr73
23
ACT-
(Au,Cu)
10 μm
90-23a 798 125 gr5
24
-ACT
(Au,Cu)-
10 μm
90-23a 798 40-1 gr101
25
ACT
(Au,Cu)-
90-23a 798 40-1 gr46
10 μm
26
(Au,Cu)-
ACT
10 μm
90-23a 798 40-1 gr6
27
-(Au,Cu)
ACT
10 μm
90-23a 798 40-1 gr129
28
-ACT
(Au,Cu)-
10 μm
90-23a 798 40-1 gr34
29
ACT
(Au,Cu)-
10 μm
90-23a 798 40-1 gr70
30
(Au,Cu)-
-ACT
10 μm
90-23a 798 40-1 gr146
31
-ACT
(Au,Cu)
10 μm
90-23a 798 40-1 gr98
32
-CHL
(Au,Cu)-
10 μm
90-23a 798 40-1 gr156

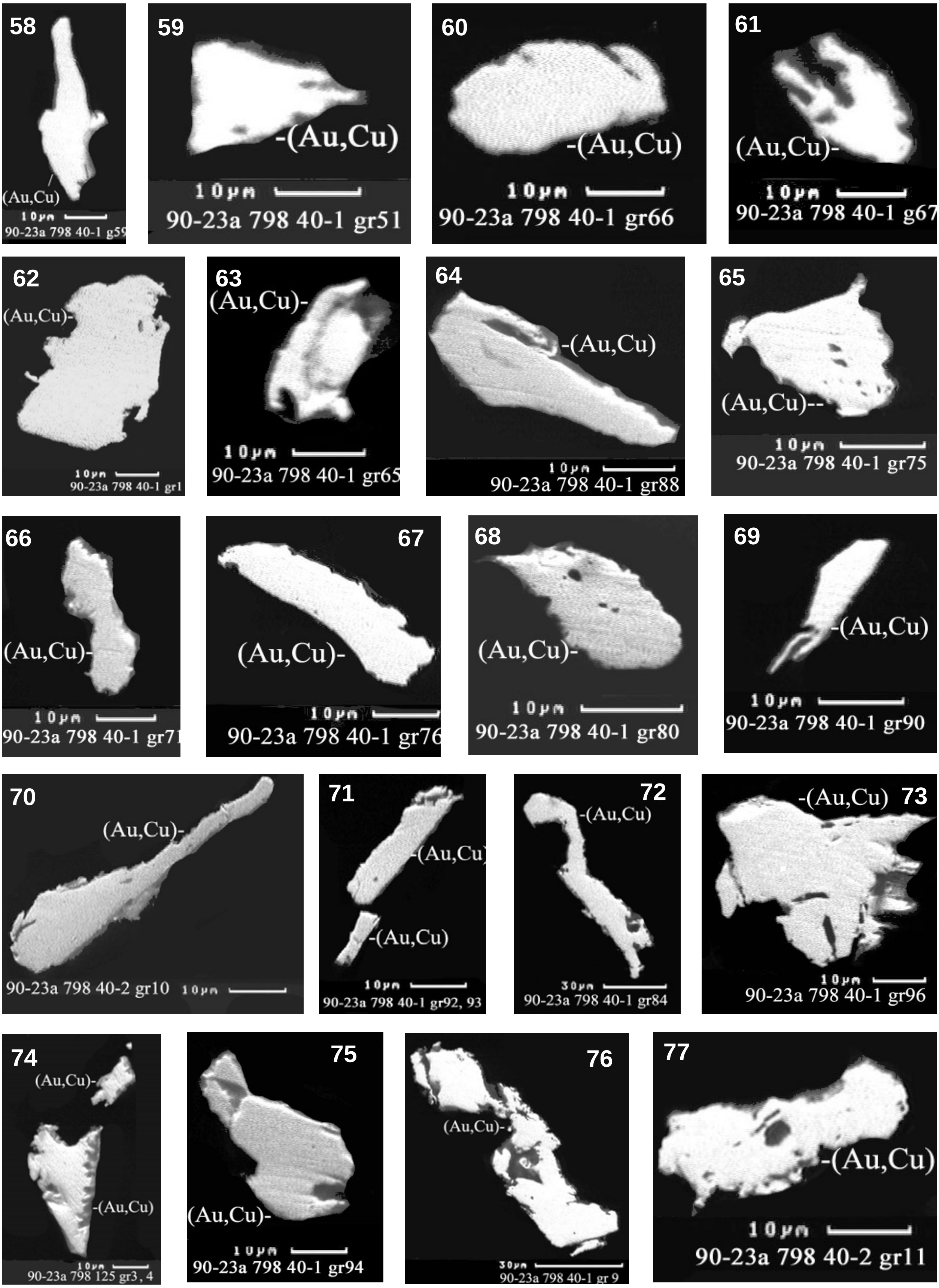
Plate 5

Completely liberated (free) grains of (Au,Cu,Ag) alloy in the heavy concentrates of sample 90-23A 798 (1-80); polished section, SEM-image (BIE).

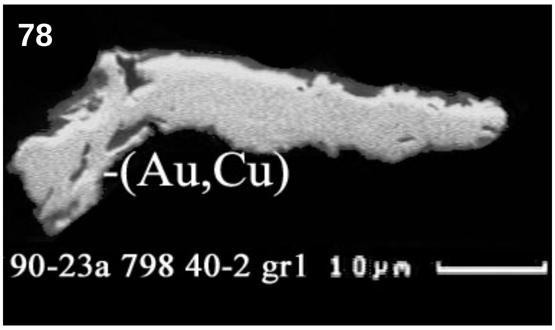

1
(Au,Cu)
10 µm
90-23a 798 40-1 gr89
2
(Au,Cu)
10 µm
90-23a 798 40-1 gr131
(Au,Cu)
3
10 µm
90-23a 798 40-1 gr74
4
(Au,Cu)-
10 µm
90-23a 798 40-1 gr125
(Au,Cu)-
5
10 µm
90-23a 798 40-1 gr126
6
(Au,Cu)-
10 µm
90-23a 798 40-1 gr114
7
-(Au,Cu)
10 µm
90-23a 798 40-1 gr103
8
-(Au,Cu)
10 µm
90-23a 798 40-1 gr64
(Au,Cu)
9
10 µm
90-23a 798 40-1 gr49
(Au,Cu)
10
10 µm
90-23a 798 40-1 gr47
11
(Au,Cu)-
10 µm
90-23a 798 40-1 gr119
12
(Au,Cu)
10 µm
90-23a 798 40-1 gr50
13
-(Au,Cu)
10 µm
90-23a 798 40-2 gr6
14
(Au,Cu)
90-23a 798 40-1 gr134
10 µm
(Au,Cu)-
15
10 µm
90-23a 798 40-1 gr54
16
(Au,Cu)
90-23a 798 40-1 gr10
10 µm
17
(Au,Cu)-
10 µm
90-23a 798 40-1 gr123
(Au,Cu)-
18
10 µm
90-23a 798 40-1 gr77
(Au,Cu)-
19
10 µm
90-23a 798 40-1 gr81

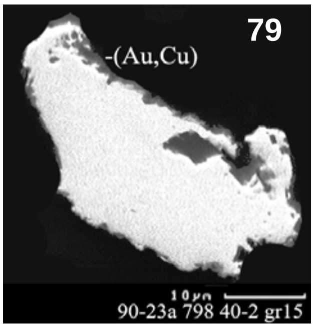

20
-(Au,Cu)
10μm
90-23a 798 40-1 gr35
21
-(Au,Cu)
10μm
90-23a 798 40-1 gr58
22
-(Au,Cu)
90-23a 798 80 gr 2
10μm
23
(Au,Cu)-
10μm
90-23a 798 40-1 gr104
(Au,Cu)
24
10μm
90-23a 798 40-1 gr60
25
(Au,Cu)-
10μm
90-23a 798 40-1 gr41
26
(Au,Cu)
10μm
90-23a 798 40-2 g5
27
(Au,Cu)-
90-23a 798 80 gr1
10μm
28
(Au,Cu)-
10μm
90-23a 798 40-2 gr8
29
(Au,Cu)
10μm
90-23a 798 40-1 g111
30
-(Au,Cu)
10μm
90-23a 798 40-1 gr106
31
(Au,Cu)
10μm
90-23a 798 40-1 gr155
32
(Au,Cu)
90-23a 798 40-1 gr12
10μm
33
(Au,Cu)-
10μm
90-23a 798 40-1 gr120
34
(Au,Cu)-
10μm
90-23a 798 40-1 gr124
35
(Au,Cu)
10μm
90-23a 798 40-1 gr118
36
(Au,Cu)-
90-23a 798 40-1 gr133
10μm
37
-(Au,Cu)
10μm
90-23a 798 40-1 gr132
38
(Au,Cu)-
10μm
90-23a 798 40-1g121


39
(Au,Cu)
10 μm
90-23a 798 40-2 gr9
40
-(Au,Cu)
10 μm
90-23a 798 40-1 gr127
41
(Au,Cu)
90-23a 798 40-1 gr140
10 μm
42
(Au,Cu)
10 μm
90-23a 798 40-1 g14
43
-(Au,Cu)
10 μm
90-23a 798 40-1 gr136
44
-(Au,Cu)
10 μm
90-23a 798 40-1 gr139
45
(Au,Cu)-
10 μm
90-23a 798 40-1 gr142
46
-(Au,Cu)
10 μm
90-23a 798 40-1 gr145
47
-(Au,Cu)
90-23a 798 40-1 gr20
10 μm
48
-(Au,Cu)
10 μm
90-23a 798 40-1 gr 149
49
(Au,Cu)
10 μm
90-23a798 40 g147
50
(Au,Cu)
10 μm
90-23a 798 40g154
51
-(Au,Cu)
10 μm
90-23a 798 40-1 gr17
52
-(Au,Cu)
10 μm
90-23a 798 40-1 gr28
53
-(Au,Cu)
90 23a 798 40-1 gr33
10 μm
54
-(Au,Cu)
(Au,Cu)-
10 μm
90-23a 798 40-1 gr44, 45
55
(Au,Cu)
10 μm
90-23a 798 40-1gr25
56
(Au,Cu)-
10 μm
90-23a 798 40-1 gr63
57
(Au,Cu)-
10 μm
90-23a 798 40-1 gr62



58
(Au,Cu)
10μm
90-23a 798 40-1 g59
59
-(Au,Cu)
10μm
90-23a 798 40-1 gr51
60
-(Au,Cu)
10μm
90-23a 798 40-1 gr66
61
(Au,Cu)-
10μm
90-23a 798 40-1 g67
62
(Au,Cu)-
10μm
90-23a 798 40-1 gr1
63
(Au,Cu)-
10μm
90-23a 798 40-1 gr65
64
-(Au,Cu)
10μm
90-23a 798 40-1 gr88
65
(Au,Cu)--
10μm
90-23a 798 40-1 gr75
66
(Au,Cu)-
10μm
90-23a 798 40-1 gr71
67
(Au,Cu)-
10μm
90-23a 798 40-1 gr76
68
(Au,Cu)-
10μm
90-23a 798 40-1 gr80
69
-(Au,Cu)
10μm
90-23a 798 40-1 gr90
70
(Au,Cu)-
90-23a 798 40-2 gr10
10μm
71
-(Au,Cu)
-(Au,Cu)
10μm
90-23a 798 40-1 gr92, 93
72
-(Au,Cu)
30μm
90-23a 798 40-1 gr84
-(Au,Cu)
73
10μm
90-23a 798 40-1 gr96
74
(Au,Cu)-
-(Au,Cu)
10μm
90-23a 798 125 gr3, 4
75
(Au,Cu)-
10μm
90-23a 798 40-1 gr94
76
(Au,Cu)-
30μm
90-23a 798 40-1 gr 9
77
-(Au,Cu)
10μm
90-23a 798 40-2 gr11


78
-(Au,Cu)
90-23a 798 40-2 gr1
10μm


79
-(Au,Cu)
10μm
90-23a 798 40-2 gr15

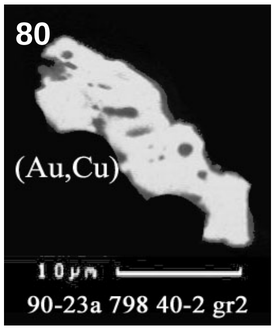
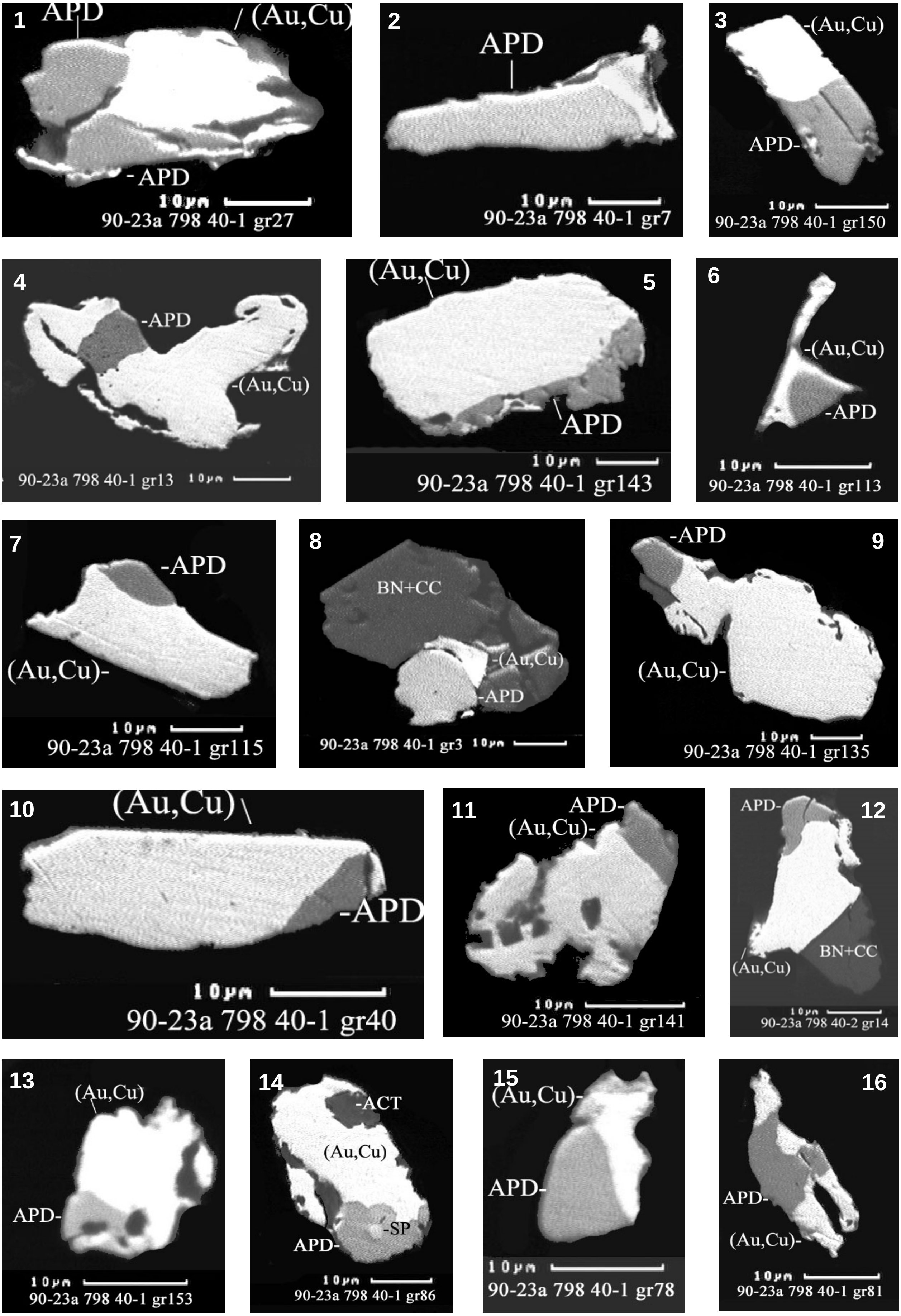
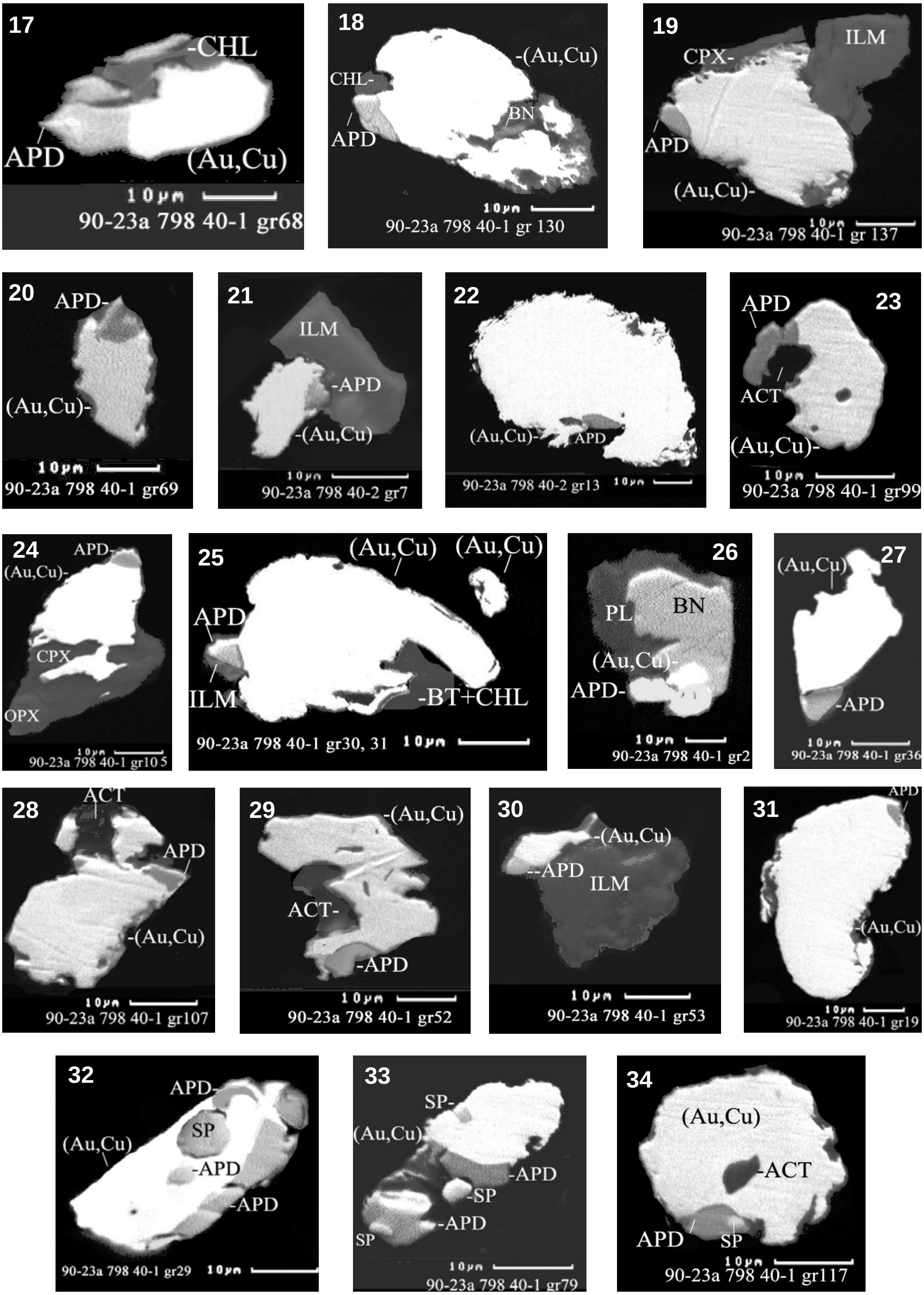
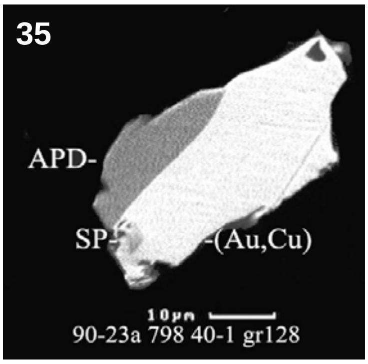

80
(Au,Cu)
10μm
90-23a 798 40-2 gr2

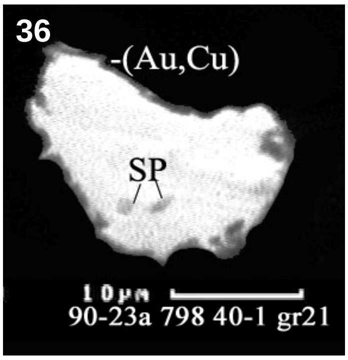
Plate 6

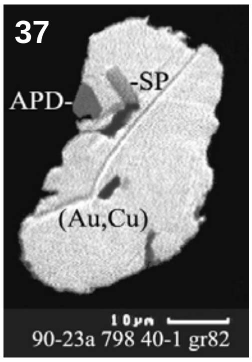
Relationships of PGM (arsenopalladinite, sperrylite and kotulskite) and (Au,Cu,Ag) alloy in grains of precious metal minerals from the heavy concentrates in the sample 90-23a 798 (1-45); polished section, SEM-image (BIE).

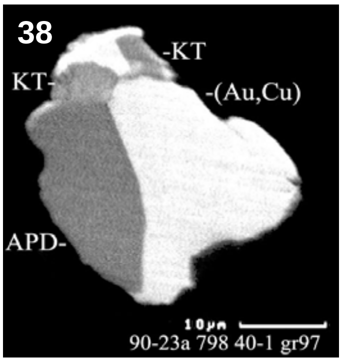

1
APD
(Au,Cu)
-APD
10μm
90-23a 798 40-1 gr27
2
APD
10μm
90-23a 798 40-1 gr7
3
-(Au,Cu)
APD-
10μm
90-23a 798 40-1 gr150
4
-APD
-(Au,Cu)
90-23a 798 40-1 gr13
10μm
(Au,Cu)
5
APD
10μm
90-23a 798 40-1 gr143
6
-(Au,Cu)
-APD
10μm
90-23a 798 40-1 gr113
7
-APD
(Au,Cu)-
10μm
90-23a 798 40-1 gr115
8
BN+CC
-(Au,Cu)
-APD
90-23a 798 40-1 gr3
10μm
-APD
9
(Au,Cu)-
10μm
90-23a 798 40-1 gr135
10
(Au,Cu)
-APD
10μm
90-23a 798 40-1 gr40
11
APD-
(Au,Cu)-
10μm
90-23a 798 40-1 gr141
APD-
12
BN+CC
(Au,Cu)
10μm
90-23a 798 40-2 gr14
13
(Au,Cu)
APD-
10μm
90-23a 798 40-1 gr153
14
-ACT
(Au,Cu)
-SP
APD-
10μm
90-23a 798 40-1 gr86
15
(Au,Cu)-
APD-
10μm
90-23a 798 40-1 gr78
16
APD-
(Au,Cu)-
10μm
90-23a 798 40-1 gr81

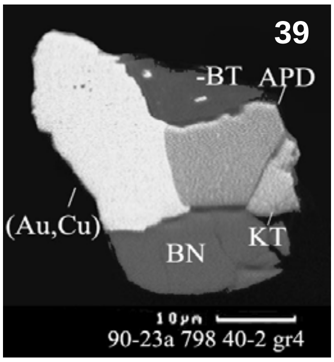

17
-CHL
APD
(Au,Cu)
10μm
90-23a 798 40-1 gr68
18
-(Au,Cu)
CHL-
BN
APD
10μm
90-23a 798 40-1 gr 130
19
ILM
CPX-
APD
(Au,Cu)-
10μm
90-23a 798 40-1 gr 137
20
APD-
(Au,Cu)-
10μm
90-23a 798 40-1 gr69
21
ILM
-APD
-(Au,Cu)
10μm
90-23a 798 40-2 gr7
22
(Au,Cu)-
APD
90-23a 798 40-2 gr13
10μm
APD
23
ACT
(Au,Cu)-
10μm
90-23a 798 40-1 gr99
24
APD-
(Au,Cu)-
CPX
OPX
10μm
90-23a 798 40-1 gr10 5
25
(Au,Cu)
(Au,Cu)
APD
ILM
-BT+CHL
90-23a 798 40-1 gr30, 31
10μm
26
PL
BN
(Au,Cu)-
APD-
10μm
90-23a 798 40-1 gr2
(Au,Cu)
27
-APD
10μm
90-23a 798 40-1 gr36
28
ACT
APD
-(Au,Cu)
10μm
90-23a 798 40-1 gr107
29
-(Au,Cu)
ACT-
-APD
10μm
90-23a 798 40-1 gr52
30
-(Au,Cu)
--APD
ILM
10μm
90-23a 798 40-1 gr53
31
APD
-(Au,Cu)
10μm
90-23a 798 40-1 gr19
32
APD-
SP
(Au,Cu)
-APD
-APD
90-23a 798 40-1 gr29
10μm
33
SP-
(Au,Cu)
-APD
-SP
-APD
SP
10μm
90-23a 798 40-1 gr79
34
(Au,Cu)
-ACT
APD
SP
10μm
90-23a 798 40-1 gr117

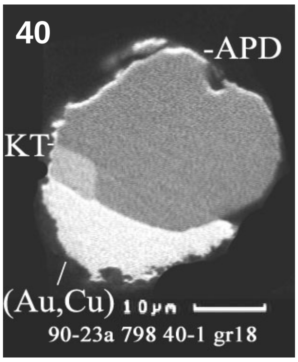

35
APD-
SP-
-(Au,Cu)
10μm
90-23a 798 40-1 gr128

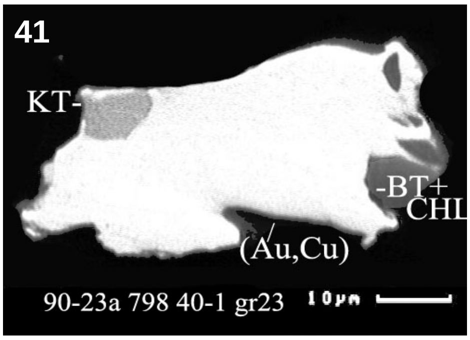

36
-(Au,Cu)
SP
10μm
90-23a 798 40-1 gr21

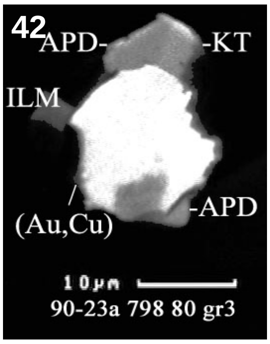

37
APD-
-SP
(Au,Cu)
10μm
90-23a 798 40-1 gr82

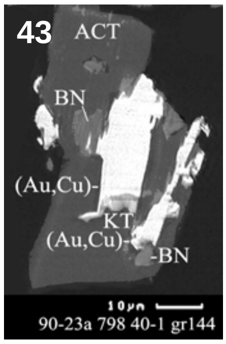

38
-KT
KT-
-(Au,Cu)
APD-
10μm
90-23a 798 40-1 gr97

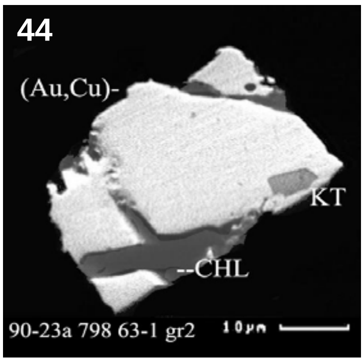

39
-BT
APD
(Au,Cu)
BN
KT
10μm
90-23a 798 40-2 gr4

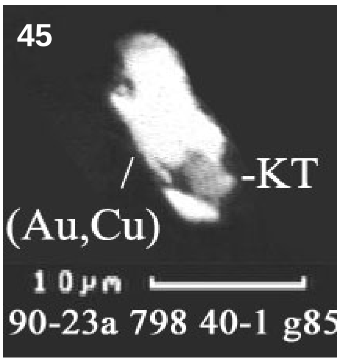

40
-APD
KT-
(Au,Cu)
10μm
90-23a 798 40-1 gr18


41
KT-
-BT+
CHL
(Au,Cu)
90-23a 798 40-1 gr23
10μm


42
APD-
-KT
ILM
(Au,Cu)
-APD
10μm
90-23a 798 80 gr3


43
ACT
BN
(Au,Cu)-
KT
(Au,Cu)-
-BN
10μm
90-23a 798 40-1 gr144


44
(Au,Cu)-
KT
--CHL
90-23a 798 63-1 gr2
10μm


45
-KT
(Au,Cu)
10μm
90-23a 798 40-1 g85