DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2003/53

PGE and sulphide phases of the precious metal mineralisation of the Skaergaard intrusion

Part 4: sample 90-23A, 806

T. F. D. Nielsen, H. Rasmussen, N. S. Rudashevsky,
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Contents

Abstract

The Paleaogene Skaergaard intrusion, 68^oN, in East Greenland hosts a large tonnage, low-grade, precious metal mineralisation. The Pd5 level of the mineralisation contains more than 20 million ounces of palladium and minor platinum and gold. The Pd:Pt:Au ratio is ca. 83:9:7.The report presents the results of mineralogical investigations of sample 90-23A 806 (core 90-23A from 806 to 807 meters, 0.52 kg) from just below the most palladium-rich one-meter interval in the main Pd-level in the mineralisation.

The non-magnetic heavy concentrates of sample 90-23A 806 were subjected to separation using HS-01 Hydroseparator technology. From the concentrates enriched in platinum group and Au-minerals were prepared polished thin sections. The thin sections were investigated under the scanning electron microscope and the electron microprobe. The magnetic concentrates contain no precious metal grains, except for rare grains intergrown with Fe-Ti-oxides.

The sample was found to contain 86 precious metal grains, including 50 grains of platinum group minerals (PGMs) and 36 grains of Au- and Ag-minerals. The dominant PGMs are zviagintsevite (Pd_3Pb, 24%) and arsenopalladinite (Pd_8As_3; 17%) followed by sperrylite (PtAs2; 9%) and guanglinite (Pd3As; 8%). The Au- and Ag-bearing phases are dominated by (Au,Cu,Pd,Ag)-alloys (23%) and stephanite (Ag_5SbS_4; 8%). The grain size of PGMs, Ag- and Au-minerals varies between 2 and 60 μm with an average of 17 μm.

The HS-concentrates contain spherical sulphide grains identified as sulphide droplets composed of one or more of the Cu-sulphides bornite (dominant), chalcopyrite, chalcosine and digenite. But most of the sulphides are related to the interstitial domains and they are most commonly related to a secondary paragenesis characterized by H_2O-bearing silicate phases and matrix Fe-Ti oxides. Rare grains of sphalerite, arsenopyrite and galena have been observed.

Most of the identified PGMs grains are in close association with H_2O-bearing phases. Zviagintsevite is commonly euhedral and clearly coexists with the H_2O-bearing re-equilibration paragenesis, that was probably the result of reaction between trapped late stage hydrous fluids and the primary silicates, Fe-Ti oxide phases and PGM-bearing, immiscible, sulphide droplets formed from the interstitial silicate magma.

The possibly primary PGMs, such as Pd-arsenides are founds as inclusions in zviagintsevite and single grains of PGMs that were probably liberated from rims of preserved liquidus phases.

Introduction

The report describes the mineralogy of sample 90-23A 806 from the lower palladium horizon in the ”Platinova Reef” of the Skaergaard intrusion. The report consists of an introduction to the mineralisation and the investigated sample and a mineralogical report. The mineralogical report has been prepared by N.S. Rudashevsky, Yu.L.Kretser and V.N. Rudashevsky on the request of the Geological Survey of Denmark and Greenland. Electron microprobe data collected in 1993 by H. Rasmussen (Geological Survey of Denmark and Greenland and Department of Geology at University of Copenhagen) are included as an appendix.

The mineralogical report is based on concentrates of platinum group metal phases produced using the patented Hydroseparator HS-01. Mounts with concentrate have been studied using electron microscopy and electron microprobe. The report gives descriptions of the grain characteristics, the parageneses and the compositional variation within the identified groups of minerals, alloys and sulphide-droplets.

T.F.D. Nielsen has edited the report.

The Platinova Reef of the Skaergaard intrusion

The Skaergaard intrusion precious metal mineralisation, often referred to as the “Platinova Reef”, is a gabbro-hosted, stratiform Au and PGE mineralisation in the macrorythmic Triple Group of the Skaergaard intrusion (Bird et al., 1991). The Triple Group forms the upper c. 100 meters of the Middle Zone in the Layered Series in the intrusion. The host rocks are well-preserved oxide-rich tholeiitic gabbros.

The mineralisation was located in 1987 by Platinova Resources Ltd. Exploration was conducted by Platinova Resources Ltd. and partners from 1986 to 1990. Exploration drilling was carried out in 1989 (DDH 89-01 to DDH 89-9b) and in 1990 (DDH 90-10 to DDH 90-27). Exploration results are summarised in Watts, Griffis and McOuat (1991).

The general structure of the Platinova reef mineralisation is described in Andersen et al. (1998) and in Nielsen (2001). Peak concentrations of Au and Pd are separated by less that 1 meter at the margin of the intrusion, but by >60 meters in the south, central part of the intrusion.

The mineralisation consists of a series of levels enriched in Pd. The lower Pd5 level reaches across the intrusion. Up the stratigraphy subsequent Pd-levels have ever-decreasing lateral extend from a central axis in the south central part of the intrusion. Gabbros between the Pd-levels are not mineralised. The structure is best visualised as a series of bowl-shaped Pd-levels of decreasing size. Gold is concentrated at the edges of the bowls. Nielsen (2001) gives further descriptions.

The Pd5-level in the mineralisation is estimated to contain in excess of 300 million tons of gabbro with *c.* 2 g/t PGE over a width of 5 meters. The Pd5 mineralisation alone is suggested to contain > 20 million ounces of precious metals equivalent to >600 tons of palladium, >40 tons of platinum and >30 tons of gold (Nielsen, 2001).

The Pd5 level

The Pd5-level contains the main Pd mineralisation and is located within a macrorythmic layer located below L1 of the Triple Group. The leucogabbro layer in the megacycle below L1 is unofficially named L0.

The Pd variation across Pd5 is quite characteristic and paralleled in all investigated cores and chip lines from the intrusion. Relative changes in Pd/Pt can be correlated across the intrusion (see Nielsen, 2001).

The hanging wall 1 g/t cut-off of the mineralisation is located in the middle of L0 and the foot wall 1 g/t cut-off is located at the density peak below L0. In most cores the distance between foot wall and hanging wall is 5 meters (based on 1-meter average concentrations of Pd). The Pd variation over the 5-meter mineralisation interval is paralleled in all cores from a 19 km^2 area (Nielsen, 2001). The Pd concentration increase slowly from 1 g/t over the first 3 meters, to levels of 3-6 g/t at *c.* 4 meters above the foot wall before Pd rapidly decreases to less that 1 g/t above the hanging wall 1 g/t cut-off (Nielsen, 2001).

Sample 90-23A, 806

Sample 90-23A 806 was collected from BQ drill core #90-23A. The core was drilled with an azimuth of 35^o and an inclination of –70 from top of Nunatak II. Nunataq II is located on the south side of Forbindelsegletscher and close to the eastern contact of the Intrusion. The Hanging wall of the mineralisation (1 g/t cut-off) is located at 806 meters and the foot wall at 811 meters.

Sample 90-23A, 806 collects the 1 m interval below the hanging wall (1 g/t cut off) in Pd5-level between 806 and 807 m. The average Pd concentration between 806 meters and 807 meters is 1.6 g/t Pd and an average of combined PGE plus Au of 2.0 g/t.

The recovery between 806 and 807 meters is c. 60 %. The core has previously been sampled for other purposes. The sample collects 1/3 of the diameter of the preserved core.

Sample	From	To	Length	Au	Pd	Pt
GEUS	m	m	m	average	average	average
				ppb	ppb	ppb
90-23A 804	804.00	805.00	1.00	85	330	40
90-23A 805	805.00	806.00	1.00	143	790	70
90-23A 806	806.00	807.00	1.00	250	1600	110
90-23A 807	807.00	808.00	1.00	270	2800	140
90-23A 808	808.00	809.00	1.00	52	2300	120
90-23A 809	809.00	810.00	1.00	32	1600	160
90-23A 810	810.00	811.00	1.00	10	1000	90
90-23A 811	811.00	812.00	1.00	10	840	60
90-23A 812	812.00	813.00	1.00	12	900	70

Data from Watt, Griffis and McOuat (1991).

The mineralogical report

The mineralogical investigation has been carried out by N.S. Rudashevsky, Yu.L. Kretser and V.N. Rudashevsky on request from the Geological Survey of Denmark and Greenland. The mineralogical report has been prepared by N.S. Rudashevsky, Yu.L. Kretser and V.N. Rudashevsky and edited by T.F.D. Nielsen.

Electron microprobe data

During a Ph.D. study Henrik Rasmussen (GEUS) collected a suite of microprobe analyses from a thin section at 806.14 meters (thin section # 90-23A 806.14). The data is shown in the appendix. In the appendix names of phases are suggested purely on the basis of their chemical compositions.

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Mineralogical investigation

Rudashevsky, N.S., Kretser, Yu.L. and Rudashevsky, V.N.
Edited by T.F.D. Nielsen

Introduction

The sample

The drill core sample 90-23A, 806 (0.52 kg by weight) of oxide-rich tholeiitic gabbro with Pd mineralisation from the Skaergaard intrusion was provided for investigation by T.F.D. Nielsen (Geological Survey of Denmark and Greenland). Assays reported by Watts, Griffis and McOuat (1991) indicate concentrations of 110 ppb Pt, 1600 ppb Pd and 250 ppb Au in that particular core interval. In addition, one thin section (90-23 806.14) was provided for optical investigation.

Sample preparation and analytical techniques

Analytical techniques are described in Nielsen et al. (2003a).
Two polished sections (806-1 and 806-2) were made from two fragments of the sample. Subsequently the remaining core material was crushed to –500 μm. After complete grinding, the sample was passed through standard sieves on “Retsch” classifier: -45 μm (109 g), 45-75 μm (90 g), 75-125 μm (105 g) and +125 μm (200 g).

After wet magnetic separation, the powdered fractions with grain sizes -45 μm, 45-75 μm and 75-125 μm were passed through Hydroseparator HS-01. Two polished sections were prepared from the HS-concentrates.

Results

Rock forming minerals and sulphide mineralogy

Silicates and oxides

In the thin sections of sample 90-23A, 806, cumulus crystals are only represented by monoclinic ferrous pyroxene (Mg# = 55; Table 1, analyses 3-5) with exsolution of orthorhombic ferrous pyroxene (Mg# = 0.47; Table 1, analyses 6-8). Plagioclase (An_{49}; Table 1, analyses 1-2) and Fe-Ti-oxides (Table 1, analyses 9-10) represents intercumulus mineral paragenesis (Plate 1, #1).

Exsolution textures in pyroxene are often obliterated in halos around inclusions of Fe-Ti oxides, but accompanied by development of large orthopyroxene grains adjancent to the inclusions of Fe-Ti oxide (Plate 1, #*2*).

Sulphides

Despite of the high concentrations of PGE (~2 ppm), these rocks are relatively poor in sulphides. The content of Cu-Fe sulphide is less than 0.1%. The aggregates of sulphides are <0.1 mm in size and occur as inclusions in and between rock-forming minerals.

The sectors of rock-forming pyroxenes and plagioclase that are enriched in sulphides are generally intensively replaced by fine-grained aggregates of the secondary minerals. These include chlorite, actinolite, ferrous talc, hornblende, biotite and quartz (Plate 1, #3-6; Table 1, analyses11-17). The secondary phases are closely associated to the sulphides.

The Cu-Fe sulphide grains in the HS concentrate include:

1) irregular shaped grains (Plate 2, #1-4, 7, 10 and 12),
2) spherical grains, up to 150 μm lin size (Plate 1, #6, 8-9, 11 and 13).

The dominant sulphide is *bornite* (Plate 2, #1, 2 and 7-18; Table 2, analyses 1-8 and 10-12). Some grains of bornite are associated with *chalcopyrite* (Plate 2, #3-5 and 13; Table 2, analyses 9) or chalcosine (Plate 2, #6). Rare sulphides include: *galena* (Plate 2, #13, 15), *arsenopyrite* (Plate 2, #14) and *sphalerite*.

Quite common are intergrowths between Cu-Fe sulphides and H_2O-bearing minerals such as:

1) *actinolite* (Plate 2, #10-12; Table 1, analyses 12-15)
2) *chlorite* (Plate 2, 7-#10, 12; Table 1, ananalyses16, 17)
3) ferrous talc (Plate 2, #13)
4) *biotite*
5) *hornblende*

Some intergrowths of Cu-Fe sulphides with ilmenite and titaniferous magnetite (Plate 2, #1) are found in the heavy concentrates too.

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

Recovery

No PGM grains were found the two polished thin sections. A search with scanning electron microscope equipped with a Link AN-10000 system located no PGMs.

HS-concentrates, however, contained a wide range of minerals including 50 PGM grains and 36 grains of Au-minerals (Table 3). The dominant minerals are:

1) *zvyagintsevite*

2) Pd-arsenides including:
    a) *arsenopalladinite*
    b) *guanglinite*
    c) *palladoarsenide*

3) Au-Cu-Pd-Ag alloys,
    a) (*Au-Pd-Cu-Ag)-alloys*
    b) *bogdanovite*
    c) *tetra-auricupride*

Many grains of precious metal minerals have inclusions of:
1) *sperrylite*
2) *keithconnite*

Other rare phases include:
1) *vasilite*
2) *atokite*
3) *isomertieite*
4) *kotulskite*
5) *stephanite*

In total, 14 different precious metal mineral phases were found in the sample 90-23A, 806 (Table 3). Taking the size of the grains into account the volume ratios of the dominant groups of precious metal minerals are as follows (see also Table 3 and Fig. 1):

Mineral or group	Volume %
Pd-arsenides	27
zvyagintsevite	24
Au-Pd-Cu-Ag alloys	28
Sperrylite	9
Stephanite	8
Keithconnite	2
others	2

Grain size of PGMs and Au-minerals

The grain size of PGMs and Au-minerals in sample 90-23A, 806, varies from about 2 to 60 μm. The average is 17 μm (Table 3; Fig. 2). Note should be taken, that the majority of the grains have preserved their primary shape and size (see Plates 3-5). The grains have not been broken during their extraction.

Petrographic observations

PGMs and Au-minerals are found as:

1) monomineral PGM grains (Plate 3, #14-17; Plate 4, #11, 13, 20-21 and 24) and Au-Cu-Pd-Ag alloys (Plate 5, #6-13 and 31),
2) intergrowths with sulphides including:
    a) *bornite*; common (Plate 3, #1, 2, 4-12 and 21-22; Plate 4, #1, 4-10, 15, 16, 19 and 22-23; Plate 5, #19, 33-34 and 37),
    b) *chalcopyrite*, rare (Plate 3, #2; Fplate 5, #24, 30 and 33),
    c) *chalcosine*, rare (Plate 3, #7 and 13).

In addition was found the rare association:

1) *zvyagintsevite* + *bornite* + *chalcopyrite* + *galena* + *talc* (Plate 3, #2),
2) *(Au,Ag)-alloy* + *bornite* + *chalcopyrite* + *galena* (Plate 5, #33).

PGMs and Au-Cu-Pd-Ag alloys are often found to be intergrown with Fe-Ti oxides and silicates, usually with H_2O-bearing silicates such as:

1) *actinolite* (Plate 3, #4 and 21; Plate 4, #1; Plate 5, #1, 5, 17, 27, 29-30, and 36)
2) *chlorite* (Plate 3, #1, 4 and 10)
3) *ferrous talc* (Plate 3, #2 and 3; Plate 4, #3; Plate 5, #5, 18 and 25-26)
4) *biotite* (Plate 4, #12; Plate 5, #4)
5) *hornblende* (Plate 5, #2, 3)

Intergrowth with primary rock-forming minerals are less common, but PGMs and Au-minerals are also seen to coexist with:

1) *ilmenite* (Plate 4, #15; Plate 5, #18)
2) *plagioclase* (Plate 3, #1; Plate 5, #5)
3) *orthopyroxene* (Plate 5, #14 and 28)
4) *magnetite* (Plate 4, #2 and 14)

Many polymineral intergrowths of PGMs (Plate 3, #18-21; Plate 4, #8; Plate 5, #17 and 26) and intergrowths of PGMs with (Au-Cu-Pd-Ag)-alloys (Plate 3, #22-23; Plate 4, #10 and 18-19; Plate 5, #3, 14-26, 29-32 and 35) are observed. Palladoarsenide is found in the concentrates only as monominerallic grains (Plate 4, #20-21).

Description and chemistry of PGMs and Au-minerals

Zvyagintsevite

Description

Zvyagintsevite is found in the heavy concentrate as:

1) anhedral grains (Plate 3, #1-8, 10, 12 and 23; Plate 5, #17 and 26)
2) euhedral crystals (Plate 3, #9 and 11)

The grain size varies from around 3 to 40 μm, with an average of 19 μm (Table 4).

The majority of the grains are not associated with other PGMs (Plate 3, #1-17). However, intergrowth of zvyaginsevite with the following PGE-minerals are observed:

1) *guanglinite* (Plate 3, #18 and 19)
2) *keithconnite* (Plate 3, #21; Plate 5, #17 and 26)
3) *(Au-Cu-Pd)-alloys* (Plate 3, #22-23; Plate 5, #17 and 26)
4) *atokite* (Plate 3, #20)

Mineral chemistry

The chemical composition of zvyagintsevite varies from Pd_3Pb (Table 4, analyses 1, 19 and 22) to a suite of admixture-rich varieties.

site	Substituting element	Max. admixture (wt %)	Reference
Pd	Pt	6.1	Table 4, analysis 4
Pd	Au	5.4	Table 4, analysis 4
Pd	Cu	2.2	Table 4, analysis 16
Pd	Fe	9.2	Table 4, analysis 11
Pb	Sn	7.0	Table 4, analysis 2
Pb	As	4.6	Table 4, analysis 11
Pb	Te	9.9	Table 4, analysis 11

Some zoned and markedly heterogeneous grains of zvyagintsevite are observed (Plate 5, #15; Table 4, analyses 10-11). The average chemical composition of zvyagintsevite (Table 4; 23 analyses) is:

Element	Wt %
Pd	57.2
Pt	1.39
Au	1.58
Cu	0.28
Fe	0.44
Pb	36.5
Sn	0.50
Te	0.63
As	0.28
Total	98.80

The composition corresponds to the formula:

$(Pd_{2.852}Au_{0.042}Fe_{0.042}Pt_{0.038}Cu_{0.024})_{\Sigma 2.998}(Pb_{0.935}Te_{0.026}Sn_{0.022}As_{0.020})_{\Sigma 1.003}$.

Pd-arsenides

Description

In the sample 90-23A, 806 Pd-arsenides are represented by 3 minerals (Table 3; Fig 1):

1) *arsenopalladinite*
2) *guanglinite*
3) *palladoarsenide* (rare)

The grain sizes vary as follows (Table 3):

1) arsenopalladinite (Plate 4, #1-11; Plate 5, #14) varies from 4 to 50 μm, with an average of 20 μm
2) guanglinite (Plate 3, #18-19; Plate 4, #10, 12-19 and 23; Plate 5, #15-16) varies from 8 to 36 μm, with an average of 19 μm
3) palladoarsenide (Plate 4, #20-21) varies from 15 to 26 μm, with an average of 20 μm

Pd-arsenides occur as:

1) anhedral grains, most common (Plate 4, #1, 3-5, 7-10, 12 and 17-21)
2) droplet like grains, occasional (Plate 4, #2, 6 and 11)
3) euhedral crystals, occasional (Plate 4, #13, 15, 16 and 22)

Arsenopalladinite and guanglinite are in the heavy concentrates found as:

1) individual crystals (Plate 4, #1-7 and 12-14)
2) grains with fine inclusions of sperrylite (Plate 4, #8, 11 and 15-17)
3) in intergrowths with:
    a) *zvyagintsevite* (Plate 3, #18-19)
    b) *sperrylite* (Plate 4, #22-23)
    c) *isomertiete* (Plate 4, #10)
    d) *kotulskite* (Plate 4, #9)
    e) *(Au-Cu-Pd-Ag)-alloys* (Plate 4, #10 and 18-19; Plate 5, #14-16)

Palladoarsenide, has not been found in direct associated with any other precious metal mineral.

Mineral chemistry

The compositions of Pd-arsenides are calculated as:

1) *arsenopalladinite* - Pd_8As_3 (Table 5, analyses 1-13) or
2) *guanglinite* - Pd_3As (Table 5, analyses 14-27) or
3) *palladoarsenide* – Pd_2As (Tabe 6, analyses 28-29)

In Pd-arsenites Pd is found to be partly and variably replaced:

site	Substituting element	Max. Admixture (wt%)	reference
Pd	Au	6.7	Table 5, analysis 14
Pd	Cu	3.6	Table 5, analysis 29
Pd	Fe	2.0	Table 5, analysis 11
Pd	Pt (rare)	1.5	Table 5, analysis 23
As	Sn	5.4	Table 5, analysis 21
As	Te (rare)	12.4	Table 5, analysis 23
As	Sb (rare)	11.0	Table 5, analysis 16
As	Pb (rare)	7.6	Table 5, analysis 24

Arsenopalladinite and guanglinite have admixtures of Au. The average Au contents in 14 analyses of these minerals is 1.4 % (Table 5).

Sperrylite

A characteristic of the studied sample is in the presence of the notable quantities of sperrylite (Table 3; Fig. 1). Several single grains of sperrylite with sizes of ca. 60 μm are found (Plate 4, #22-24; Table 5, analyses 30-32). Sperrylite also occurs as fine inclusions in grains of Pd-arsenide (Plate 4, #8, 11 and 15-17).

Keithconnite

Keithconnite (Table 3; Fig. 1; Table 5, analyses 34-46) is a common PGM in the HS-concentrates. Keithconnite does not form individual grains, but occurs as inclusion in the polymineral aggregates of the precious metal minerals together with:

1) *(Au-Cu-Pd-Ag)-alloys* (Plate 5, #17-24, 26 and 30-31)
2) *zvyagintsevite* (Plate 3, #21; Plate 5, #17 and 26)

Keithconnite grains are small, usually from 3 to 16 μm, and have an average size of 7 μm. The grains are irregular.

Other PGMs

A number of other PGMs have been found in small amounts in sample 90-23A, 806 (Table 3). They include:

1) *vasilite* (Plate 5, #37; Table 6, analysis 42)
2) *atokite* (Plate 3, 20; Plate 5, #25, 35; Table 5, analyses 47-48)
3) *isomertieite* (Plate 4, #10; Table 5, analysis 33)
4) *kotulskite* (Plate 4, #9; Table 5, analysis 49)
5) *stephanite* (Plate 5, #36; Table 6, analysis 43)

Au-minerals

Another peculiarity of the sample 90-23A, 806 is the significant proportion of Au-minerals. About 40% of the recovered grains of precious metal minerals are Au-minerals. They divide into three groups of alloys (Table 3; Table 6, analyses 1-41; Fig. 1):

1) *(Au-Cu-Pd-Ag)-alloys*, dominant (Plate 5, #1-25 and 33-34; Table 6, analyses 1-31)
2) *bogdanovite* $(Au,Pd,Pt)_3(Cu,Fe)$, less common (Plate 5, #26-32; Table 6, analyses 32-39)
3) *tetra-auricupride* (Au,Pd,Pt)(Cu,Fe), rare (Plate 3, #22; Plate 5, #35; Table 6, analyses 40-41)

All of these form anhedral grains, only, and they vary from 4 to 39 μm with an average size of 17 μm.

Grains of (Au-Cu-Pd-Ag)-alloys have not been seen in direct contact with PGMs (Plate 5, #1-13, 27, 28, 31, 33 and 34), but they do form intergrowth with:

1) *keithconnite* (Plate 5, #17-24, 26 and 30-31)
2) *zvyagintsevite* (Plate 3, #22-23; Plate 5, #17 and 26)
3) *Pd-arsenides* (Plate 4, 10 and 18-19; Plate 5, #14-16 and 32)
4) *atokite* (Plate 5, #25 and 35)

Bulk rock concentrations

The whole-rock PGE assay of the sample 90-23A, 806 can not be reproduced from the volume proportions and compositions of the precious metal phases reported in this work (Table 3 and 4-6):

Element	assay	Mass balance
Pd	1600	1090
Au	250	700
Pt	110	170

The differences are significant and two explanations are offered:

1) The recovery for the sample used in the mineralogical investigation is only ca. 60 %. Part of the core has been used for other investigations. The assay was made prior to the extraction of these samples. A bias may have been introduced.
2) The studied sample has a very heterogeneous distribution of PGM and Au-minerals. A representative sample should have been much larger that the available sample.

The first explanation may be important as the assay concentrations are reasonably well reproduced in all other mineralogical investigations of samples from the Skaergaard mineralisation (Nielsen et al., 2003 a-c and e). In all of these samples the recovery was higher. It is suspected that sample 90-23A 806 is biased and that it does not include the lowermost part of the interval between 806 and 807 meters. The lower part of the interval is suggested to contain the highest concentrations of Pd (see p. 5).

Summary

1. All studied grains of precious metal minerals in the concentrates of the sample 90-23A, 806 can be divided on to three mineral associations:
    1) *Pd-Pt-arsenide group:*
    Arsenopalladinite + guanglinite + sperrilite + palladoarsenide (?) (Plate 4)
    2) *zvyagintsevite group:*
    zvyagintsevite (Plate 3)
    3) *(Au-Cu-Pd-Ag)-alloys:*
    Au-Cu-Pd-Ag alloys + keithconnite + atokite (Plate 5)

2. The minerals of all these groups are closely associated with Cu-Fe sulphides, mainly bornite, and with H_2O-bearing silicates such as actinolite, chlorite, ferrous talc, biotite and hornblende.

3. In the studied grains were observed intergrowths between zvyagintsevite and Pd-arsenides (Plate 3, #18-19), between zvyagintsevite and Au-Cu-Pd-Ag alloys (Plate 3, #22-23; Plate 5, #17 and 26), and also intergrowths between Pd-arsenides and (Au-Cu-Pd-Ag)-alloys (Plate 4, #10 and 18-19; Plate 5, #14-16 and 32).

4. The observations in thin sections (Plate 1) and in the grains of the concentrates (Plate 2) suggests the occurrence of one common paragenesis of the PGE-, Au-mineral and Au-bearing sulphide phases in sample 90-23A 806.

5. All these observation seem to indicate that the PGM, Au-mineral and sulphide paragenesis is a late mineral assemblage related to the crystallisation of the late hydrous silicate assemblage. The paragenesis is possibly a subsolidus re-eqilibration paragenesis See also conclusions in Nielsen et al., (2003a).

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List of abbreviations

Abbreviations used in figures and tables.

Rock-forming minerals

PL	= plagioclase
CPX	= monoclinic pyroxene
OPX	= orthorombic pyroxene
ILM	= ilmenite
TIMT	= titaniferous magnetite
MT	= magnetite
ACT	= actinolite
HB	= hornblende
BT	= biotite
CHL	= chlorite
TLC	= talc
Q	= quartz

Sulphides

BORN	= bornite
CP	= chalcopyrite
CHC	= chalcosine
GN	= galena
ASPY	= arsenopyrite

Precious metal minerals

ZV	= zviagintsevite
ASPD	= arsenopalladinite
GNG	= guanglinite
PLAS	= palladoarsenide
KTH	= keithconnite
AT	= atokite
VSL	= vasilite
SP	= sperrylite
BGD	= bogdanovite
STPH	= stephanite
(Au,Pd)Cu	= tetra-auricupride
(Au,Pd,Cu)	= alloys of Au, Pd and Cu.
(Au,Cu,Pd)	= alloys of Au, Pd and Cu.
(Au,Cu,Ag)	= alloys of Au, Ag and Cu.
(Au,Ag,Cu)	= alloys of Au, Ag and Cu.
(Au,Ag,Pd,Cu)	= alloys of Au, Pd, Cu and Ag.
(Au,Ag)	= alloys of Au and Ag.

Table 1: Chemical composition and formulas of silicates and oxides of oxide-rich tholeiitic gabbros (sample 90-23A, 806)

An.	Object	Association of minerals	Mineral		SiO_2	TiO_2	Al_2O_3	V_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	Total
1	P. s.	PL+CPX+OPX+ ILM+MT	PL	**Wt.%**	**57.2**	**-**	**26.3**	**-**	**0.43**	**-**	**-**	**-**	**9.8**	**5.7**	**0.36**	**99.79**
				F. c.	2.59	-	1.40	-	0.01	-	-	-	0.48	0.50	0.02	O=8
2	P. s.	PL+CPX+OPX+ ILM+MT	PL	**Wt.%**	**55.7**	**-**	**27.2**	**-**	**0.39**	**-**	**-**	**-**	**10.5**	**5.5**	**0.36**	**99.65**
				F. c.	2.52	-	1.45	-	0.01	-	-	-	0.51	0.48	0.02	O=8
3	P. s.	PL+CPX+OPX+ ILM+MT	CPX	**Wt.%**	**49.9**	**0.67**	**1.1**	**-**	**2.9**	**14.4**	**0.39**	**12.1**	**18.6**	**-**	**-**	**100.06**
				F. c.	1.91	0.02	0.05	-	0.08	0.46	0.01	0.69	0.77	-	-	ΣK=4
4	P. s.	PL+CPX+OPX+ ILM+MT	CPX	**Wt.%**	**50.3**	**0.83**	**-**	**-**	**2.3**	**15.2**	**0.39**	**11.9**	**18.7**	**-**	**-**	**99.62**
				F. c.	1.94	0.02	-	-	0.07	0.49	0.01	0.69	0.78	-	-	ΣK=4
5	P. s.	CPX+OPX(exs)	CPX	**Wt.%**	**50.5**	**0.83**	**0.76**	**-**	**1.1**	**16.0**	**0.39**	**11.6**	**18.7**	**-**	**-**	**99.88**
				F. c.	1.94	0.02	0.03	-	0.03	0.52	0.01	0.67	0.77	-	-	ΣK=4
6	P. s.	PL+CPX+OPX+ ILM+MT	OPX	**Wt.%**	**49.9**	**0.33**	**-**	**-**	**3.0**	**27.0**	**0.65**	**15.3**	**3.9**	**-**	**-**	**100.08**
				F. c.	1.95	0.01	-	-	0.09	0.88	0.02	0.89	0.16	-	-	ΣK=4
7	P. s.	PL+CPX+OPX+ ILM+MT	OPX	**Wt.%**	**50.5**	**0.33**	**-**	**-**	**1.2**	**28.1**	**0.78**	**15.1**	**3.8**	**-**	**-**	**99.81**
				F. c.	1.97	0.01	-	-	0.03	0.92	0.03	0.88	0.16	-	-	ΣK=4
8	P. s.	CPX+OPX(exs)	OPX	**Wt.%**	**49.9**	**0.33**	**-**	**-**	**1.8**	**28.3**	**0.65**	**14.9**	**3.4**	**-**	**-**	**99.28**
				F. c.	1.96	0.01	-	-	0.05	0.93	0.02	0.88	0.14	-	-	ΣK=4
9	P. s.	TIMT+ILM	TIMT	**Wt.%**	**-**	**6.2**	**1.5**	**1.0**	**55.2**	**35.7**	**-**	**-**	**-**	**-**	**-**	**99.6**
				F. c.	-	1.39	0.53	0.25	12.4	9.39	-	-	-	-	-	ΣK=24
10	P. s.	TIMT+ILM	ILM	**Wt.%**	**0.64**	**49.4**	**-**	**0.44**	**2.7**	**44.0**	**1.2**	**-**	**-**	**-**	**-**	**98.38**
				F. c.	0.02	0.95	-	0.01	0.05	0.94	0.03	-	-	-	-	ΣK=2
11	P. s.	CPX+OPX+BORN +TLC	TLC	**Wt.%**	**60.0**	**-**	**-**	**-**	**-**	**19.7**	**-**	**18.8**	**-**	**-**	**-**	**98.5**
				F. c.	4.01	-	-	-	-	1.11	-	1.88	-	-	-	ΣK=7
12	125, 2	GNG+ACT	ACT	**Wt.%**	**54.7**	**0.32**	**-**	**-**	**-**	**19.6**	**-**	**11.6**	**12.1**	**-**	**-**	**98.32**
				F. c.	8.08	0.04	-	-	-	2.42	-	2.55	1.92	-	-	ΣK=15
13	125, 3	BORN+ACT	ACT	**Wt.%**	**55.6**	**-**	**1.3**	**-**	**-**	**14.3**	**-**	**14.5**	**12.5**	**-**	**-**	**98.2**
				F. c.	8.01	-	0.22	-	-	1.72	-	3.11	1.93	-	-	ΣK=15

Table 1 continued: Chemical composition and formulas of silicates and oxides of oxide-rich tholeiitic gabbros (sample 90-23A, 806)

An.	Object	Association of minerals	Mineral		SiO_2	TiO_2	Al_2O_3	V_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	Total
14	125, 4	BORN+<u>ACT</u>	ACT	**Wt.%**	**54.6**	**-**	**-**	**-**	**-**	**18.6**	**-**	**12.1**	**12.9**	**-**	**-**	**98.2**
				F. c.	8.04	-	-	-	-	2.29	-	2.67	2.03	-	-	ΣK=15
15	125, 5	BORN+<u>ACT</u>	ACT	**Wt.%**	**54.2**	**-**	**-**	**-**	**-**	**19.0**	**0.5**	**12.3**	**12.3**	**-**	**-**	**98.3**
				F. c.	7.97	-	-	-	-	2.33	0.06	2.69	1.94	-	-	ΣK=15
16	125, 6	BORN+<u>CHL</u>	CHL	**Wt.%**	**37.1**	**-**	**7.2**	**0.28**	**-**	**27.3**	**-**	**15.6**	**0.4**	**-**	**-**	**87.88**
				F. c.	8.03	-	1.84	0.05	-	4.95	-	5.05	0.09	-	-	ΣK=20
17	125, 7	BORN+<u>CHL</u>	CHL	**Wt.%**	**34.3**	**0.46**	**10.4**	**-**	**-**	**25.6**	**-**	**17.4**	**-**	**-**	**-**	**88.16**
				F. c.	7.27	0.07	2.61	-	-	4.54	-	5.51	-	-	-	ΣK=20

P. s. – polished section, f. c. – formula coefficient; FeO and Fe_2O_3 – are colculated from tipical formula of minerals, ΣK – sum of kations.

Table 2: Chemical composition and formulas of Cu-Fe sulphides of oxide-rich tholeiitic gabbros (sample 90-23A, 806)

An.	Object	Association of minerals	Mineral		Cu	Fe	S	Total
1	45-1, 3	ZV+BORN	BORN	**Wt.%**	**62.2**	**11.2**	**24.6**	**98.0**
				F. c.	5.03	1.03	3.94	10
2	45-1, 11	ASPD+ BORN	BORN	**Wt.%**	**62.5**	**11.6**	**24.8**	**98.9**
				F. c.	5.01	1.06	3.94	10
3	45-1, 31	ASPD+BORN	BORN	**Wt.%**	**62.6**	**11.0**	**24.7**	**98.3**
				F. c.	5.05	1.01	3.95	10
4	45-1, 32	(Au,Pd,Cu)+KTH+ BORN	BORN	**Wt.%**	**60.4**	**13.0**	**25.0**	**98.4**
				F. c.	4.84	1.19	3.97	10
5	45-1, 40	ZV+BORN	BORN	**Wt.%**	**63.2**	**11.2**	**25.2**	**99.6**
				F. c.	5.02	1.01	3.96	10
6	45-2, 1	ZV+(Au,Pd)Cu+ BORN	BORN	**Wt.%**	**63.1**	**11.4**	**25.2**	**99.7**
				F. c.	5.00	1.03	3.96	10
7	45-2, 13	ZV+GNG+BORN	BORN	**Wt.%**	**62.5**	**11.6**	**25.1**	**99.2**
				F. c.	4.98	1.05	3.97	10
8	75-1, w. n.	BORN+CP	BORN	**Wt.%**	**61.5**	**11.3**	**25.2**	**98.0**
				F. c.	4.95	1.03	4.02	10
9	75-1, w. n.	BORN+CP	CP	**Wt.%**	**34.7**	**30.1**	**34.0**	**98.8**
				F. c.	1.02	1.00	1.98	4
10	75-1, 7	ZV+BORN	BORN	**Wt.%**	**61.8**	**11.6**	**25.4**	**98.8**
				F. c.	4.93	1.05	4.02	10
11	75-1, 8	(Au,Ag,Cu)+BORN	BORN	**Wt.%**	**61.9**	**11.5**	**26.1**	**99.5**
				F. c.	4.88	1.03	4.08	10
12	75-2, 3	ZV+BORN	BORN	**Wt.%**	**62.5**	**11.2**	**24.5**	**98.2**
				F. c.	5.05	1.03	3.92	10

F. c. – formula coefficient.

Table 3: PGE, Au and Ag minerals of heavy concentrates of the sample 90-23A, 806

N	Mineral	General formula	Number of grains	Grain size (E.C.D), μm			Vol.%
				min	max	average	
1	Zvyagintsevite	$(Pd,Au,Pt)_3(Pb,Sn)$	24 (3*)	3	40	19	24
2	Arsenopalladinite	$(Pd,Cu,Au)_8(As,Sn)3$	12 (1*)	4	50	20	17
3	Guanglinite	$(Pd,Cu,Au)_3(As,Sn,Te,Sb)$	8 (7*)	8	36	19	8
4	Palladoarsenide	$(Pd,Cu)_2As$	2	15	26	20	2
5	Sperrylite	$PtAs_2$	3 (5*)	2	60	29	9
6	(Au,Cu,Pd,Ag) alloys	(Au,Cu,Pd,Ag,Pt)	26 (3*)	4	39	17	23
7	Bogdanovite	$(Au,Pd,Pt)_3(Cu,Fe)$	8	8	29	18	5
8	Tetra-auricupride	(Au,Pd,Pt)(Cu,Fe)	2	2	11	7	<0.5
9	Keithconnite	$Pd_{3-x}(Te,Pb,As,Sn)$	(12*)	3	16	7	2
10	Vasilite	$Pd_{12}Cu_4S_7$	1	-	-	19	1
11	Stephanite	Ag_5SbS_4	1	-	-	60	8
12	Atokite	$(Pd,Pt)_3(Sn,As,Te)$	(3*)	2	12	2	<0.5
13	Isomertieite	$Pd_{11}As_2(Sb,Te)_2$	(1*)	-	-	8	<0.5
14	Kotulskite	Pd(Te,Pb)	(1*)	-	-	4	<0.5
		Total	86			18	100

*As inclusions in grains of other precious metal minerals.

Table 4: Chemical composition and formulas of the zvyagintsevite in PGM-grains of the heavy concentrates (sample 90-23A, 806)

An.	Grain	Association of minerals in the grain		Pd	Pt	Au	Cu	Fe	Pb	Sn	Te	As	Total
1	45-1, 1	ZV+BORN	**Wt.%**	**61.2**	**-**	**-**	**-**	**-**	**39.8**	**-**	**-**	**-**	**101.0**
			F. c.	3.00	-	-	-	-	1.00	-	-	-	4
2	45-1, 2	ZV+BORN+CHC	**Wt.%**	**60.2**	**4.0**	**1.7**	**0.8**	**0.4**	**25.3**	**7.0**	**-**	**-**	**99.4**
			F. c.	2.84	0.10	0.04	0.06	0.04	0.61	0.3	-	-	4
3	45-1, 3	ZV+BORN	**Wt.%**	**62.0**	**-**	**-**	**2.1**	**0.7**	**25.1**	**2.4**	**4.6**	**1.8**	**98.7**
			F. c.	2.81	-	-	0.16	0.06	0.59	0.09	0.18	0.11	4
4	45-1, 4	(Au,Pd,Cu)+KTH+ZV+ACT	**Wt.%**	**53.0**	**6.1**	**5.4**	**-**	**-**	**33.9**	**-**	**-**	**-**	**98.4**
			F. c.	2.76	0.17	0.15	-	-	0.91	-	-	-	4
5	45-1, 6	ZV	**Wt.%**	**55.7**	**2.3**	**4.5**	**-**	**1.1**	**35.8**	**-**	**-**	**-**	**99.4**
			F. c.	2.79	0.06	0.12	-	0.11	0.92	-	-	-	4
6	45-1, 8	ZV+BORN+SIL?	**Wt.%**	**54.0**	**2.4**	**3.9**	**0.7**	**1.2**	**36.6**	**-**	**-**	**-**	**98.8**
			F. c.	2.71	0.07	0.11	0.06	0.11	0.94	-	-	-	4
7	45-1, 14	ZV+BORN+CP+CHL+PL	**Wt.%**	**59.0**	**-**	**1.2**	**-**	**-**	**40.8**	**-**	**-**	**-**	**101.0**
			F. c.	2.93	-	0.03	-	-	1.04	-	-	-	4
8	45-1, 16	ZV	**Wt.%**	**57.4**	**-**	**3.1**	**-**	**0.5**	**39.0**	**-**	**-**	**-**	**100.0**
			F. c.	2.87	-	0.02	-	0.05	1.00	-	-	-	4
9	45-1, 26	ZV+KTH+BORN+ACT	**Wt.%**	**56.2**	**2.7**	**-**	**-**	**0.4**	**39.1**	**-**	**-**	**-**	**98.4**
			F. c.	2.86	0.08	-	-	0.04	1.02	-	-	-	4
10	45-1, 28	ZV (zone1)	**Wt.%**	**57.0**	**2.5**	**1.6**	**-**	**0.7**	**35.5**	**2.2**	**-**	**-**	**99.5**
			F. c.	2.82	0.07	0.04	-	0.07	0.90	0.10	-	-	4
11	45-1, 28	ZV (zone 2)	**Wt.%**	**55.4**	**-**	**-**	**-**	**9.2**	**20.8**	**-**	**9.9**	**4.6**	**99.9**
			F. c.	2.24	-	-	-	0.71	0.44	-	0.34	0.27	4
12	45-1, 37	ZV	**Wt.%**	**58.9**	**-**	**1.9**	**-**	**0.5**	**38.5**	**-**	**-**	**-**	**99.8**
			F. c.	2.92	-	0.05	-	0.05	0.98	-	-	-	4
13	45-1, 40	ZV+BORN	**Wt.%**	**56.9**	**-**	**-**	**0.3**	**-**	**39.6**	**-**	**-**	**-**	**98.6**
			F. c.	2.89	-	-	0.03	-	1.03	-	-	-	4
14	45-1, 42	(Au,Cu,Pd)+ZV	**Wt.%**	**54.7**	**3.7**	**3.8**	**-**	**0.8**	**36.7**	**-**	**-**	**-**	**99.7**
			F. c.	2.76	0.10	0.10	-	0.08	0.95	-	-	-	4
15	45-2, 9	ZV+GNG+BORN	**Wt.%**	**55.4**	**3.5**	**1.2**	**-**	**0.4**	**38.5**	**-**	**-**	**-**	**99.0**
			F. c.	2.83	0.10	0.03	-	0.04	1.01	-	-	-	4

Table 4 continued: Chemical composition and formulas of the zvyagintsevite in PGM-grains of the heavy concentrates (sample 90-23A, 806)

An.	Grain	Association of minerals in the grain		Pd	Pt	Au	Cu	Fe	Pb	Sn	Te	As	Total
16	45-2, 13	ZV+GNG+BORN	**Wt.%**	**53.1**	**-**	**5.0**	**2.2**	**0.6**	**37.6**	**-**	**-**	**-**	**98.5**
			F. c.	2.66	-	0.14	0.18	0.06	0.97	-	-	-	4
17	45-2, 23	ZV+ AT	**Wt.%**	**58.6**	**-**	**-**	**-**	**0.6**	**39.7**	**-**	**-**	**-**	**98.9**
			F. c.	2.93	-	-	-	0.06	1.02	-	-	-	4
18	45-2, 24	ZV+CHC	**Wt.%**	**57.9**	**-**	**-**	**-**	**0.6**	**41.2**	**-**	**-**	**-**	**99.7**
			F. c.	2.89	-	-	-	0.06	1.06	-	-	-	4
19	75-1, 2	ZV+BORN+ACT+CHL	**Wt.%**	**57.7**	**-**	**-**	**-**	**-**	**40.5**	**-**	**-**	**-**	**98.2**
			F. c.	2.94	-	-	-	-	1.06	-	-	-	4
20	75-1, 7	ZV+BORN	**Wt.%**	**57.9**	**-**	**1.7**	**-**	**-**	**39.6**	**-**	**-**	**-**	**99.2**
			F. c.	2.93	-	0.05	-	-	1.03	-	-	-	4
21	75-2, 1	ZV+TLC	**Wt.%**	**55.9**	**4.8**	**-**	**-**	**0.8**	**37.5**	**-**	**-**	**-**	**99.0**
			F. c.	2.82	0.13	-	-	0.08	0.97	-	-	-	4
22	75-2, 2	ZV+BORN+CHL	**Wt.%**	**59.2**	**-**	**-**	**-**	**-**	**40.3**	**-**	**-**	**-**	**99.5**
			F. c.	2.96	-	-	-	-	1.04	-	-	-	4
23	75-2, 3	ZV+BORN	**Wt.%**	**58.0**	**-**	**1.4**	**0.4**	**0.4**	**39.1**	**-**	**-**	**-**	**99.3**
			F. c.	2.89	-	0.04	0.04	0.04	1.00	-	-	-	4

Table 5: Chemical composition and formulas of arsenopalladinite, guanglinite, palladoarsenide, sperrylite, isomertieite, keithconnite, atokite, and kotulskite in PGM-grains of the heavy concentrates (sample 90-23A, 806)

An.	Grain	Association of minerals in the grain	Mineral		Pd	Pt	Au	Cu	Fe	As	Sn	Te	Pb	Sb	Total
1	45-1, 11	ASPD+BORN	ASPD	**Wt.%**	**74.7**	**-**	**-**	**3.4**	**0.3**	**21.4**	**-**	**-**	**-**	**-**	**99.8**
				F. c.	7.37	-	-	0.56	0.06	3.01	-	-	-	-	11
2	45-1, 15	ASPD+SP	ASPD	**Wt.%**	**69.7**	**-**	**4.9**	**1.1**	**0.9**	**17.1**	**4.3**	**-**	**-**	**-**	**98.0**
				F. c.	7.36	-	0.28	0.19	0.18	2.58	0.41	-	-	-	11
3	45-1, 18	ASPD+(Au,Ag,Cu)+ISM +GNG+BORN	ASPD	**Wt.%**	**73.8**	**-**	**-**	**2.8**	**0.3**	**22.0**	**-**	**-**	**-**	**-**	**98.9**
				F. c.	7.36	-	-	0.47	0.06	3.12	-	-	-	-	11
4	45-1, 23	ASPD+BORN	ASPD	**Wt.%**	**71.4**	**-**	**3.7**	**1.5**	**0.3**	**19.3**	**3.8**	**-**	**-**	**-**	**100.0**
				F. c.	7.32	-	0.21	0.26	0.06	2.81	0.35	-	-	-	11
5	45-1, 29	ASPD+SP+BORN	ASPD	**Wt.%**	**69.9**	**-**	**4.3**	**1.1**	**0.7**	**18.6**	**4.4**	**-**	**-**	**-**	**99.0**
				F. c.	7.26	-	0.25	0.19	0.14	2.75	0.41	-	-	-	11
6	45-1, 31	ASPD+BORN	ASPD	**Wt.%**	**75.3**	**-**	**-**	**3.2**	**0.5**	**20.5**	**-**	**-**	**-**	**-**	**99.51**
				F. c.	7.44	-	-	0.52	0.10	2.94	-	-	-	-	11.0
7	45-1, 41	ASPD+SP+BORN+MT	ASPD	**Wt.%**	**78.0**	**-**	**-**	**0.3**	**-**	**16.9**	**4.3**	**-**	**-**	**-**	**99.5**
				F. c.	8.06	-	-	0.05	-	2.49	0.40	-	-	-	11
8	45-2, 4	ASPD	ASPD	**Wt.%**	**70.2**	**-**	**2.8**	**1.9**	**0.5**	**19.0**	**3.7**	**-**	**-**	**-**	**98.1**
				F. c.	7.27	-	0.16	0.33	0.10	2.80	0.34	-	-	-	11
9	45-2, 20	ASPD+MT	ASPD	**Wt.%**	**70.1**	**-**	**4.2**	**1.3**	**0.3**	**18.4**	**4.0**	**-**	**-**	**-**	**98.3**
				F. c.	7.36	-	0.24	0.23	0.06	2.74	0.38	-	-	-	11
10	75-1, 3	ASPD+TLC	ASPD	**Wt.%**	**74.0**	**-**	**-**	**1.2**	**1.0**	**19.4**	**3.3**	**-**	**-**	**-**	**98.9**
				F. c.	7.51	-	-	0.20	0.19	2.80	0.30	-	-	-	11
11	75-1, 5	(Au,Ag,Cu)+ASPD+TLC	ASPD	**Wt.%**	**74.2**	**-**	**-**	**-**	**2.0**	**17.1**	**3.8**	**-**	**-**	**1.5**	**98.6**
				F. c.	7.63	-	-	-	0.39	2.50	0.35	-	-	0.13	11
12	75-1, 7	ASPD+KT+BORN	ASPD	**Wt.%**	**77.4**	**-**	**-**	**-**	**0.4**	**18.2**	**3.5**	**-**	**-**	**-**	**99.1**
				F. c.	7.95	-	-	-	0.08	2.65	0.32	-	-	-	11
13	125-2	ASPD+BORN+ACT	ASPD	**Wt.%**	**78.1**	**-**	**-**	**0.3**	**-**	**18.0**	**2.0**	**1.2**	**-**	**-**	**99.6**
				F. c.	8.03	-	-	0.05	-	2.62	0.19	0.11	-	-	11
14	45-1, 7	(Au,Cu,Ag)+GNG	GNG	**Wt.%**	**69.7**	**-**	**6.7**	**1.0**	**0.6**	**16.1**	**4.5**	**-**	**-**	**-**	**98.6**
				F. c.	2.71	-	0.14	0.07	0.04	0.89	0.16	-	-	-	4

Table 5 continued: Chemical composition and formulas of arsenopalladinite, guanglinite, palladoarsenide, sperrylite, isomertieite, keithconnite, atokite, and kotulskite in PGM-grains of the heavy concentrates (sample 90-23A, 806)

An.	Grain	Association of minerals in the grain	Mineral		Pd	Pt	Au	Cu	Fe	As	Sn	Te	Pb	Sb	Total
15	45-1, 9	GNG+SP+CHC+BORN+ ILM	GNG	**Wt.%**	**79.5**	**-**	**-**	**-**	**0.5**	**17.8**	**1.9**	**-**	**-**	**-**	**99.7**
				F. c.	2.96	-	-	-	0.04	0.94	0.06	-	-	-	4
16	45-1, 18	ASPD+(Au,Ag,Cu)+ISM +GNG+BORN	GNG	**Wt.%**	**75.2**	**-**	**-**	**1.0**	**0.3**	**12.1**	**-**	**-**	**-**	**11.0**	**99.6**
				F. c.	2.88	-	-	0.07	0.02	0.66	-	-	-	0.37	4
17	45-1, 19	GNG+(Au,Ag,Pd)+ BORN	GNG	**Wt.%**	**75.9**	**-**	**-**	**0.7**	**0.6**	**16.1**	**3.6**	**-**	**-**	**1.5**	**98.4**
				F. c.	2.87	-	-	0.04	0.04	0.87	0.12	-	-	0.05	4
18	45-1, 21	GNG+(Au,Cu,Pd)	GNG	**Wt.%**	**78.6**	**-**	**-**	**-**	**1.0**	**17.2**	**-**	**-**	**-**	**1.8**	**98.6**
				F. c.	2.95	-	-	-	0.07	0.92	-	-	-	0.06	4
19	45-1, 25	GNG+SP+BORN	GNG	**Wt.%**	**76.4**	**-**	**-**	**-**	**0.5**	**16.1**	**3.8**	**1.4**	**-**	**-**	**98.2**
				F. c.	2.92	-	-	-	0.04	0.87	0.13	0.04	-	-	4
20	45-1, 27	GNG+BT	GNG	**Wt.%**	**78.8**	**-**	**-**	**-**	**1.1**	**16.0**	**3.9**	**-**	**-**	**-**	**99.8**
				F. c.	2.94	-	-	-	0.08	0.85	0.13	-	-	-	4
21	45-1, 33	(Au,Cu,Pd)+GNG	GNG	**Wt.%**	**69.2**	**-**	**6.5**	**1.1**	**0.4**	**7.6**	**5.4**	**9.7**	**-**	**-**	**98.7**
				F. c.	2.79	-	0.14	0.08	0.03	0.43	0.20	0.33	-	-	4
22	45-1, 44	GNG+SP+BORN	GNG	**Wt.%**	**78.6**	**-**	**-**	**1.3**	**0.9**	**15.8**	**2.7**	**-**	**-**	**-**	**99.3**
				F. c.	2.93	-	-	0.08	0.07	0.84	0.09	-	-	-	4
23	45-2, 6	BGD+GNG	GNG	**Wt.%**	**72.0**	**1.5**	**-**	**-**	**0.8**	**9.6**	**3.6**	**12.4**	**-**	**-**	**99.9**
				F. c.	2.89	0.04	-	-	0.06	0.55	0.13	0.41	-	-	4
24	45-2, 13	ZV+GNG+BORN	GNG	**Wt.%**	**74.3**	**-**	**-**	**1.9**	**0.7**	**14.7**	**-**	**-**	**7.6**	**-**	**99.2**
				F. c.	2.87	-	-	0.12	0.05	0.81	-	-	0.15	-	4
25	45-2, 16	(Au,Ag,Cu)+GNG	GNG	**Wt.%**	**71.8**	**-**	**4.3**	**1.5**	**0.7**	**17.3**	**2.9**	**-**	**-**	**-**	**98.5**
				F. c.	2.73	-	0.09	0.10	0.05	0.93	0.10	-	-	-	4
26	45-2, 22	GNG+SP	GNG	**Wt.%**	**77.1**	**-**	**-**	**0.5**	**0.3**	**16.1**	**5.0**	**-**	**-**	**-**	**99.0**
				F. c.	2.91	-	-	0.03	0.02	0.86	0.17	-	-	-	4
27	75-1, 4	GNG	GNG	**Wt.%**	**77.8**	**-**	**-**	**-**	**-**	**16.5**	**5.0**	**-**	**-**	**-**	**99.3**
				F. c.	2.94	-	-	-	-	0.89	0.17	-	-	-	4
28	45-1, 32	PLAS	PLAS	**Wt.%**	**73.4**	**-**	**-**	**-**	**0.5**	**22.7**	**-**	**-**	**-**	**2.2**	**98.8**
				F. c.	2.03	-	-	-	0.03	0.89	-	-	-	0.05	3

Table 5 continued: Chemical composition and formulas of arsenopalladinite, guanglinite, palladoarsenide, sperrylite, isomertieite, keithconnite, atokite, and kotulskite in PGM-grains of the heavy concentrates (sample 90-23A, 806)

An.	Grain	Association of minerals in the grain	Mineral		Pd	Pt	Au	Cu	Fe	As	Sn	Te	Pb	Sb	Total
29	45-2, 14	PLAS	PLAS	**Wt.%**	**70.6**	**-**	**-**	**3.6**	**0.5**	**23.4**	**-**	**-**	**-**	**-**	**98.1**
				F. c.	1.91	-	-	0.16	0.03	0.90	-	-	-	-	3
30	45-1, 9	GNG+SP+CHC+ BORN+ILM	SP	**Wt.%**	**-**	**56.5**	**-**	**-**	**-**	**43.4**	**-**	**-**	**-**	**-**	**99.9**
				F. c.	-	1.00	-	-	-	2.00	-	-	-	-	3
31	45-1, 41	ASPD+SP+BORN+MT	SP	**Wt.%**	**-**	**57.5**	**-**	**-**	**-**	**44.2**	**-**	**-**	**-**	**-**	**101.7**
				F. c.	-	1.00	-	-	-	2.00	-	-	-	-	3
32	125-1	SP	SP	**Wt.%**	**-**	**56.6**	**-**	**-**	**-**	**44.0**	**-**	**-**	**-**	**-**	**100.6**
				F. c.	-	0.99	-	-	-	2.01	-	-	-	-	3
33	45-1, 18	ASPD+ISM+GNG+ (Au,Ag,Cu)+BORN	ISM	**Wt.%**	**73.7**	**-**	**-**	**1.1**	**0.6**	**9.3**	**-**	**1.8**	**-**	**12.6**	**99.1**
				F. c.	10.79	-	-	0.27	0.17	1.94	-	0.22	-	1.61	15
34	45-1, 4	(Au,Pd,Cu)+KTH+ZV+ ACT	KTH	**Wt.%**	**73.4**	**-**	**-**	**-**	**-**	**6.9**	**-**	**15.0**	**3.9**	**-**	**99.2**
				F. c.	3.00	-	-	-	-	0.40	-	0.51	0.08	-	4
35	45-1, 13	(Au,Cu,Pd)+KTH+CP	KTH	**Wt.%**	**66.2**	**-**	**-**	**-**	**0.8**	**-**	**-**	**26.4**	**5.1**	**-**	**98.5**
				F. c.	2.87	-	-	-	0.07	-	-	0.95	0.11	-	4
36	45-1, 26	ZV+KTH+BORN+ACT	KTH	**Wt.%**	**69.2**	**-**	**-**	**-**	**0.6**	**6.2**	**-**	**15.8**	**6.3**	**-**	**98.1**
				F. c.	2.9	-	-	-	0.05	0.37	-	0.55	0.37	-	4
37	45-1, 30	(Au,Pd,Cu)+KTH+ HB+BT	KTH	**Wt.%**	**67.5**	**-**	**-**	**-**	**0.4**	**-**	**-**	**27.4**	**3.5**	**-**	**98.8**
				F. c.	2.91	-	-	-	0.03	-	-	0.98	0.08	-	4
38	45-1, 32	(Au,Pd,Cu)+KTH+ BORN	KTH	**Wt.%**	**63.8**	**-**	**-**	**1.8**	**1.1**	**-**	**-**	**25.0**	**4.5**	**-**	**100.2**
				F. c.	2.68	-	-	0.12	0.09	-	-	1.02	0.10	-	4
39	45-1, 35	BGD+KTH	KTH	**Wt.%**	**70.4**	**-**	**5.3**	**-**	**0.4**	**4.9**	**3.1**	**15.8**	**-**	**-**	**100.1**
				F. c.	2.90	-	0.12	-	0.03	0.29	0.11	0.54	-	-	4
40	45-2, 2	BGD+KTH+CP+ACT	KTH	**Wt.%**	**73.5**	**-**	**-**	**-**	**-**	**6.2**	**2.9**	**16.1**	**-**	**-**	**98.7**
				F. c.	2.99	-	-	-	-	0.36	0.11	0.55	-	-	4

Table 5 continued: Chemical composition and formulas of arsenopalladinite, guanglinite, palladoarsenide, sperrylite, isomertieite, keithconnite, atokite, and kotulskite in PGM-grains of the heavy concentrates (sample 90-23A, 806)

An.	Grain	Association of minerals in the grain	Mineral		Pd	Pt	Au	Cu	Fe	As	Sn	Te	Pb	Sb	Total
41	45-2, 5	BGD+ZV+KTH+BORN+ TLC	KTH	**Wt.%**	**72.4**	**-**	**-**	**-**	**0.8**	**6.6**	**1.4**	**14.4**	**4.2**	**-**	**99.8**
				F. c.	2.93	-	-	-	0.06	0.38	0.05	0.49	0.09	-	4
42	45-2, 7	(Au,Pd,Cu)+KTH+ILM+ TLC	KTH	**Wt.%**	**71.8**	**-**	**-**	**-**	**0.7**	**7.0**	**-**	**16.0**	**3.5**	**-**	**99.0**
				F. c.	2.92	-	-	-	0.06	0.41	-	0.54	0.07	-	4
43	45-2, 7	(Au,Pd,Cu)+KTH+ILM+ TLC	KTH	**Wt.%**	**62.8**	**-**	**2.6**	**-**	**0.7**	**-**	**-**	**28.8**	**4.9**	**-**	**99.8**
				F. c.	2.73	-	0.06	-	0.06	-	-	1.04	0.11	-	4
44	45-2, 11	(Au,Cu,Pd)+KTH	KTH	**Wt.%**	**65.2**	**-**	**1.6**	**-**	**0.6**	**-**	**-**	**27.9**	**4.0**	**-**	**99.3**
				F. c.	2.82	-	0.04	-	0.05	-	-	1.01	0.09-	-	4
45	45-2, 12	(Au,Pd,Cu)+KTH	KTH	**Wt.%**	**61.9**	**-**	**-**	**-**	**0.5**	**-**	**-**	**31.8**	**3.9**	**-**	**98.1**
				F. c.	2.71	-	-	-	0.04	-	-	1.16	0.09	-	4
46	45-2, 15	KTH+(Au,Pd,Cu)	KTH	**Wt.%**	**70.7**	**-**	**-**	**-**	**1.0**	**6.8**	**-**	**15.6**	**5.4**	**-**	**99.5**
				F. c.	2.88	-	-	-	0.08	0.39	-	0.53	0.11	-	4
47	45-2, 21	(Au,Pd)Cu+AT	AT	**Wt.%**	**62.8**	**6.2**	**2.9**	**1.1**	**0.5**	**1.1**	**26.3**	**-**	**-**	**-**	**99.8**
				F. c.	2.67	0.14	0.07	0.27	0.04	0.09	1.00	-	-	-	4
48	45-2, 25	(Au,Ag,Cu)+AT+TLC	AT	**Wt.%**	**69.2**	**-**	**2.6**	**-**	**0.5**	**6.9**	**14.5**	**3.0**	**-**	**2.1**	**99.2**
				F. c.	2.80	-	0.06	-	0.04	0.40	0.53	0.10	-	0.07	4
49	75-1, 6	ASPD+KT+BORN	KT	**Wt.%**	**42.8**	**-**	**-**	**0.4**	**1.1**	**-**	**-**	**52.0**	**3.1**	**-**	**99.4**
				F. c.	0.95	-	-	0.01	0.05	-	-	0.96	0.04	-	2

Table 6: Chemical composition and formulas of Au-Pd-Cu-Ag alloys, vasilite and stephanite in PGM-grains of the heavy concentrates (sample 90-23A, 806)

An.	Grain	Association of minerals in the grain	Mineral		Pd	Pt	Au	Ag	Cu	Fe	S	Sb	Total
1	45-1, 4	(Au,Pd,Cu)+KTH+ZV+ ACT	(Au,Pd,Cu)	**Wt.%**	**7.3**	**-**	**84.6**	**2.2**	**4.1**	**-**	**-**	**-**	**98.2**
				F. c.	0.12	-	0.74	0.03	0.11	-	-	-	1
2	45-1, 5	(Au,Ag,Cu)+BT	(Au,Ag,Cu)	**Wt.%**	**-**	**-**	**90.3**	**5.6**	**2.2**	**0.3**	**-**	**-**	**98.4**
				F. c.	-	-	0.83	0.09	0.06	0.01	-	-	1
3	45-1, 7	(Au,Cu,Ag)+GNG	(Au,Cu,Ag)	**Wt.%**	**-**	**-**	**91.0**	**2.4**	**4.8**	**0.4**	**-**	**-**	**98.6**
				F. c.	-	-	0.81	0.04	0.13	0.01	-	-	1
4	45-1, 12	(Au,Cu,Pd)	(Au,Cu,Pd)	**Wt.%**	**8.1**	**-**	**84.4**	**1.7**	**5.1**	**-**	**-**	**-**	**99.3**
				F. c.	0.13	-	0.71	0.03	0.13	-	-	-	1
5	45-1, 13	(Au,Cu,Pd)+KTH+CP	(Au,Cu,Pd)	**Wt.%**	**8.1**	**-**	**84.6**	**-**	**5.4**	**-**	**-**	**-**	**98.1**
				F. c.	0.13	-	0.73	-	0.14	-	-	-	1
6	45-1, 18	ASPD+(Au,Ag,Cu)+ISM +GNG+BORN	(Au,Ag,Cu)	**Wt.%**	**-**	**-**	**89.2**	**7.9**	**1.3**	**0.6**	**-**	**-**	**99.0**
				F. c.	-	-	0.81	0.13	0.04	0.02	-	-	1
7	45-1, 19	GNG+(Au,Ag,Pd)+ BORN	(Au,Ag,Pd)	**Wt.%**	**4.3**	**-**	**84.2**	**10.8**	**0.6**	**-**	**-**	**-**	**99.9**
				F. c.	0.07	-	0.74	0.18	0.01	-	-	-	1
8	45-1, 20	(Au,Pd,Cu)	(Au,Pd,Cu)	**Wt.%**	**14.7**	**-**	**76.6**	**-**	**6.7**	**1.4**	**-**	**-**	**99.4**
				F. c.	0.21	-	0.59	-	0.16	0.04	-	-	1
9	45-1, 21	(Au,Cu,Fe,Pd)	(Au,Cu,Fe,)	**Wt.%**	**3.3**	**-**	**88.0**	**2.1**	**3.0**	**1.9**	**-**	**-**	**98.3**
				F. c.	0.05	-	0.77	0.03	0.05	0.06	-	-	1
10	45-1, 22	(Au,Cu,Pd)+ACT	(Au,Cu,Pd)	**Wt.%**	**8.5**	**-**	**84.8**	**-**	**5.2**	**0.4**	**-**	**-**	**98.9**
				F. c.	0.13	-	0.72	-	0.14	0.01	-	-	1
11	45-1, 24	(Au,Cu,Pd)+HB+MT	(Au,Cu,Pd)	**Wt.%**	**8.2**	**-**	**84.4**	**-**	**5.3**	**0.5**	**-**	**-**	**98.4**
				F. c.	0.13	-	0.72	-	0.14	0.01	-	-	1
12	45-1, 30	(Au,Pd,Cu)+KTH+ HB+BT	(Au,Pd,Cu)	**Wt.%**	**8.6**	**-**	**84.5**	**-**	**5.2**	**-**	**-**	**-**	**98.3**
				F. c.	0.14	-	0.73	-	0.14	-	-	-	1
13	45-1, 32	(Au,Pd,Cu)+KTH+BORN	(Au,Pd,Cu)	**Wt.%**	**7.6**	**1.3**	**80.6**	**4.5**	**4.3**	**1.1**	**-**	**-**	**99.4**
				F. c.	0.12	0.01	0.66	0.07	0.11	0.03	-	-	1
14	45-1, 33	(Au,Cu,Pd)+GNG	(Au,Cu,Pd)	**Wt.%**	**3.7**	**1.7**	**86.5**	**3.8**	**3.0**	**0.5**	**-**	**-**	**99.2**
				F. c.	0.06	0.02	0.77	0.06	0.08	0.02	-	-	1

Table 6 continued: Chemical composition and formulas of Au-Pd-Cu-Ag alloys, vasilite and stephanite in PGM-grains of the heavy concentrates (sample 90-23A, 806)

An.	Grain	Association of minerals in the grain	Mineral		Pd	Pt	Au	Ag	Cu	Fe	S	Sb	Total
15	45-1, 38	(Au,Cu,Ag)	(Au,Cu,Ag)	**Wt.%**	**1.4**	**-**	**90.0**	**2.7**	**3.8**	**0.7**	**-**	**-**	**98.6**
				F. c.	0.02	-	0.81	0.04	0.11	0.02	-	-	1
16	45-1, 42	(Au,Cu,Pd)+ZV	(Au,Cu,Pd)	**Wt.%**	**7.6**	**1.5**	**83.1**	**1.7**	**5.3**	**0.6**	**-**	**-**	**99.8**
				F. c.	0.12	0.01	0.69	0.03	0.14	0.02	-	-	1
17	45-1, 43	(Au,Cu,Pd)	(Au,Cu,Pd)	**Wt.%**	**6.2**	**1.7**	**84.3**	**3.3**	**3.7**	**-**	**-**	**-**	**99.2**
				F. c.	0.10	0.01	0.73	0.05	0.10	-	-	-	1
18	45-2, 7	(Au,Pd,Cu)+KTH+ILM+TLC	(Au,Pd,Cu)	**Wt.%**	**6.8**	**1.6**	**84.5**	**2.1**	**3.6**	**0.7**	**-**	**-**	**99.3**
				F. c.	0.11	0.01	0.72	0.03	0.10	0.02	-	-	1
19	45-2, 8	(Au,Pd,Cu)	(Au,Pd,Cu)	**Wt.%**	**9.7**	**1.7**	**78.3**	**4.4**	**3.4**	**1.6**	**-**	**-**	**99.1**
				F. c.	0.15	0.02	0.64	0.07	0.09	0.05	-	-	1
20	45-2, 10	(Au,Ag,Cu)	(Au,Ag,Cu)	**Wt.%**	**-**	**2.0**	**88.5**	**5.2**	**2.1**	**0.5**	**-**	**-**	**98.3**
				F. c.	-	0.02	0.82	0.09	0.06	0.02	-	-	1
21	45-2, 11	(Au,Cu,Pd)+KTH	(Au,Cu,Pd)	**Wt.%**	**7.6**	**2.5**	**83.2**	**-**	**5.6**	**0.3**	**-**	**-**	**99.2**
				F. c.	0.12	0.02	0.70	-	0.15	0.01	-	-	1
22	45-2, 12	(Au,Pd,Cu)+KTH	(Au,Pd,Cu)	**Wt.%**	**13.2**	**2.2**	**76.8**	**-**	**7.0**	**0.4**	**-**	**-**	**99.6**
				F. c.	0.19	0.02	0.61	-	0.17	0.01	-	-	1
23	45-2, 15	KTH+(Au,Pd,Cu)	(Au,Pd,Cu)	**Wt.%**	**7.7**	**1.9**	**82.4**	**2.6**	**3.5**	**1.2**	**-**	**-**	**99.3**
				F. c.	0.12	0.02	0.70	0.04	0.09	0.04	-	-	1
24	45-2, 16	(Au,Ag,Cu)+GNG	(Au,Ag,Cu)	**Wt.%**	**1.3**	**-**	**90.8**	**5.2**	**2.0**	**0.3**	**-**	**-**	**99.6**
				F. c.	0.02	-	0.82	0.09	0.06	0.01	-	-	1
25	45-2, 17	(Au,Ag,Cu)	(Au,Ag,Cu)	**Wt.%**	**-**	**2.0**	**88.3**	**6.1**	**1.7**	**1.0**	**-**	**-**	**99.1**
				F. c.	-	0.02	0.80	0.10	0.05	0.03	-	-	1
26	45-2, 18	(Au,Pd,Cu)	(Au,Pd,Cu)	**Wt.%**	**6.6**	**2.5**	**82.0**	**2.6**	**3.7**	**0.8**	**-**	**-**	**98.2**
				F. c.	0.11	0.02	0.71	0.04	0.10	0.02	-	-	1
27	45-2, 19	(Au,Pd,Cu)	(Au,Pd,Cu)	**Wt.%**	**7.3**	**1.2**	**75.6**	**-**	**7.3**	**-**	**-**	**-**	**98.2**
				F. c.	0.18	0.01	0.6	-	0.18	-	-	-	1
28	45-2, 25	(Au,Ag,Pd)	(Au,Ag,Pd)	**Wt.%**	**3.4**	**2.4**	**83.1**	**6.0**	**1.7**	**2.1**	**-**	**-**	**98.7**
				F. c.	0.05	0.02	0.72	0.09	0.05	0.06	-	-	1

Table 6 continued: Chemical composition and formulas of Au-Pd-Cu-Ag alloys, vasilite and stephanite in PGM-grains of the heavy concentrates (sample 90-23A, 806)

An.	Grain	Association of minerals in the grain	Mineral		Pd	Pt	Au	Ag	Cu	Fe	S	Sb	Total
29	75-1, 5	(Au,Ag,Cu)+ASPD+OPX	(Au,Ag,Cu)	**Wt.%**	**-**	**-**	**89.7**	**6.2**	**2.1**	**0.5**	**-**	**-**	**98.5**
				F. c.	-	-	0.82	0.10	0.06	0.02	-	-	1
30	75-1, 8	(Au,Ag,Cu)+BORN	(Au,Ag,Cu)	**Wt.%**	**1.4**	**-**	**74.5**	**17.9**	**3.2**	**1.1**	**-**	**-**	**98.1**
				F. c.	0.02	-	0.60	0.26	0.08	0.03	-	-	1
31	75-1, 9	(Au,Cu,Ag)+ACT+TLC+PL	(Au,Cu,Ag)	**Wt.%**	**-**	**1.8**	**90.2**	**2.9**	**3.3**	**-**	**-**	**-**	**98.2**
				F. c.	-	0.02	0.84	0.05	0.10	-	-	-	1
32	45-1, 10	BGD+ZV+ACT	BGD	**Wt.%**	**6.4**	**-**	**82.5**	**-**	**10.0**	**-**	**-**	**-**	**98.9**
				F. c.	0.38	-	2.63	-	0.99	-	-	-	4
33	45-1, 35	BGD+KTH	BGD	**Wt.%**	**16.8**	**-**	**72.8**	**-**	**7.9**	**0.8**	**-**	**-**	**98.3**
				F. c.	0.95	-	2.22	-	0.75	0.08	-	-	4
34	45-1, 36	BGD	BGD	**Wt.%**	**16.5**	**-**	**72.8**	**-**	**8.1**	**1.2**	**-**	**-**	**98.6**
				F. c.	0.92	-	2.19	-	0.76	0.13	-	-	4
35	45-2, 2	BGD+KTH+CP+ACT	BGD	**Wt.%**	**15.6**	**-**	**75.0**	**-**	**8.6**	**-**	**-**	**-**	**99.2**
				F. c.	0.22	-	0.58	-	0.80	-	-	-	4
36	45-2, 3	BGD+ACT	BGD	**Wt.%**	**8.9**	**2.4**	**79.9**	**-**	**7.7**	**0.4**	**-**	**-**	**99.3**
				F. c.	0.53	0.08	2.58	-	0.77	0.04	-	-	4
37	45-2, 5	BGD+ZV+KTH+BORN+TLC	BGD	**Wt.%**	**5.6**	**2.0**	**80.1**	**1.2**	**9.5**	**0.5**	**-**	**-**	**98.9**
				F. c.	0.33	0.06	2.55	0.07	0.94	0.06	-	-	4
38	45-2, 6	BGD+GNG	BGD	**Wt.%**	**0.8**	**2.2**	**86.3**	**-**	**7.7**	**2.4**	**-**	**-**	**99.4**
				F. c.	0.08	0.07	2.81	-	0.77	0.27	-	-	4
39	75-1, 1	BGD+OPX	BGD	**Wt.%**	**13.1**	**1.6**	**76.2**	**-**	**8.5**	**0.5**	**-**	**-**	**99.9**
				F. c.	0.75	0.05	2.34	-	0.81	0.05	-	-	4
40	45-2, 1	ZV+(Au,Pd)Cu	(Au,Pd)Cu	**Wt.%**	**16.8**	**2.7**	**50.7**	**-**	**27.4**	**1.1**	**-**	**-**	**98.7**
				F. c.	0.36	0.03	0.59	-	0.98	0.04	-	-	2
41	45-2, 21	(Au,Pd)Cu+AT	(Au,Pd)Cu	**Wt.%**	**10.5**	**2.6**	**65.0**	**-**	**20.2**	**1.0**	**-**	**-**	**99.3**
				F. c.	0.25	0.03	0.85	-	0.82	0.05	-	-	2

Table 6 continued: Chemical composition and formulas of Au-Pd-Cu-Ag alloys, vasilite and stephanite in PGM-grains of the heavy concentrates (sample 90-23A, 806)

An.	Grain	Association of minerals in the grain	Mineral		Pd	Pt	Au	Ag	Cu	Fe	S	Sb	Total
42	45-2, 39	VSL+BORN	VSL	**Wt.%**	**72.2**	**-**	**-**	**-**	**13.6**	**0.5**	**12.4**	**-**	**98.7**
				F. c.	12.11	-	-	-	3.82	0.16	6.90	-	23
43	45-2, 45	STPH+ACT	STPH	**Wt.%**	**-**	**-**	**-**	**68.3**	**-**	**-**	**15.5**	**15.5**	**99.3**
				F. c.	-	-	-	5.09	-	-	3.89	1.02	10

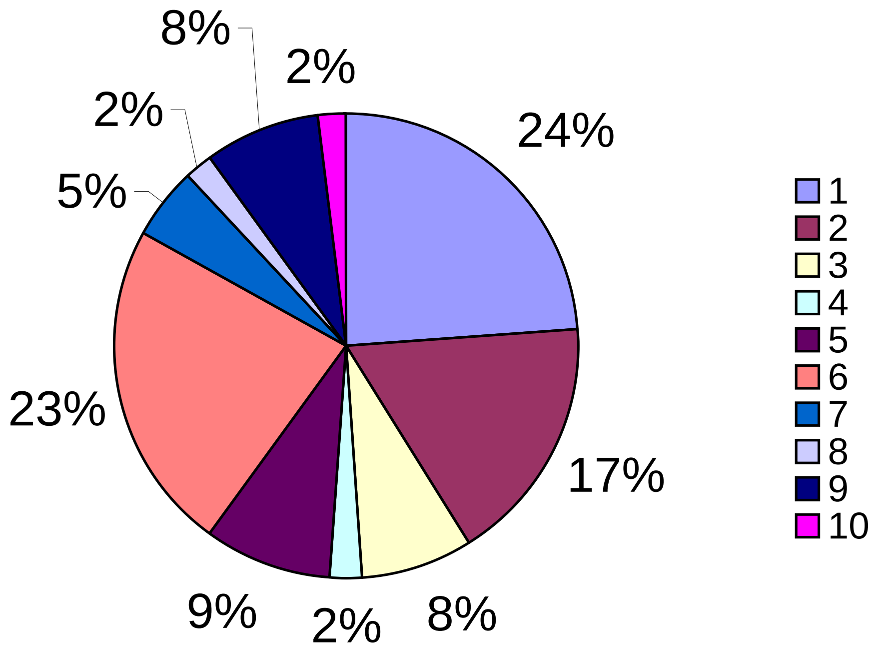

Fig. 1. PGE, Au and Ag minerals relative contents of the sample 90-23A, 806.
1: zvyagintsevite, 2: arsenopalladinite, 3: guanglinite, 4: palladoasenide, 5: sperrilyte,
6: Au-Cu-Pd-Ag-alloys, 7: bogdanovite, 8: keithconnite, 9: sephanite, 10: others.

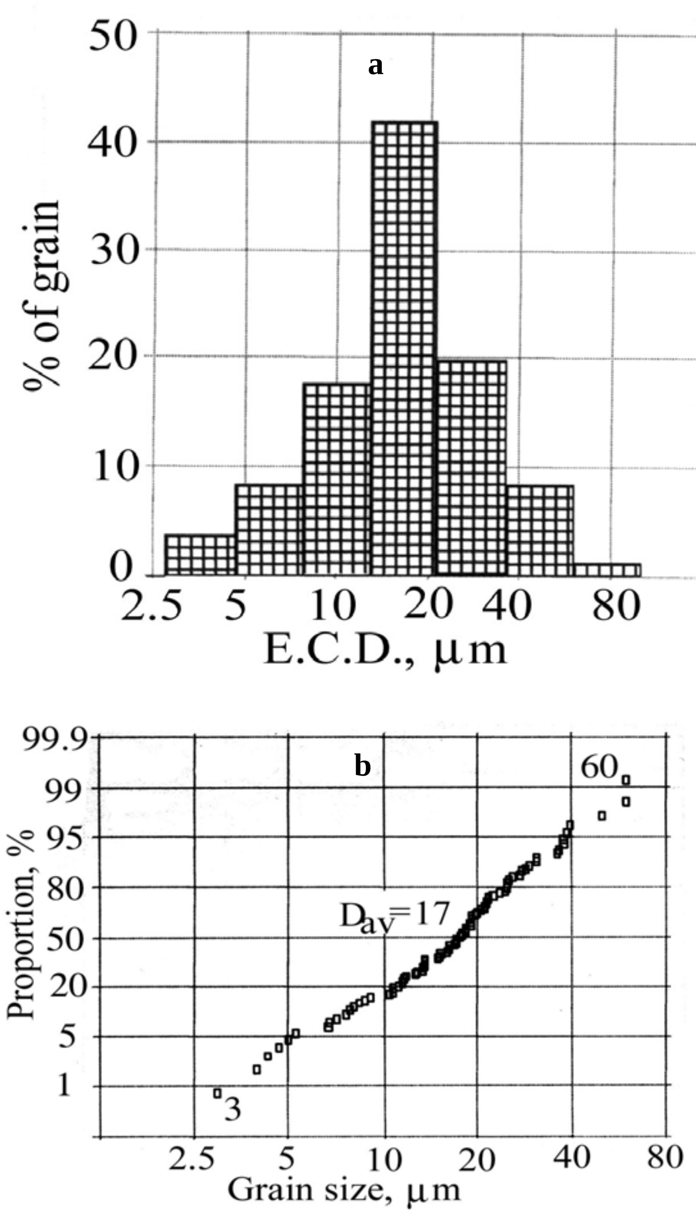

Fig. 2. Grain sizes of precious metal mineral grains (N=86), extracted in the heavy concentrates of the sample 90-23A, 806.
a:histogram, b: lognormal probability plot.

Appendix

Sample 90-23A 806.14
Electron microprobe analyses of sulphides.

Analyses collected at Department of Geology, University of Copenhagen Denmark using a GEOL Superprobe and metal and sulphide standards at 20 KV and 15 nA by H. Rasmussen.

thin section	level	type	grain	mineral	Cu	Fe	S	Au	Pd	Pt	Sn	Bi	Zn	Te	Sb	As	Ag	Ni	TOTAL
23A-806.14	Pd5	S	1Sc	bornite	62.05	12.06	25.79	0.01	0.01	0.06	0.03	n.a.	n.a.	0.01	0.04	0.01	0.01	0.01	100.08
23A-806.14	Pd5	S	1Sd	bornite	62.30	12.08	25.89	0.17	0.02	0.10	0.06	n.a.	n.a.	0.01	0.02	0.01	0.01	0.01	100.67
23A-806.14	Pd5	S	3Sa	bornite	63.42	11.67	26.22	0.01	0.01	0.04	0.01	n.a.	n.a.	0.01	0.01	0.01	0.27	0.01	101.69
23A-806.14	Pd5	S	3Sb	bornite	63.12	11.62	25.46	0.01	0.01	0.06	0.06	n.a.	n.a.	0.01	0.02	0.01	0.01	0.02	100.42
23A-806.14	Pd5	S	1Sb	chalcopyrite	34.41	29.65	34.52	0.01	0.07	0.14	0.01	n.a.	n.a.	0.01	0.02	0.01	0.32	0.01	99.18

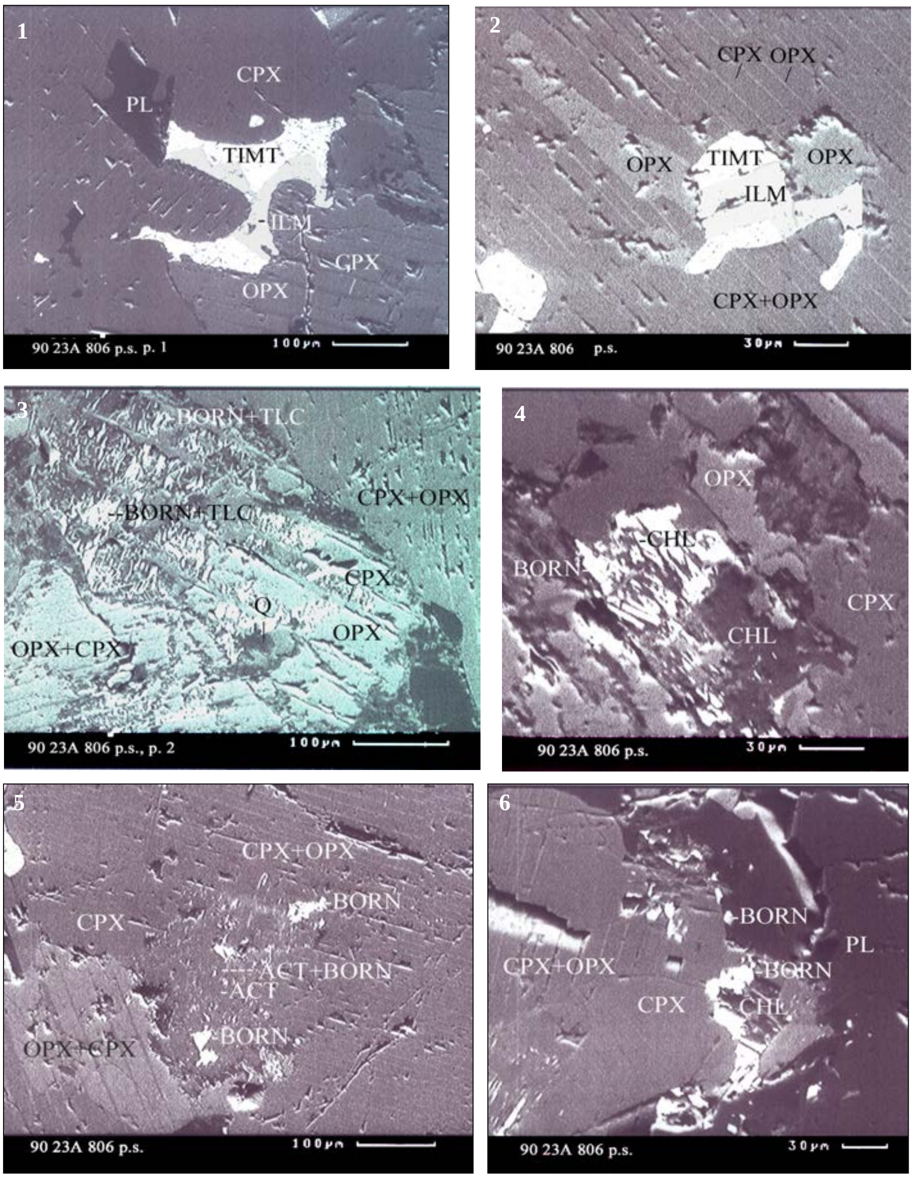

Plate 1. Relationships of rock-forming minerals, Fe-Ti-oxides and sulphides in the oxide-rich tholeiitic gabbros of the sample 90-23A, 806 (1-6). SEM-image (BIE), polished section # 90 23A, 806.

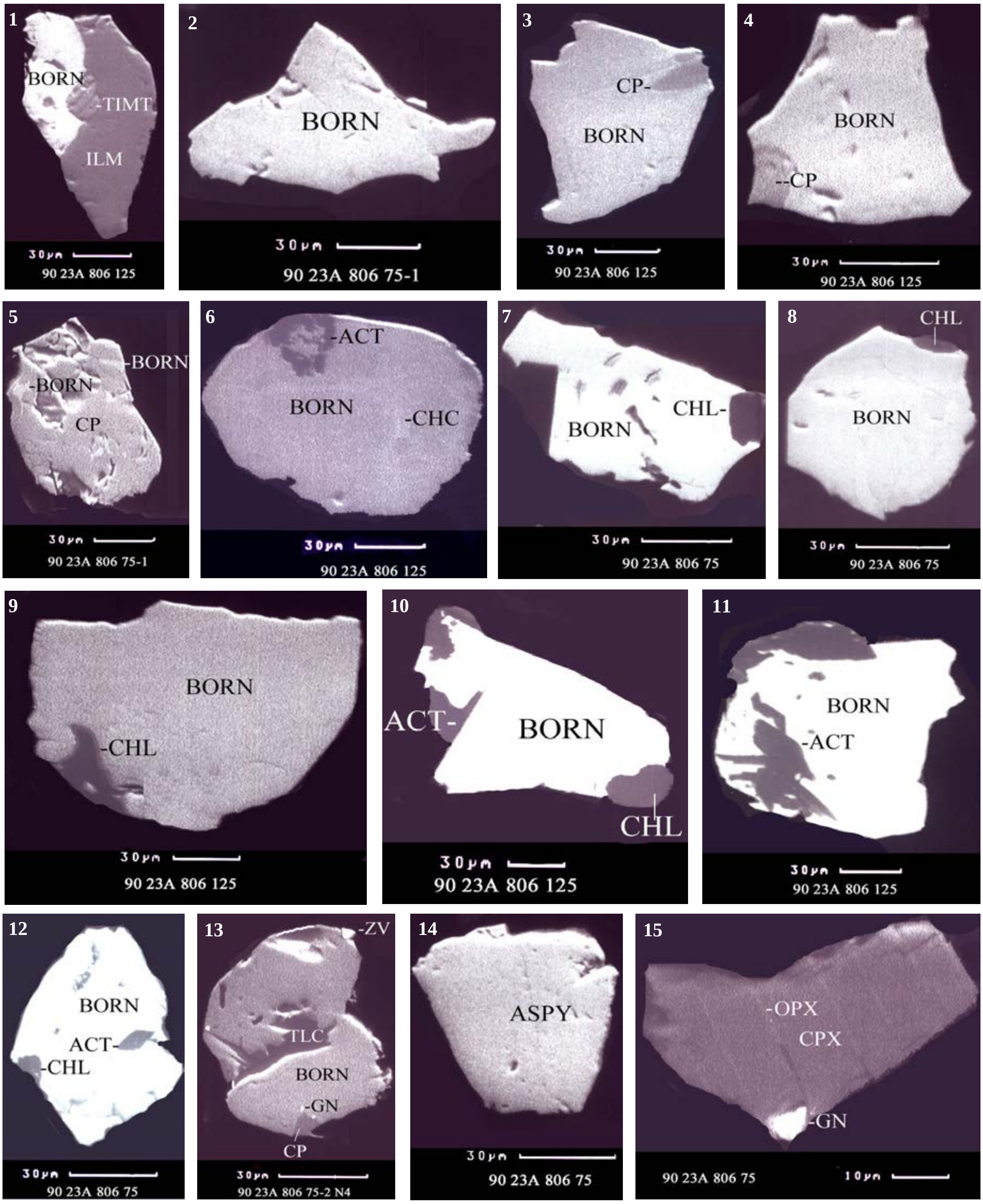

Plate 2. Grains of sulphide mineralisation from oxide-rich tholeiitic gabbros, the sample 90-23A, 806 (1-15); polished sections of grains, extracted in the heavy concentrates; SEM-image (BIE).

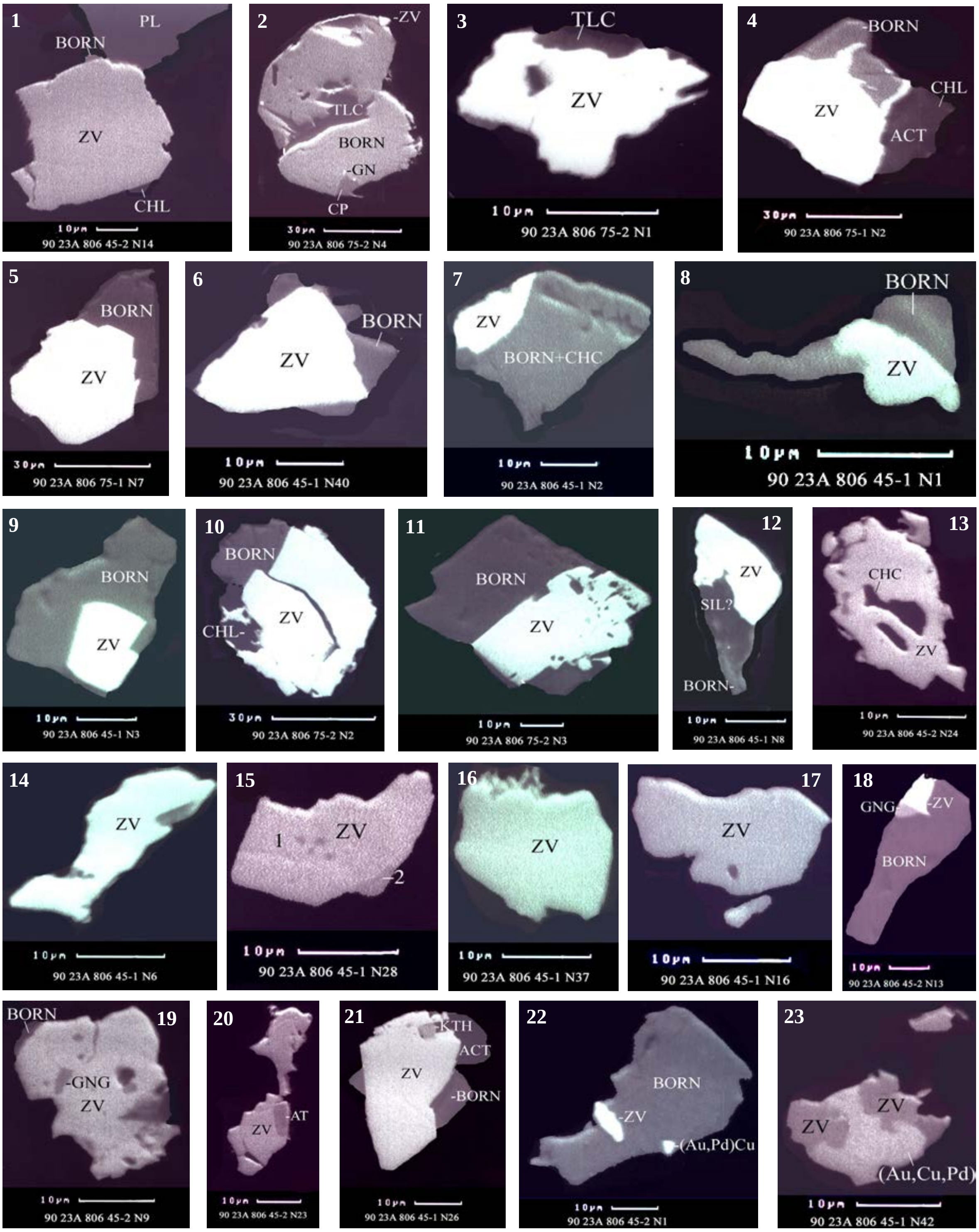

Plate 3. Grains of zvyagintsevite, extracted in heavy concentrates of the the sample 90-23A, 806 (1-23); polished sections; SEM-image (BIE).

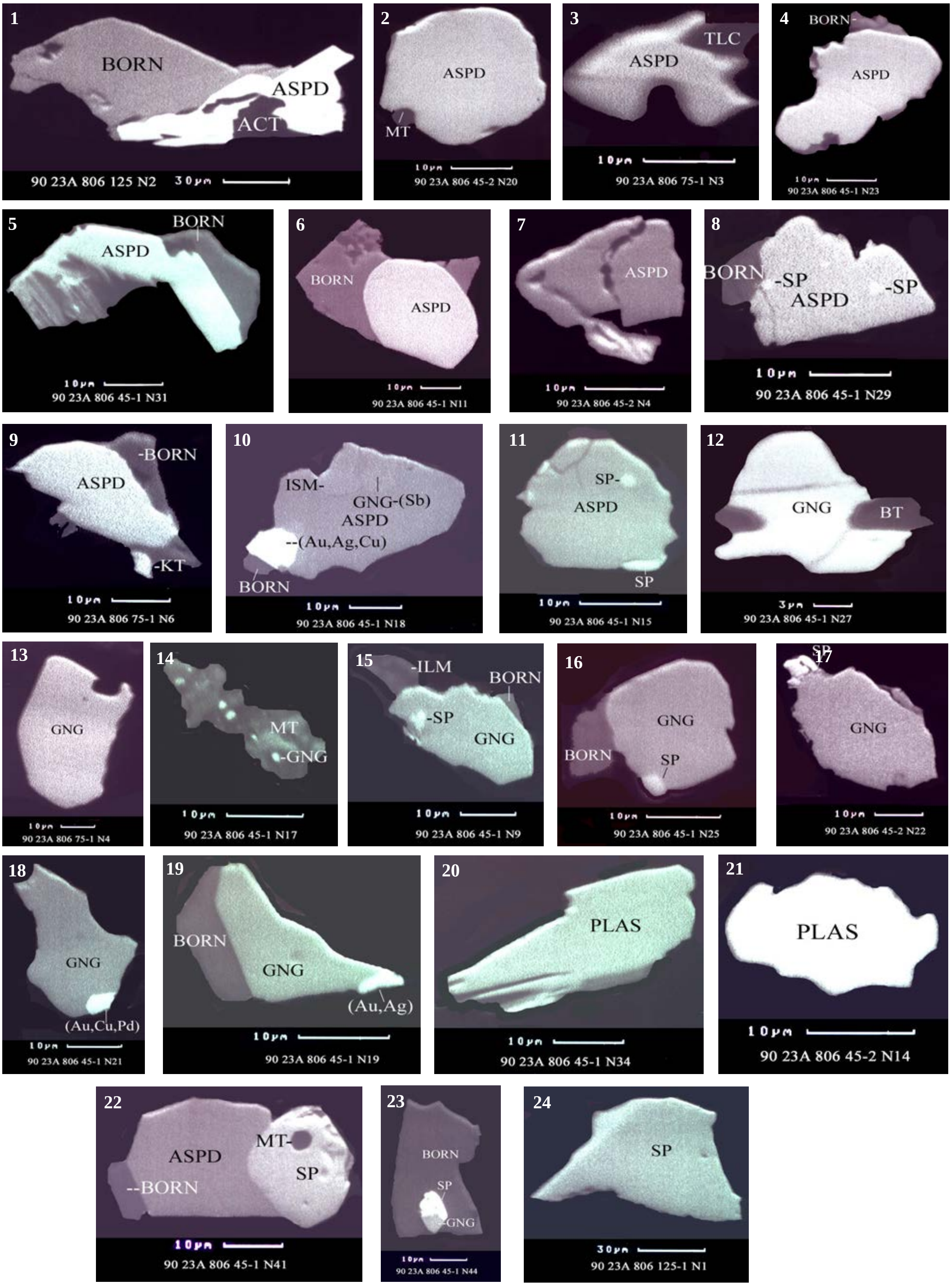

Plate 4. Grains of arsenopalladinite, guanglinite, palladoarsenide and sperrylite, extracted in heavy concentrates of the the sample 90-23A, 806 (1-24); polished sections; SEM-image (BIE).

Plate 5. Grains of Au-Pd-Cu-Ag alloys, bogdanovite, tetra-auricupride, stephanite and vasilite, extracted in heavy concentrates of the the sample 90-23A, 806 (1-37); polished sections; SEM-image (BIE).

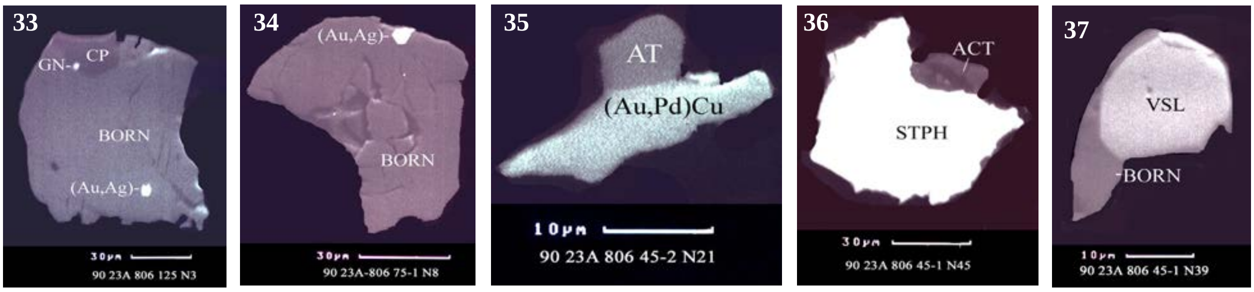

Plate 5 continued. Grains of Au-Pd-Cu-Ag alloys, bogdanovite, tetra-auricupride, stephanite and vasilite, extracted in heavy concentrates of the the sample 90-23A, 806 (1-37); polished sections; SEM-image (BIE).