DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2003/54

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

Part 5: sample 90-23A, 808

T. F. D. Nielsen, H. Rasmussen, N. S. Rudashevsky,
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MINISTRY OF THE ENVIRONMENT

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G E U S

Content

Abstract

The Paleaogene Skaergaard intrusion, 68^{o}N, 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 808 (core 90-23A from 808 to 809 meters) 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 808 (0.71 kg) 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 inter-grown with Fe-Ti-oxides.

The sample was found to contain 115 precious metal grains, including 112 grains of platinum group minerals (PGMs) and 3 grains of Au-minerals. The dominant PGM is zviagintsevite (Pd_3Pb, 73%), followed by guanglinite (Pd3As; 8%) and vasilite ($Pd_{12}Cu_4S_7$; 6%). The grain size of PGMs and Au-minerals varies between 1 and 69 μm with an average of 15 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 grains of zviagintsevite, often in close association with H_2O-bearing phases. Very often zviagintsevite is 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 are founds as inclusions in zviagintsevite and single grains of PGMs that were probably liberated from rims of preserved liquidus phases. They include Pd-arsenides and unnamed PdCu.

Introduction

The report describes the mineralogy of sample 90-23A 808 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.

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, 808

Sample 90-23A 808 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, 808 collects the 1-meter interval between 808 and 809 meters, just below the maximum concentration of Pd in the Pd5-level. The average Pd concentration between 808 meters and 809 meters is 2.3 g/t Pd and an average of combined PGE plus Au of 2.5 g/t.

The recovery between 808 and 809 meters is c. 75 %. 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 is edited by T.F.D. Nielsen.

References

Andersen, J. C. Ø., Rasmussen, H., Nielsen, T. F. D. & Rønsbo, J. G. 1998: The Triple Group and the Platinova gold and palladium reefs in the Skaergaard intrusion: Stratigraphic and petrographic relations. Economic Geology **93**, 488-509.

Bird, D.K., Brooks, C.K., Gannicott, R.A. & Turner, P.A. 1991: A gold-bearing horizon in the Skaergaard intrusion, East Greenland. Economic Geology **86**, 1083-1092.

Nielsen, T. F. D. 2001: The palladium potential of the Skaergaard intrusion, South-East Greenland. Report GEUS **2001/23**, 38 pp.

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).

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, 808 (0.71 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 average concentrations of 120 ppb Pt, 2300 ppb Pd and 52 ppb.

Analytical techniques

Analytical techniques are described in Nielsen et al. (2003a).

Two polished sections (808-1 and 808-2) were prepared of fragments taken from the submitted core 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 (149 g), 45-75 μm (116 g), 75-125 μm (142 g) and +125 μm (282 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

The only obvious cumulus phase observed in sample 90-23A, 808 is monoclinic ferrous pyroxene with typical exsolution of orthorhombic ferrous pyroxene. Plagioclase (Table 1, analyses 1-2) and Fe-Ti-oxides (Table 1, analyses 3-5) belong to the intercumulus mineral paragenesis. Fine grained polymineral aggregates of H_2O-bearing, secondary, minerals rim aggregates of Fe-Ti-oxides and occur in veins that cut across grains of rock-forming minerals (Plate 1, #1, 3 and 7; Table 1, analyses 6-8).

Sulphides

The sulphide mineralisation, As observed in polished section 808-1 and 808-2 the suphide content is less than 0.1 %. Sulphides form fine and irregularly distributed grains or aggregates of Cu-Fe sulphides. The aggregates of sulphides of <0.1 mm in size occur as inclusions in the intensively re-equilibrated or re-crystallised grains of the rock-forming minerals (Plate 1, #4-6 and 8-9), and sometimes in the veins that cut across rock forming monerals (e. g., Plate 1, #7). The sulphide-bearing parts of rock-forming silicates (e. g., pyroxene and plagioclase) are intensively replaced by fine-grained aggregates of H_2O-bearing, secondary minerals such as chlorite, actinolite, ferrous talc, hornblende, biotite and quartz (Plate 1, #4-9, Table 1, analyses 7-15). The secondary minerals are closely to the sulphide grains. The Cl-concentrations in hornblede (1.6-2.4 wt.% - Table 1, analyses 7, 11, 14) and biotite (0.2-0.4 wt. % - Table 1, analyses 6, 10) should be noted.

The HS-concentrates are enriched in Cu-Fe sulphide grains of irregular shapes (Plate 2, #1, 3, 9 and 11-15) together with spherical sulphides globules up to 100 μm in size (Plate 2, #2 and 4-8). The main sulphide mineral is bornite (Plate 2; Table 2, analyses 1-4, 6-7, 9 and 11-12). In some grains bornite is associated with chalcopyrite (Plate 2, #3-5; Table 2, an. 5, 8), chalcosine (Plate 2, #6-9 and 14-15; Table 2, analyses 10 and 16) and digenite (Table 2, analysis 14). Besides of the Cu-Fe sulphides are observed rare grains of galena (Plate 2, #3), arsenopyrite and sphalerite.

The sulphide aggregates are generally associated with H_2O-bearing minerals such as:

1) actinolite (Plate 2, #14-15; Table 1, analyses 19-20)
2) chlorite (Plate 2, #1, 11-14; Table 1, analyses 21-25)
3) ferrous talc (Plate 2, #9 and 16)
4) biotite and
5) hornblende

The grains-intergrowths of Cu-Fe sulphides with ilmenite and titanic magnetite (Plate 2, #9, 10, 12; Table 1, analyses 16-18) are found in the heavy concentrates too.

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

Recovery

In the polished sections was found several very fine grains (<10 μm) of the PGMs *zvyagintsevite* and *arsenopalladinite*. They occur together with bornite as inclusions in ilmenite (Plate 1, #2), and also within aggregates of H_2O-bearing secondary silicates and quartz (Plate 1, #4-5).

The HS-concentrates of sample 90-23A, 808 yielded a large number of PGE and Au-minerals including 112 PGM grains and 3 grains of Au-minerals (Table 3). The majority of the grains of precious metal minerals are represented by:

1*) zvyagintsevite*,

2) Pd-arsenides including:

    a) arsenopalladinite

    b) *guanglinite*

    c) *palladoarsenide*

More rarely observed precious metal minerals include:

1) vasilite

2) vysotskite

3) keithconnite

4) *isomertieite*

5) *sperrylite*

6) *bogdanovite*

7) *unnamed PdCu*

8) *(Au-Cu-Pd)-alloy*

9) *(Pd-Pt-Cu)-alloy*

10) *(Pt-Fe-Pd*)-alloy

In total, 14 different precious metal minerals are documented in the sample 90-23A, 808 (Table 3).

Taking the size of the grains into account the volume rations of the PGM and Au.minerals are as follows (se also Table 3 and Fig. 1):

Mineral or group	Volume %
zvyagintsevite	73.0
Pd-arsenides	12.0
vasilite	6.0
vysotskite	4.0
(Au-Pd-Cu-Ag)-alloys	1.9
unnamed PdCu	1.0
keithconnite	0.5
isomertieite	0.7
others	ca 1

Grain size of PGMs and Au-minerals

The grain size (E.C.D.) of the precious metal mineral grains in sample 90-23A, 808 varies from around 2 to 69 μm, with an average of 15 μm (Table 3; Fig. 2). The occurrence of small, liberated grains (5-10 μm) of precious metal phases in the HS- (Plate 3, #24-28 and Plate 4, #4, 8, 11-13 and 22) demonstrates the efficiency of the preparation techniques.

Petrographic observations

In the HS-concentrates PGMs occur as:

1) monomineralic grains (Plate 3, #24-30, 3*2*, 34-36, 38-43, 45 and 57; Plate 4, #15 and 21-23; Plate 5, #6, 17-20, 13, 15-17 and 20)
2) in intergrowths with sulphides including:
    a) bornite, most common (Plate 3, #1, 6, 8-10, 12-23, 31, 33, 37, 46-50, 52-56, 60, 62-63 and 65; Plate 4, #1-4, 6-7, 9, 17 and 20; Plate 5, #1-3, 5, 7-9, 13 and 21);
    b) chalcopyrite, rare (Plate 3, #*13*; Plate 5, #5),
    c) chalcosine, rare (Plate 3, #14-15; Plate 4, #9; Plate 5, #2 and 7),
    d) digenite, rare (Plate 3, #54).

Many polymineral intergrowths of PGMs and (Au-Cu-Pd-Ag) alloys with different silicates and oxides were found in the HS-concentrates: usually with H_2O-bearing silicates such as:

1) actinolite (Plate 3, #6-8, 17, 44 and 58; Plate 4, #2 and 9; Plate 5, #9, 12 and 14)
2) chlorite (Plate 3, #9-12, 14, 46 and 53; Plate 5, #7)
3) ferrous talc (Plate 3, #6 and 50)

and more rarely with rock-forming minerals such as:

1) ilmenite (Plate 3, #1-5 and 49; Plate 5, #4, 11 and 14)
2) magnetite (Plate 3, #9 and 11; Plate 5, #7 and 12)

Many polymineral intergrowths of different PGMs (Plate 3, #59-65; Plate 4, #6, 16 and 18-20; Plate 5, #8-10) and (Au-Cu-Pd-Ag)-alloys (Plate 4, #7; Plate 5, #14-16) were also observed.

In the HS-concentrates palladoarsenide (Plate 4, #21-23) and unnamed PdCu (Plate 5, #17-19) only occur as individual monomineralic grains.

Description and chemistry of PGMs and Au-minerals

Zvyagintsevite

Description

Zvyagintsevite is in the HS-concentrates found as:

1) anhedral grains (Plate 3, #1-4, 6-44, 46, 48-54 and 56-65), sometimes as
2) euhedral crystals (Plate 3, #45, 47 and 55) varied from around 2 to 69 μm, with an average of 16 μm (Table 3).

The majority of its grains is not associated with other PGMs (Plate 3, #1-58). zvyagintsevite occurs commonly in intergrowths with:

1) guanglinite (Plate 3, #59-64; Plate 4, #16)

and also with:

2) keithconnite (Plate 3, #65; Plate 5, #14), and with
3) Au-Cu-Pd alloy (Plate 5, #14).

Mineral chemistry

The composition of zvyagintsevite varies from Pd_3Pb (Table 4, analyses 5, 27, 37, 48, 50, 54, 56, 58-59 and 64) to a suite compositions characterized by of substitutions. Both Pd and Pb are substituted to variable extend. The variations can be summarized as follows:

site	Substituting element	Max. admixture (wt %)	Analysis in Table 4
Pd	Pt	6.8	26
Pd	Au	7.8	6
Pd	Cu	1.5	49
Pd	Fe	1.7	38 and 60
Pb	Sn	3.7	31
Pb	As	7.5	7
Pb	Te	2.6	55

Zoned and very heterogeneous grains of zvyagintsevite are have been observed (Plate 3, #60; Table 4, analyses 50 and 51). The average chemical composition of zvyagintsevite (Table 4) is:

Element	Wt %
Pd	57.10
Pt	0.81
Au	0.43
Cu	0.22
Fe	0.62
Pb	39.10
Sn	0.60
Te	0.06
As	0.19
Total	98.69

The composition corresponds to the structural formula:

$$(Pd_{2.86}\,Fe_{0.06}Pt_{0.02}Cu_{0.02}Au_{0.01})_{\Sigma 2.97}(Pb_{1.01}Sn_{0.01}As_{0.01})_{\Sigma 1.03}.$$

Pd-arsenides

Description

Pd-arsenides are in the sample 90-23A, 808 represented by 3 mineral phases (Table 3; Fig. 1):

1) Arsenopalladinite, common, grain size between 7 to 19 µm and with an average of12 µm (Plate 4, #1-8 and 20; Plate 5, #15)
2) Guanglinite, common, grain size between 3 to 42 µm and with an average of 13 µm, (Plate 3, #59-64; Plate 4, #9-20)
3) Palladoarsenide, rare; grain size between from 8 to 10 µm and with an average of 9 µm (Plate 4, #21-23)

Pd-arsenides mostly form anhedral grains (Plate 4, #1-5, 9-17 and 19-23), but euhedral crystals can also be found (Plate 4, #6-8 and 18). Arsenopalladinite and guanglinite are in the HS-concentrates found as individual PGM grains (Plate 4, #1-5, 8-15 and 17). Some may contain fine inclusions of sperrylite (Plate 4, #6 and 18-19). Pd-arsenides occur in intergrowth with:

1) other Pd-arsenide(s) (Plate 4, #20),
2) zvyagintsevite (Plate 3, #59-64, Plate 4, #16),
3) isomertiete (Plate 4, #20),
4) (Au-Cu-Pd-Ag)-alloys (Plate 4, #7; Plate 5, #15).

Palladoarsenide has not been observed in direct contact with any other precious metal minerals.

Mineral chemistry

Microprobe analyses of Pd-arsenides are calculated as:

1) arsenopalladinite: Pd_8As_3 (Table 5, analyses 1-7 and 18)
2) guanglinite: Pd_3As (Table 5, analyses 8-17 and 19-20)
3) palladoarsenide: Pd_2As (Table 5, analyses 21- 3)

The analyses show that most of the Pd-arsenides have substitution by other elements. Observed substitution include:

Site	Substituting element	Max. admixture (wt%)	Analysis in Table 5
Pd	Au	1.4	14
Pd	Cu	4.6	22
Pd	Fe	3.0	23
As	Sn	4.8	19
As	Pb	19.1	13
As	Te	9.5	9
As	Sb	3.3	6

Au-minerals

Only four grains of Au-minerals were located in the HS-concentrates (Fig. 2, Table 3) and include:

1) bogdanovite, two grains (Plate 5, #15-16; Table 6, analyses 2-3) and one grain of
2) (Au-Cu-Pd)-alloy, one grain (Plate 5, #14; Table 6, analysis 1), as well as
3) fine inclusion of *(Au-Ag)- alloy* in arsenopalladinite (Plate 4, # 7).

Bogdanovite is in close associations with arsenopalladinite and (Pt-Fe-Pd)-alloy, whereas (Au-Cu-Pd)-alloy is in association with keithconnite and zvyagintsevite.

Other PGMs

Other PGMs identified in sample 23A 808 can be divided in two groups:

1) minerals, that are closely associated with the main PGMs, zvyagintsevite and Pd-arsenides, or Au-minerals. They include:
    a) sperrylite (Plate 4, 6, 18, 19; Table 3; Table 5, analysis 24)
    b) isomertieite (Fig. 2;Plate 4, 20; Plate 5, #11-13; Tabe 3; Table 5, analyses 25-28)
    c) keithconnite (Fig. 2; Plate 3, #65; Plate 5, #9, 10, 14; Table 3; Table 5, analyses 29-31)
    d) vasilite (Fig. 2; Plate 5, #5-10; Table 3; Table 6, analyses 12-17)
    e) Pt-Fe-Pd alloy (Plate 5, #6)

2) minerals that have not been related yet to any other precious metal minerals of the investigated sample. They include:
    a) vysotskite (Fig. 2; Plate 5, #1-4; Table 3; Table 6, analyses 18-20)
    b) unnamed PdCu (Fig. 2; Plate 5, #17-19; Table 3; Table 6, analyses 9-11)
    c) Pd-Pt-Cu alloy (Plate 5, #20-21; Table 3; Table 6, analyses 5-7)

Order of crystallisation and parageneses

The SE images and the descriptions above strongly suggest that sperrylite and isomertieite are contemporaneous with Pd-arsenides. This is indicated by their intergrowths with guanglinite and arsenopalladinite (Plate 4, #6 and 18-20). These phases could, as may monomminerallic grains of, e. g., unnamed PdCu represent early magmatic PGM phases that were preserved as inclusions in rock forming minerals. In Nielsen et al. (2003a), that describes sample 90-23A 807 just above the present sample, a Pd-arsenide paragenesis predates the dominant zvyagintsevite paragenesis.

To zviagintsevite and (Au-Cu-Pd)-alloys is associated keithconnite (Plate 3, #65; Plate 5, #14), vasilite (Plate 5, #9-10) and (Pt-Fe-Pd)-alloy (Plate 5, #16). These phases are intimately associated and crystallised together with zvyagintsevite. With reference to Nielsen et al. (2003a and d) this paragenesis is suggested to represent a re-equilibration paragenesis that coexists with the high temperature metasomatic paragenesis of H_2O-bearing silicates.

Bulk rock concentrations

The whole-rock PGE plus Au combined concentration is 2472 ppb. Based on the recovered minerals and phases (Table 3) and their compositions (Table 4-6) the distribution of Pd, Au and Pt can be recalculated as shown below:

element	assay (ppb)	this work (ppb)
Pd	2300	2330
Au	52	97
Pt	120	46

Summary

1. The HS-concentrates of sample 90-23A 808 yielded 112 grains of PGMs and 3 grains of Au-minerals.

2. The grain size varies from 2 to 69 μm with an average of 15 μm.

3. PGMs of all identified groups of PGMs are in close association with Cu-Fe sulphides, mainly bornite, and with H_2O-bearing silicates such as actinolite, chlorite, ferrous talc, biotite, and hornblende.

4. The three 3 dominant groups of PGMs in the HS-concentrates of the sample 90-23A, 808 are: zvyagintsevite (73 %); Pd-arsenide, including guanglinite, arsenopalladinite and palladoarsenide (12 %); and Pd-sulphides, including vasilite and vysotskite (10 %).

5. Zviagintsevite forms intergrowths with Pd-arsenides as well as with (Au-Cu-Pd-Ag)-alloys; Pd-arsenides form intergrowth with (Au-Cu-Pd-Ag)-alloys; keithconnite and vasilite forms intergrowth with zvyagintsevite.

6. Except for Pd-arsenides and unnamed PdCu, all other PGMs and Au-minerals seem to belong to a single paragenesis related to: 1) Cu-Fe sulphides including bornite, chalcopyrite, chalcosine and digenite, 2) H_2O-bearing silicates, and 3) quartz. This paragenesis is suggested to represent an auto-metasomatic paragenesis caused by reaction between primary phases and trapped H_20-bearing fluid/melt.

7. Pd-arsenides and unnamed PdCu are, with reference to Nielsen (2003a and d) suggested to represent early primary precious metal phases. They could have been preserved in rims of cumulus phases.

8. The recovery of Au-minerals from sample 90-23A 808 demonstrates the sensitivity of the HS-concentrator. The assay indicates a concentration of 52 ppb Au in the sample. This suggests a < 0.1 ppm sentivity of the HS-technology for PGMs and Au-minerals.

References

Nielsen, T.F.D., Rasmussen, H., Rudashevsky, N.V., Kretser, Yu.L. , Rudashevsky, V.N. 2003a): PGE and sulphide phases of the precious metal mineralisation of the Skaergaard intrusion. Part 1: Sample 90-23A 807. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2003/47**, 19 pp.

Nielsen, T.F.D., Rasmussen, H., Rudashevsky, N.V., Kretser, Yu.L., Rudashevsky, V.N. 2003d: PGE and sulphide phases of the precious metal mineralisation of the Skaergaard intrusion. Part 4: Sample 90-23A 806. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2003/53**, 18 pp.

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).

List of abbreviations

Abbreviations used in figures and tables.

Rock-forming minerals

PL	= plagioclase
CPX	= monoclinic pyroxene
OPX	= orthorhombic 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
DGN	= digenite

Precious metal minerals

ZV	= zviagintsevite
ASPD	= arsenopalladinite
GNG	= guanglinite
PLAS	= palladoarsenide
KTH	= keithconnite
VSL	= vasilite
SP	= sperrylite
PdCu	= unnamed PdCu
ISM	= isomerteite
BGD	= bogdanovite
VYS	= vysotskite
(Au,Pd,Cu)	= alloys of Au, Pd and Cu.
(Au,Cu,Pd)	= alloys of Au, Pd and Cu.
(Au,Ag)	= alloys of Au and Ag.
(Pd,Pt,Cu)	= (Pd-Pt-Cu)-alloy
(Pt,Fe,Pd)	= (Pt-Fe-Pd)-alloy
(Pd,Pt,Fe,Cu)	= (Pd-Pt-Fe-Cu)-alloy
(Pd,Pb,Cu,Au)	= (Pd-Pb-Cu-Au)-alloy
(Pd,Pt)Cu	= unnamed PdCu with Pt substitution

Table 1: Chemical composition and formulas of silicates and oxides of oxide-rich tholeiitic gabbros (sample 90-23A, 808)

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	Cl	Total
1	808-1, p2	PL+CPX+OPX+ ILM+TIMT	PL	**Wt.%**	**56.1**	**-**	**26.7**	**-**	**0.51**	**-**	**-**	**-**	**9.8**	**5.7**	**0.48**	**-**	**99.29**
				F. c.	2.55	-	1.43	-	0.02	-	-	-	0.48	0.50	0.03	-	O=8
2	808-1, p3	PL+CPX+OPX+ ILM+TIMT	PL	**Wt.%**	**55.5**	**-**	**26.7**	**-**	**0.39**	**-**	**-**	**-**	**9.5**	**5.4**	**0.48**	**-**	**98.97**
				F. c.	2.58	-	1.43	-	0.01	-	-	-	0.47	0.48	0.03	-	O=8
3	808-1, p3	PL+CPX+OPX+ ILM+TIMT	TIMT	**Wt.%**	**0.83**	**2.7**	**1.3**	**1.7**	**58.3**	**34.9**	**-**	**-**	**-**	**-**	**-**	**-**	**99.63**
				F. c.	0.25	0.63	0.46	0.42	13.35	8.88	-	-	-	-	-	-	ΣK=24
4	808-1, p3	PL+CPX+OPX+ ILM+MT	ILM	**Wt.%**	**-**	**50.9**	**-**	**0.58**	**3.3**	**45.0**	**0.76**	**-**	**-**	**-**	**-**	**-**	**100.54**
				F. c.	-	0.96	-	0.01	0.06	0.95	0.02	-	-	-	-	-	ΣK=2
5	808-1, p3	TIMT+ILM(exs)	ILM	**Wt.%**	**-**	**51.1**	**-**	**0.44**	**1.9**	**45.1**	**0.78**	**-**	**-**	**-**	**-**	**-**	**99.32**
				F. c.	-	0.98	-	0.01	0.04	0.96	0.02	-	-	-	-	-	ΣK=2
6	808-2, p3	PL+BT+ILM+TIMT	BT	**Wt.%**	**35.8**	**0.50**	**15.7**	**-**	**-**	**24.1**	**-**	**16.1**	**-**	**-**	**5.4**	**0.20**	**100.08**
				F. c.	2.70	0.03	1.40	-	-	1.52	-	1.81	-	-	0.52	0.03	ΣK=8
7	808-1, p2	BORN+HB+ACT+ CHL	HB	**Wt.%**	**36.5**	**-**	**13.3**	**-**	**21.2**	**9.2**	**0.25**	**3.0**	**11.1**	**2.4**	**0.35**	**1.6**	**98.9**
				F. c.	5.69	-	2.45	-	2.48	1.20	0.03	0.72	1.86	0.72	0.07	0.41	ΣK1=13
8	808-1, p2	BORN+HB+ACT+ CHL	ACT	**Wt.%**	**50.3**	**0.33**	**3.0**	**-**	**5.9**	**15.4**	**0.26**	**12.3**	**11.5**	**-**	**-**	**-**	**98.99**
				F. c.	7.38	0.04	0.52	-	0.65	1.89	0.03	2.69	1.80	-	-	-	ΣK=15
9	808-2, p1	ASPD+BORN+Q+ TLC+ACT+HB+ BT+CHL	ACT	**Wt.%**	**54.3**	**-**	**-**	**-**	**1.5**	**16.9**	**-**	**13.6**	**12.1**	**-**	**-**	**-**	**98.4**
				F. c.	7.92	-	-	-	0.17	2.06	-	2.95	1.90	-	-	-	ΣK=15
10	808-2, p1	---“---	BT	**Wt.%**	**35.9**	**1.0**	**14.4**	**-**	**-**	**29.2**	**-**	**9.3**	**-**	**-**	**8.1**	**0.40**	**98.3**
				F. c.	2.79	0.06	1.32	-	-	1.90	-	1.08	-	-	0.80	0.05	ΣK=8
11	808-2, p1	---“---	HB	**Wt.%**	**40.1**	**1.0**	**8.4**	**-**	**29.5**	**2.6**	**-**	**3.5**	**10.0**	**-**	**1.4**	**2.4**	**98.9**
				F. c.	6.19	0.11	1.52	-	3.43	0.34	-	0.82	1.66	-	0.28	0.64	ΣK=15
12	808-2, p1	---“---	TLC	**Wt.%**	**60.1**	**-**	**-**	**-**	**-**	**16.3**	**-**	**21.6**	**-**	**-**	**-**	**-**	**98.0**
				F. c.	3.97	-	-	-	-	0.90	-	2.13	-	-	-	-	ΣK=7
13	808-2, p1	---“---	CHL	**Wt.%**	**31.7**	**-**	**13.8**	**-**	**-**	**30.1**	**-**	**13.4**	**-**	**-**	**-**	**-**	**89.0**
				F. c.	6.68	-	3.42	-	-	5.30	-	4.21	-	-	-	-	O=28

Table 1 continued: Chemical composition and formulas of silicates and oxides of oxide-rich tholeiitic gabbros (sample 90-23A, 808)

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	Cl	Total
14	808-2, p2	BORN+Q+TLC+HB+BT+CHL	HB	**Wt.%**	**43.4**	**0.17**	**7.1**	**-**	**21.6**	**9.4**	**0.25**	**3.7**	**10.4**	**-**	**0.9**	**2.0**	**98.92**
				F. c.	6.68	0.02	1.30	-	2.51	1.20	0.03	0.85	1.72	-	0.18	0.51	ΣK=15
15	808-2, p2	BORN+Q+TLC+HB+BT+CHL	TLC	**Wt.%**	**60.4**	**-**	**1.1**	**-**	**-**	**14.8**	**-**	**20.7**	**-**	**-**	**-**	**-**	**97.0**
				F. c.	4.01	-	0.07	-	-	0.82	-	2.05	-	-	-	-	O=11
16	75-1, 4s	BORN+ILM+CHL	ILM	**Wt.%**	**-**	**51.6**	**-**	**-**	**1.6**	**45.4**	**0.9**	**-**	**-**	**-**	**-**	**-**	**99.58**
				F. c.	-	0.99	-	-	0.03	0.97	0.02	-	-	-	-	-	ΣK=24
17	125, 1	ZV+BORN+CHL+TIMT	TIMT	**Wt.%**	**-**	**9.4**	**4.5**	**0.88**	**44.4**	**40.4**	**-**	**-**	**-**	**-**	**-**	**-**	**100.54**
				F. c.	-	2.1	1.6	0.21	9,99	10.10	-	-	-	-	-	-	ΣK=2
18	125, 2	BORN+CHL+MT	MT	**Wt.%**	**1.1**	**0.34**	**-**	**-**	**65.7**	**32.8**	**-**	**-**	**-**	**-**	**-**	**-**	**99.94**
				F. c.	0.34	0.08	-	-	15.16	8.42	-	-	-	-	-	-	ΣK=24
19	75-1, 3s	BORN+CHC+ACT	ACT	**Wt.%**	**53.6**	**-**	**1.1**	**-**	**0.85**	**17.7**	**-**	**12.5**	**-**	**-**	**-**	**-**	**98.25**
				F. c.	7.86	-	0.19	-	0.09	2.17	-	1.96	-	-	-	-	ΣK=15
20	75-1, 5s	BORN+CHC+ACT+CHL	ACT	**Wt.%**	**52.5**	**0.49**	**-**	**-**	**0.5**	**23.5**	**-**	**9.9**	**11.0**	**-**	**-**	**-**	**97.89**
				F. c.	7.91	0.06	-	-	0.06	2.96	-	2.23	1.77	-	-	-	ΣK=15
21	125, 2	BORN+CHL+MT	CHL	**Wt.%**	**27.2**	**0.34**	**15.6**	**0.3**	**3.2**	**24.4**	-	**17.5**	-	-	-	-	**88.54**
				F. c.	5.73	0.05	3.88	0.05	0.51	4.29	-	5.49	-	-	-	-	ΣK=20
22	125, 1	ZV+CHL+BORN+TIMT	CHL	**Wt.%**	**27.6**	**0.34**	**15.4**	**0.3**	**1.4**	**26.6**	-	**16.4**	-	-	-	-	**88.04**
				F. c.	5.88	0.05	3.86	0.05	0.22	4.74	-	5.19	-	-	-	-	ΣK=20
23	125, 3	BORN+CHL	CHL	**Wt.%**	**27.3**	-	**19.8**	**0.3**	**4.1**	**11.0**	-	**25.8**	-	-	-	-	**88.3**
				F. c.	5.37	-	4.60	0.05	0.61	1.81	-	7.56	-	-	-	-	ΣK=20
24	75-1, 1s	BORN+CHL	CHL	**Wt.%**	**30.8**	**1.2**	**12.3**	-	-	**27.4**	-	**16.8**	-	-	-	-	**88.5**
				F. c.	6.55	0.19	3.08	-	-	4.87	-	5.31	-	-	-	-	ΣK=20
25	75-1, 23	ZV+BORN+CHL	CHL	**Wt.%**	**33.0**	**0.54**	**11.3**	-	-	**22.3**	-	**21.0**	-	-	-	-	**88.14**
				F. c.	6.81	0.08	2.76	-	-	3.85	-	6.50	-	-	-	-	ΣK=20

P. s. – polished section, f. c. – formula coefficient; FeO and Fe_2O_3 – are calculated from typical formula of minerals, ΣK – sum of kations, ΣK1 - sum of kations without of Na, K and Ca.

Table 2: Chemical composition and formulas of Cu-Fe sulphides of oxide-rich tholeiitic gabbros (sample 90-23A, 808)

An.	Object	Association of minerals	Mineral		Cu	Fe	S	Total
1	45-1, 32	ZV+BORN+ACT	BORN	**Wt.%**	**61.2**	**11.6**	**25.8**	**98.6**
				F. c.	4.88	1.05	4.07	10
2	45-1, 49	ASPD+SP+BORN	BORN	**Wt.%**	**61.3**	**11.6**	**25.9**	**98.8**
				F. c.	4.87	1.05	4.08	10
3	45-1, 65	VYS+BORN	BORN	**Wt.%**	**61.8**	**11.4**	**25.4**	**98.6**
				F. c.	4.94	1.04	4.02	10
4	75-1, 1	ZV+BORN+CP	BORN	**Wt.%**	**61.5**	**11.5**	**26.5**	**99.5**
				F. c.	4.84	1.03	4.13	10
5	75-1, 1	ZV+BORN+CP	CP	**Wt.%**	**34.6**	**30.2**	**34.8**	**99.5**
				F. c.	1.00	1.00	2.00	4
6	75-1, 3	ZV+BORN+CHL	BORN	**Wt.%**	**61.7**	**11.6**	**25.9**	**99.2**
				F. c.	4.89	1.05	4.07	10
7	75-1, 5	VSL+BORN+CP	BORN	**Wt.%**	**62.0**	**11.8**	**25.2**	**99.0**
				F. c.	4.95	1.07	3.98	10
8	75-1, 5	VSL+BORN+CP	CP	**Wt.%**	**33.6**	**30.4**	**35.6**	**99.6**
				F. c.	0.97	1.00	2.03	4
9	75-1, 9	ZV+BORN+TLC	BORN	**Wt.%**	**60.5**	**11.8**	**26.4**	**98.7**
				F. c.	4.79	1.06	4.14	10
10	75-1, 10	ZV+BORN+CHC	CHC	**Wt.%**	**77.7**	**1.0**	**20.5**	**99.2**
				F. c.	1.95	0.03	1.02	3
11	75-1, 10	ZV+BORN+CHC	BORN	**Wt.%**	**62.3**	**11.5**	**25.6**	**99.4**
				F. c.	4.94	1.04	4.02	10
12	75-1, 14	ZV+BORN	BORN	**Wt.%**	**61.6**	**11.2**	**26.0**	**98.8**
				F. c.	4.89	1.01	4.09	10
13	75-1, 19	ZV+BORN+DGN	BORN	**Wt.%**	**60.5**	**11.7**	**26.0**	**98.2**
				F. c.	4.83	1.06	4.11	10
14	75-1, 19	ZV+BORN+DGN	DGN	**Wt.%**	**74.4**	**2.3**	**22.2**	**98.9**
				F. c.	8.61	0.30	5.09	14
15	75-1, 26	VSL+BORN+CHC+CHL+MT	BORN	**Wt.%**	**62.3**	**11.6**	**25.8**	**99.7**
				F. c.	4.92	1.04	4.04	10
16	75-1, 26	VSL+BORN+CHC+CHL+MT	CHC	**Wt.%**	**77.6**	**2.3**	**19.9**	**99.8**
				F. c.	1.94	0.07	0.99	3

F. c. – formula coefficient.

Table 3: PGE, Au and Ag minerals of heavy concentrates of the sample 90-23A, 808

N	Mineral	General formula	Number of grains	Grain size (E.C.D), μm			Vol.%
				min	max	average	
1	Zvyagintsevite	$(Pd,Pt,Au)_3(Pb,Sn,As)$	68 (2*)	2	69	16	73
2	Guanglinite	$(Pd,Cu,Fe)_3(As,Pb)$	12 (6*)	3	42	13	8
3	Arsenopalladinite	$(Pd,Cu)_8As_3$	9	7	19	12	3
4	Palladoarsenide	$(Pd,Cu,Fe)_2As$	3	8	10	9	0.7
5	Vasilite	$Pd_{12}Cu_4S_7$	6	3	40	16	6
6	Vysotskite	$(Pd,Ni)S$	4	5	27	17	4
7	Bogdanovite	$(Au,Pd,Pt)_3(Cu,Fe)$	2	9	19	17	1.2
8	Au-Cu-Pd alloy	(Au,Cu,Pd)	1	-	-	16	0.7
9	Keithconnite	$Pd_{3-x}(Te,As,Pb)$	2(2*)	2	1	7	0.5
10	Isomertiete	$Pd_{11}As_2(Sb,Te)_2$	3(1*)	4	14	9	0.7
11	Unnamed PdCu	$(Pd,Pt)(Cu,Fe,Zn)$	3	10	15	13	1
11	Sperrylite	$PtAs_2$	(3*)	1	10	4	0.5
12	Pd-Pt-Cu alloy	(Pd,Pt,Cu,Fe)	2	3	9	6	0.4
13	Pt-Fe-Pd alloy	(Pt,Fe,Pd,Cu)	(1*)	-	-	5	0.3
		Total	115			15	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, 808)

An.	Grain	Association of minerals in the grain		Pd	Pt	Au	Cu	Fe	Pb	Sn	Te	As	Total
1	45-1, 4	ZV+BORN	**Wt.%**	**58.1**	-	-	**0.6**	**0.7**	**40.2**	-	-	-	**99.6**
			F. c.	2.86	-	-	0.05	0.07	1.02	-	-	-	4
2	45-1, 5	ZV	**Wt.%**	**53.6**	**3.7**	**2.1**	-	**0.7**	**38.5**	-	-	-	**98.6**
			F. c.	2.75	0.10	0.06	-	0.07	1.02	-	-	-	4
3	45-1, 8	ZV+BORN	**Wt.%**	**54.1**	**1.5**	-	**0.6**	**0.8**	**41.7**	-	-	-	**98.7**
			F. c.	2.74	0.04	-	0.05	0.08	1.09	-	-	-	4
4	45-1, 9	ZV	**Wt.%**	**59.7**	-	-	-	**0.8**	**38.5**	-	-	-	**99.0**
			F. c.	2.95	-	-	-	0.08	0.98	-	-	-	4
5	45-1, 11	ZV+BORN+CHC	**Wt.%**	**60.5**	-	-	-	-	**39.1**	-	-	-	**99.6**
			F. c.	3.00	-	-	-	-	1.00	-	-	-	4
6	45-1, 14	ZV+GNG+BORN	**Wt.%**	**51.8**	**2.3**	**7.8**	**0.5**	**0.6**	**36.9**	-	-	-	**99.9**
			F. c.	2.65	0.06	0.22	0.04	0.06	0.97	-	-	-	4
7	45-1, 15	ZV	**Wt.%**	**66.4**	-	-	-	**1.2**	**23.6**	-	-	**7.5**	**98.7**
			F. c.	2.90	-	-	-	0.10	0.53	-	-	0.47	4
8	45-1, 16	ZV+BORN	**Wt.%**	**56.8**	-	-	**0.8**	**0.4**	**40.4**	-	-	-	**98.4**
			F. c.	2.85	-	-	0.07	0.04	1.04	-	-	-	4
9	45-1, 20	(Au,Cu,Pd)+ZV+KTH+ILM+ACT	**Wt.%**	**53.1**	**2.1**	**2.4**	-	**0.6**	**41.1**	-	-	-	**99.3**
			F. c.	2.73	0.06	0.07	-	0.06	1.09	-	-	-	4
10	45-1, 22	ZV +BORN+ILM	**Wt.%**	**56.9**	-	-	**0.5**	**0.6**	**40.6**	-	-	-	**98.6**
			F. c.	2.85	-	-	0.04	0.06	1.05	-	-	-	4
11	45-1, 23	ZV	**Wt.%**	**54.6**	**2.9**	-	-	**0.9**	**40.1**	-	-	-	**98.5**
			F. c.	2.78	0.08	-	-	0.09	1.05	-	-	-	4
12	45-1, 24	ZV	**Wt.%**	**57.7**	**1.4**	-	-	**1.1**	**38.9**	-	-	-	**99.1**
			F. c.	2.86	0.04	-	-	0.10	0.99	-	-	-	4
13	45-1, 25	KTH+ZV+BORN	**Wt.%**	**57.7**	**2.7**	**2.2**	**0.7**	**0.9**	**32.7**	**1.5**	**1.1**	-	**99.5**
			F. c.	2.80	0.07	0.06	0.06	0.08	0.82	0.07	0.04	-	4
14	45-1, 26	ZV+BORN	**Wt.%**	**55.0**	**2.4**	-	**0.5**	**0.3**	**41.1**	-	-	-	**99.3**
			F. c.	2.79	0.07	-	0.04	0.03	1.07	-	-	-	4
15	45-1, 27	ZV	**Wt.%**	**57.5**	-	**1.3**	-	**1.1**	**39.3**	-	-	-	**99.2**
			F. c.	2.85	-	0.04	-	0.10	1.00	-	-	-	4

Table 4 continued: Chemical composition and formulas of the zvyagintsevite in PGM-grains of the heavy concentrates (sample 90-23A, 808)

An.	Grain	Association of minerals in the grain		Pd	Pt	Au	Cu	Fe	Pb	Sn	Te	As	Total
16	45-1, 28	ZV+BORN	**Wt.%**	**56.2**	**1.4**	**-**	**-**	**1.1**	**39.9**	**-**	**-**	**-**	**98.6**
			F. c.	2.82	0.04	-	-	0.11	1.03	-	-	-	4
17	45-1, 29	ZV+ ACT	**Wt.%**	**56.7**	**-**	**-**	**-**	**0.3**	**41.3**	**-**	**-**	**-**	**98.3**
			F. c.	2.89	-	-	-	0.03	1.08	-	-	-	4
18	45-1, 30	ZV+BORN	**Wt.%**	**57.1**	**4.2**	**-**	**-**	**0.8**	**37.0**	**-**	**-**	**-**	**99.1**
			F. c.	2.86	0.11	-	-	0.08	0.95	-	-	-	4
19	45-1, 31	ZV	**Wt.%**	**54.9**	**-**	**-**	**-**	**0.4**	**44.5**	**-**	**-**	**-**	**99.8**
			F. c.	2.80	-	-	-	0.04	1.16	-	-	-	4
20	45-1, 32	ZV+BORN+ACT	**Wt.%**	**54.9**	**1.1**	**3.2**	**-**	**0.5**	**40.0**	**-**	**-**	**-**	**99.7**
			F. c.	2.78	0.04	0.09	-	0.05	1.04	-	-	-	4
21	45-1, 33	ZV	**Wt.%**	**56.2**	**1.4**	**-**	**-**	**0.5**	**39.9**	**-**	**-**	**-**	**98.0**
			F. c.	2.86	0.05	-	-	0.05	1.04	-	-	-	4
22	45-1, 34	ZV	**Wt.%**	**60.9**	**-**	**-**	**-**	**1.3**	**36.9**	**-**	**-**	**-**	**99.1**
			F. c.	2.96	-	-	-	0.12	0.92	-	-	-	4
23	45-1, 35	ZV+GNG	**Wt.%**	**57.5**	**-**	**-**	**-**	**0.4**	**40.4**	**-**	**-**	**-**	**98.3**
			F. c.	2.91	-	-	-	0.04	1.05	-	-	-	4
24	45-1, 38	ZV+GNG	**Wt.%**	**56.8**	**-**	**-**	**-**	**0.7**	**41.6**	**-**	**-**	**-**	**99.1**
			F. c.	2.86	-	-	-	0.07	1.07	-	-	-	4
25	45-1, 39	ZV+GNG	**Wt.%**	**58.5**	**-**	**-**	**-**	**0.6**	**40.3**	**-**	**-**	**-**	**99.4**
			F. c.	2.91	-	-	-	0.06	1.03	-	-	-	4
26	45-1, 41	ZV	**Wt.%**	**56.6**	**6.8**	**-**	**-**	**0.7**	**31.9**	**2.8**	**-**	**-**	**98.8**
			F. c.	2.81	0.18	-	-	0.07	0.81	0.12	-	-	4
27	45-1, 43	ZV+BORN	**Wt.%**	**57.5**	**-**	**-**	**-**	**-**	**40.9**	**-**	**-**	**-**	**98.4**
			F. c.	2.93	-	-	-	-	1.07	-	-	-	4
28	45-1, 46	ZV	**Wt.%**	**52.3**	**4.3**	**-**	**-**	**1.0**	**40.8**	**-**	**-**	**-**	**98.4**
			F. c.	2.70	0.12	-	-	0.10	1.08	-	-	-	4
29	45-1, 47	ZV+BORN+TLC+ACT	**Wt.%**	**58.0**	**-**	**-**	**0.5**	**0.8**	**40.2**	**-**	**-**	**-**	**99.0**
			F. c.	2.86	-	-	0.04	0.08	1.02	-	-	-	4
30	45-1, 51	ZV+GNG+BORN	**Wt.%**	**57.2**	**-**	**1.1**	**-**	**-**	**40.1**	**-**	**-**	**-**	**98.4**
			F. c.	2.92	-	0.03	-	-	1.05	-	-	-	4

Table 4 continued: Chemical composition and formulas of the zvyagintsevite in PGM-grains of the heavy concentrates (sample 90-23A, 808)

An.	Grain	Association of minerals in the grain		Pd	Pt	Au	Cu	Fe	Pb	Sn	Te	As	Total
31	45-1, 52	ZV	**Wt.%**	**57.4**	**3.1**	**-**	**-**	**0.6**	**33.2**	**3.7**	**-**	**-**	**98.0**
			F. c.	2.85	0.08	-	-	0.06	0.85	0.16	-	-	4
32	45-1, 53	ZV+ILM	**Wt.%**	**58.4**	**-**	**-**	**-**	**1.1**	**40.0**	**-**	**-**	**-**	**99.5**
			F. c.	2.88	-	-	-	0.11	1.01	-	-	-	4
33	45-1, 57	ZV+ ILM	**Wt.%**	**56.1**	**2.5**	**-**	**-**	**0.5**	**39.8**	**-**	**-**	**-**	**98.9**
			F. c.	2.85	0.07	-	-	0.05	1.04	-	-	-	4
34	45-1, 58	ZV	**Wt.%**	**59.2**	**-**	**-**	**-**	**0.5**	**39.3**	**-**	**-**	**-**	**99.0**
			F. c.	2.95	-	-	-	0.05	1.00	-	-	-	4
35	45-1, 59	ZV	**Wt.%**	**49.9**	**3.9**	**-**	**-**	**0.9**	**44.6**	**-**	**-**	**-**	**99.3**
			F. c.	2.60	0.11	-	-	0.09	1.20	-	-	-	4
36	45-2, 2	ZV	**Wt.%**	**60.1**	**-**	**-**	**-**	**1.3**	**38.3**	**-**	**-**	**-**	**99.7**
			F. c.	2.92	-	-	-	0.12	0.96	-	-	-	4
37	45-2, 5	ZV	**Wt.%**	**58.0**	**-**	**-**	**-**	**-**	**41.0**	**-**	**-**	**-**	**99.0**
			F. c.	2.93	-	-	-	-	1.07	-	-	-	4
38	45-2, 8	ZV	**Wt.%**	**59.2**	**-**	**-**	**-**	**1.7**	**37.9**	**-**	**-**	**-**	**98.8**
			F. c.	2.89	-	-	-	0.16	0.95	-	-	-	4
39	45-2, 11	ZV+ACT	**Wt.%**	**57.5**	**-**	**1.6**	**-**	**0.4**	**39.5**	**-**	**-**	**-**	**99.0**
			F. c.	2.90	-	0.04	-	0.04	1.02	-	-	-	4
40	45-3, 13	ZV+BORN	**Wt.%**	**57.0**	**2.1**	**-**	**0.5**	**0.8**	**39.0**	**-**	**-**	**-**	**99.4**
			F. c.	2.83	0.06	-	0.04	0.08	0.99	-	-	-	4
41	45-2, 14	ZV+CHL+TIMT	**Wt.%**	**58.7**	**-**	**-**	**-**	**0.4**	**40.2**	**-**	**-**	**-**	**99.3**
			F. c.	2.93	-	-	-	0.04	1.03	-	-	-	4
42	45-2, 15	ZV	**Wt.%**	**55.6**	**2.6**	**-**	**-**	**1.3**	**39.6**	**-**	**-**	**-**	**99.1**
			F. c.	2.79	0.07	-	-	0.12	1.02	-	-	-	4
43	45-2, 16	ZV+BORN	**Wt.%**	**58.7**	**-**	**-**	**0.9**	**0.9**	**39.1**	**-**	**-**	**-**	**99.6**
			F. c.	2.86	-	-	0.07	0.09	0.98	-	-	-	4
44	45-2, 18	ZV+GNG	**Wt.%**	**57.7**	**-**	**1.6**	**-**	**0.9**	**38.0**	**-**	**-**	**-**	**98.2**
			F. c.	2.89	-	0.04	-	0.09	0.98	-	-	-	4
45	45-2, 19	ZV+BORN	**Wt.%**	**57.8**	**-**	**-**	**0.9**	**0.8**	**38.8**	**-**	**-**	**-**	**98.3**
			F. c.	2.86	-	-	0.07	0.08	0.99	-	-	-	4

Table 4 continued: Chemical composition and formulas of the zvyagintsevite in PGM-grains of the heavy concentrates (sample 90-23A, 808)

An.	Grain	Association of minerals in the grain		Pd	Pt	Au	Cu	Fe	Pb	Sn	Te	As	Total
46	45-2, 20	ZV	**Wt.%**	**60.2**	**-**	**-**	**-**	**1.1**	**38.6**	**-**	**-**	**-**	**99.9**
			F. c.	2.93	-	-	-	0.10	0.96	-	-	-	4
47	45-2, 21	ZV	**Wt.%**	**56.3**	**1.9**	**-**	**-**	**0.8**	**39.6**	**-**	**-**	**-**	**98.6**
			F. c.	2.84	0.05	-	-	0.08	1.03	-	-	-	4
48	75-1, 2	ZV+BORN+ILM	**Wt.%**	**57.1**	**-**	**-**	**-**	**-**	**41.7**	**-**	**-**	**-**	**98.8**
			F. c.	2.91	-	-	-	-	1.09	-	-	-	4
49	75-1, 3	ZV+ BORN+CHL	**Wt.%**	**58.9**	**-**	**-**	**1.5**	**0.8**	**37.5**	**-**	**-**	**-**	**98.7**
			F. c.	2.87	-	-	0.12	0.07	0.94	-	-	-	4
50	75-1, 6	ZV(zone1)+GNG+BORN	**Wt.%**	**58.7**	**-**	**-**	**-**	**-**	**39.9**	**-**	**-**	**-**	**98.6**
			F. c.	2.97	-	-	-	-	1.03	-	-	-	4
51	75-1, 6	ZV(zone2)+GNG+BORN	**Wt.%**	**63.5**	**-**	**-**	**1.1**	**0.4**	**31.0**	**2.8**	**-**	**-**	**98.8**
			F. c.	3.00	-	-	0.09	0.04	0.75	0.12	-	-	4
52	75-1, 7	ZV+BORN	**Wt.%**	**57.4**	**-**	**-**	**0.9**	**0.4**	**40.7**	**-**	**-**	**-**	**99.4**
			F. c.	2.85	-	-	0.07	0.04	1.04	-	-	-	4
53	75-1, 8	ZV	**Wt.%**	**57.3**	**-**	**-**	**-**	**0.3**	**40.4**	**-**	**-**	**-**	**98.0**
			F. c.	2.92	-	-	-	0.03	1.06	-	-	-	4
54	75-1, 9	ZV+BORN+TLC	**Wt.%**	**57.6**	**-**	**-**	**-**	**-**	**40.9**	**-**	**-**	**-**	**98.5**
			F. c.	2.93	-	-	-	-	1.07	-	-	-	4
55	75-1, 11	ZV+BORN+ILM	**Wt.%**	**66.0**	**-**	**-**	**-**	**0.8**	**24.0**	**-**	**2.6**	**5.5**	**98.9**
			F. c.	2.94	-	-	-	0.07	0.55	-	0.10	0.35	4
56	75-1, 12	ZV+BORN	**Wt.%**	**58.8**	**-**	**-**	**-**	**-**	**40.6**	**-**	**-**	**-**	**99.4**
			F. c.	2.95	-	-	-	-	1.05	-	-	-	4
57	75-1, 13	ZV	**Wt.%**	**57.7**	**-**	**-**	**-**	**0.4**	**40.8**	**-**	**-**	**-**	**98.9**
			F. c.	2.91	-	-	-	0.04	1.05	-	-	-	4
58	75-1, 14	ZV+BORN	**Wt.%**	**59.3**	**-**	**-**	**-**	**-**	**40.6**	**-**	**-**	**-**	**99.9**
			F. c.	2.96	-	-	-	-	1.04	-	-	-	4
59	75-1, 15	ZV+BORN+CHL	**Wt.%**	**57.4**	**-**	**-**	**-**	**-**	**41.3**	**-**	**-**	**-**	**98.7**
			F. c.	2.92	-	-	-	-	1.08	-	-	-	4
60	75-1, 16	ZV+BORN	**Wt.%**	**56.3**	**-**	**-**	**1.0**	**1.7**	**39.6**	**-**	**-**	**-**	**98.6**
			F. c.	2.76	-	-	0.08	0.16	1.00	-	-	-	4

Table 4 continued: Chemical composition and formulas of the zvyagintsevite in PGM-grains of the heavy concentrates (sample 90-23A, 808)

An.	Grain	Association of minerals in the grain		Pd	Pt	Au	Cu	Fe	Pb	Sn	Te	As	Total
61	75-1, 17	ZV+BORN+CHC	**Wt.%**	**58.1**	**-**	**-**	**0.9**	**0.6**	**39.4**	**-**	**-**	**-**	**99.0**
			F. c.	2.87	-	-	0.07	0.06	1.00	-	-	-	4
62	75-1, 19	ZV+BORN+DGN	**Wt.%**	**58.9**	**-**	**-**	**0.8**	**0.6**	**38.0**	**-**	**-**	**-**	**98.3**
			F. c.	2.91	-	-	0.07	0.06	0.96	-	-	-	4
63	75-1, 20	ZV+BORN	**Wt.%**	**60.2**	**-**	**-**	**0.8**	**0.6**	**37.8**	**-**	**-**	**-**	**99.4**
			F. c.	2.93	-	-	0.07	0.06	0.94	-	-	-	4
64	75-1, 21	ZV+GNG	**Wt.%**	**59.3**	**-**	**-**	**-**	**-**	**38.9**	**-**	**-**	**-**	**98.2**
			F. c.	2.99	-	-	-	-	1.01	-	-	-	4
65	75-1, 23	ZV+ BORN+CHL	**Wt.%**	**58.5**	**-**	**-**	**-**	**0.3**	**39.3**	**-**	**-**	**-**	**98.1**
			F. c.	2.95	-	-	-	0.03	1.02	-	-	-	4
66	75-1, 24	ZV+BORN+ILM	**Wt.%**	**55.6**	**-**	**4.2**	**0.7**	**1.0**	**38.3**	**-**	**-**	**-**	**99.8**
			F. c.	2.76	-	0.11	0/06	0.10	0.97	-	-	-	4
67	75-1, 25	ZV+GNG	**Wt.%**	**56.3**	**-**	**1.1**	**-**	**-**	**41.3**	**-**	**-**	**-**	**98.7**
			F. c.	2.88	-	0.03	-	-	1.09	-	-	-	4

Table 5: Chemical composition and formulas of arsenopalladinite, guanglinite, palladoarsenide, sperrylite, isomertieite and keithconnite in PGM-grains of the heavy concentrates (sample 90-23A, 808)

An.	Grain	Association of minerals in the grain	Mineral		Pd	Pt	Au	Cu	Fe	As	Sn	Te	Pb	Sb	Total
1	45-1, 1	ASPD+(Au,Ag)+BORN	ASPD	**Wt.%**	**79.3**	**-**	**-**	**-**	**-**	**20.6**	**-**	**-**	**-**	**-**	**99.9**
				F. c.	8.03	-	-	-	-	2.97	-	-	-	-	11
2	45-1, 7	ASPD+BORN+ACT	ASPD	**Wt.%**	**76.6**	**-**	**-**	**-**	**0.4**	**21.4**	**-**	**-**	**-**	**-**	**98.4**
				F. c.	7.82	-	-	-	0.08	3.10	-	-	-	-	11
3	45-1, 19	ASPD	ASPD	**Wt.%**	**73.7**	**-**	**-**	**2.4**	**0.8**	**21.4**	**-**	**-**	**-**	**-**	**98.3**
				F. c.	7.39	-	-	0.40	0.15	3.05	-	-	-	-	11
4	45-1, 49	ASPD+SP+BORN	ASPD	**Wt.%**	**78.3**	**-**	**-**	**0.4**	**0.5**	**20.7**	**-**	**-**	**-**	**-**	**99.9**
				F. c.	7.85	-	-	0.07	0.10	2.98	-	-	-	-	11
5	45-1, 61	BGD+ASPD	ASPD	**Wt.%**	**74.4**	**-**	**-**	**2.9**	**0.5**	**22.1**	**-**	**-**	**-**	**-**	**99.9**
				F. c.	7.33	-	-	0.48	0.09	3.09	-	-	-	-	11
6	45-2, 10	ASPD+BORN	ASPD	**Wt.%**	**77.1**	**-**	**-**	**-**	**0.8**	**16.5**	**2.0**	**-**	**-**	**3.3**	**99.7**
				F. c.	7.94	-	-	-	0.16	2.42	0.19	-	-	0.29	11.0
7	45-2, 22	GNG+ASPD+ISM+ BORN	ASPD	**Wt.%**	**74.7**	**-**	**-**	**3.4**	**-**	**21.4**	**-**	**-**	**-**	**-**	**99.5**
				F. c.	7.42	-	-	0.56	-	3.02	-	-	-	-	11
8	45-1, 18	GNG	GNG	**Wt.%**	**76.8**	**-**	**-**	**-**	**0.8**	**16.7**	**2.0**	**-**	**-**	**2.9**	**99.1**
				F. c.	2.89	-	-	-	0.06	0.89	0.07	-	-	0.09	4
9	45-1, 35	ZV+GNG	GNG	**Wt.%**	**68.2**	**-**	**-**	**-**	**-**	**5.9**	**-**	**9.5**	**15.8**	**-**	**99.4**
				F. c.	2.94	-	-	-	-	0.36	-	0.34	0.34	-	4
10	45-1, 36	GNG	GNG	**Wt.%**	**77.6**	**-**	**-**	**-**	**0.8**	**16.7**	**4.2**	**-**	**-**	**-**	**99.3**
				F. c.	2.91	-	-	-	0.05	0.89	0.15	-	-	-	4
11	45-1, 40	GNG	GNG	**Wt.%**	**75.6**	**-**	**-**	**-**	**2.1**	**14.6**	**-**	**-**	**6.6**	**-**	**98.9**
				F. c.	2.91	-	-	-	0.16	0.80	-	-	0.13	-	4
12	45-1, 48	GNG	GNG	**Wt.%**	**76.4**	**-**	**-**	**0.5**	**0.6**	**17.1**	**2.9**	**-**	**-**	**1.9**	**99.4**
				F. c.	2.86	-	-	0.03	0.04	0.91	0.10	-	-	0.06	4
13	45-1, 51	ZV+GNG+BORN	GNG	**Wt.%**	**70.3**	**-**	**-**	**-**	**0.4**	**7.2**	**-**	**2.8**	**19.1**	**-**	**99.8**
				F. c.	3.01	-	-	-	0.03	0.44	-	0.10	0.42	-	4
14	45-1, 60	GNG	GNG	**Wt.%**	**73.5**	**-**	**1.4**	**2.8**	**1.6**	**19.0**	**1.5**	**-**	**-**	**-**	**99.8**
				F. c.	2.66	-	0.03	0.46	0.31	0.98	0.05	-	-	-	4

Table 5 continued: Chemical composition and formulas of arsenopalladinite, guanglinite, palladoarsenide, sperrylite, isomertieite and keithconnite in PGM-grains of the heavy concentrates (sample 90-23A, 808)

An.	Grain	Association of minerals in the grain	Mineral		Pd	Pt	Au	Cu	Fe	As	Sn	Te	Pb	Sb	Total
15	45-1, 63	GNG+SP	GNG	**Wt.%**	**78.9**	**-**	**-**	**-**	**0.8**	**17.8**	**2.5**	**-**	**-**	**-**	**100.0**
				F. c.	2.92	-	-	-	0.06	0.94	0.08	-	-	-	4
16	45-2, 1	GNG+BORN	GNG	**Wt.%**	**76.9**	**-**	**-**	**0.9**	**0.8**	**18.5**	**1.8**	**-**	**-**	**-**	**98.9**
				F. c.	2.85	-	-	0.06	0.06	0.97	0.06	-	-	-	4
17	45-2, 7	GNG+SP	GNG	**Wt.%**	**75.1**	**-**	**-**	**3.4**	**0.7**	**20.3**	**-**	**-**	**-**	**-**	**99.7**
				F. c.	2.70	-	-	0.21	0.05	1.04	-	-	-	-	4
18	45-2, 9	ASPD	ASPD	**Wt.%**	**73.8**	**-**	**-**	**2.5**	**0.9**	**19.8**	**1.5**	**-**	**-**	**-**	**98.5**
				F. c.	7.33	-	-	0.42	0.17	2.79	0.29	-	-	-	11
19	45-2, 17	GNG	GNG	**Wt.%**	**77.5**	**-**	**-**	**-**	**1.1**	**15.5**	**4.8**	**-**	**-**	**-**	**98.9**
				F. c.	2.93	-	-	-	0.08	0.83	0.16	-	-	-	4
20	45-2, 18	ZV+GNG	GNG	**Wt.%**	**70.0**	**-**	**-**	**-**	**1.1**	**9.4**	**-**	**-**	**19.0**	**-**	**99.5**
				F. c.	2.94	-	-	-	0.09	0.56	-	-	0.41	-	4
21	45-1, 6	PLAS	PLAS	**Wt.%**	**75.6**	**-**	**-**	**-**	**0.7**	**22.7**	**-**	**-**	**-**	**-**	**99.0**
				F. c.	2.08	-	-	-	0.04	0.88	-	-	-	-	3
22	45-1, 17	PLAS	PLAS	**Wt.%**	**65.8**	**-**	**-**	**4.6**	**2.3**	**27.0**	**-**	**-**	**-**	**-**	**99.7**
				F. c.	1.70	-	-	0.20	0.11	0.99	-	-	-	-	3
23	45-1, 21	PLAS	PLAS	**Wt.%**	**68.4**	**-**	**-**	**3.1**	**3.0**	**25.0**	**-**	**-**	**-**	**-**	**99.5**
				F. c.	1.79	-	-	0.14	0.15	0.93	-	-	-	-	3
24	45-1, 49	ASPD+SP+BORN	SP	**Wt.%**	**-**	**52.7**	**-**	**0.4**	**0.7**	**41.5**	**-**	**-**	**3.0**	**-**	**98.3**
				F. c.	-	0.95	-	0.02	0.04	1.94	-	-	0.05	-	3
25	45-1, 12	ISM+MT+ACT	ISM	**Wt.%**	**71.7**	**-**	**1.3**	**1.4**	**0.8**	**9.0**	**1.5**	**-**	**-**	**14.3**	**100.0**
				F. c.	10.49	-	0.10	0.35	0.22	1.89	0.10	-	-	1.85	15
26	45-2, 37	ISM+ILM	ISM	**Wt.%**	**68.2**	**-**	**-**	**3.5**	**0.9**	**11.6**	**-**	**-**	**-**	**15.6**	**99.8**
				F. c.	9.66	-	-	0.82	0.26	2.33	-	-	-	1.93	15
27	45-2, 12	ISM+BORN	ISM	**Wt.%**	**69.0**	**-**	**-**	**2.5**	**2.6**	**9.3**	**-**	**-**	**-**	**15.5**	**98.9**
				F. c.	9.87	-	-	0.60	0.71	1.89	-	-	-	1.94	15

Table 5 continued: Chemical composition and formulas of arsenopalladinite, guanglinite, palladoarsenide, sperrylite, isomertieite and keithconnite in PGM-grains of the heavy concentrates (sample 90-23A, 808)

An.	Grain	Association of minerals in the grain	Mineral		Pd	Pt	Au	Cu	Fe	As	Sn	Te	Pb	Sb	Total
28	75-1, 22	GNG+ASPD+ISM+ BORN	ISM	**Wt.%**	**72.2**	**-**	**-**	**1.1**	**-**	**10.3**	**-**	**4.4**	**-**	**11.5**	**99.5**
				F. c.	10.58	-	-	0.27	-	2.14	-	0.54	-	1.47	15
29	45-1, 20	(Au,Cu,Pd)+ZV+KTH+ ILM+ACT	KTH	**Wt.%**	**68.5**	**-**	**-**	**-**	**0.6**	**6.4**	**-**	**15.7**	**4.7**	**2.6**	**98.1**
				F. c.	2.84	-	-	-	0.05	0.38	-	0.54	0.10	0.09	4
30	45-1, 25	KTH+ZV+BORN	KTH	**Wt.%**	**68.1**	**-**	**-**	**-**	**-**	**4.6**	**2.6**	**17.5**	**5.2**	**-**	**98.0**
				F. c.	2.89	-	-	-	-	0.28	0.10	0.62	0.11	-	4
31	45-2, 3	VSL+KTH	KTH	**Wt.%**	**68.9**	**-**	**-**	**-**	**0.7**	**-**	**-**	**29.4**	**-**	**-**	**99.0**
				F. c.	2.91	-	-	-	0.06	-	-	1.03	-	-	4

Table 6. Chemical composition and formulas of Au-Pd-Cu-Ag alloys, Pt-Fe-Pd alloy, Pd-Pt-Cu alloy, unnamed mineral phase PdCu, vasilite and vysotskite in PGM-grains of the heavy concentrates (sample 90-23A, 808)

An.	Grain	Association of minerals in the grain	Mineral		Pd	Pt	Au	Cu	Fe	Ni	Zn	Pb	Te	S	Total
1	45-1, 20	(Au,Cu,Pd)+ZV+KTH+ ILM+ACT	(Au,Cu,Pd)	**Wt.%**	**5.2**	-	**82.4**	**6.1**	**0.5**	-	-	-	-	-	**98.8**
				F. c.	0.08	-	0.70	0.16	0.02	-	-	-	-	-	1
2	45-1, 61	BGD+ASPD	BGD	**Wt.%**	**3.3**	**3.4**	**82.1**	**9.3**	**0.4**	-	-	-	-	-	**98.5**
				F. c.	0.20	0.11	2.69	0.95	0.05	-	-	-	-	-	4
3	45-1, 64	BGD+(Pt,Fe,Pd)	BGD	**Wt.%**	**19.1**	**3.7**	**59.1**	**10.2**	**1.6**	-	-	**5.9**	-	-	**99.5**
				F. c.	1.00	0.11	1.67	0.90	0.16	-	-	0.16	-	-	4
4	45-1, 64	BGD+(Pt,Fe,Pd)	(Pt,Fe,Pd)	**Wt.%**	**12.7**	**73.4**	-	**1.6**	**12.1**	-	-	-	-	-	**99.8**
				F. c.	0.16	0.51	-	0.03	0.30	-	-	-	-	-	1
5	45-1, 54	(Pd,Pt,Fe,Cu)(zone1)	(Pd,Pt,Cu,Fe)	**Wt.%**	**35.1**	**55.9**	**2.0**	**4.7**	**1.9**	-	-	-	-	-	**99.6**
				F. c.	0.45	0.39	0.01	0.10	0.05	-	-	-	-	-	1
6	45-1, 54	(Pd,Pt,Fe,Cu)(zone2)	(Pd,Cu,Pt)	**Wt.%**	**76.8**	**10.2**	**4.7**	**4.7**	**0.9**	-	-	-	**1.2**	-	**98.5**
				F. c.	0.80	0.06	0.03	0.08	0.02	-	-	-	0.01	-	1
7	45-1, 54	(Pd,Pt,Fe,Cu)(zone3)	(Pd,Pt)	**Wt.%**	**56.8**	**34.6**	**5.1**	**1.7**	**1.2**	-	-	-	-	-	**99.3**
				F. c.	0.65	0.21	0.03	0.03	0.03	-	-	-	-	-	1
8	45-1, 55	VSL+(Pd,Pb,Cu,Au)+ BORN	(Pd,Pb,Cu)	**Wt.%**	**79.3**	-	**4.9**	**2.3**	**1.0**	-	-	**10.7**	-	-	**98.2**
				F. c.	0.85	-	0.03	0.04	0.02	-	-	0.06	-	-	1
9	45-1, 42	PdCu	PdCu	**Wt.%**	**60.3**	-	**1.3**	**30.4**	**5.0**	-	**1.6**	-	-	-	**98.6**
				F. c.	0.97	-	0.01	0.82	0.16	-	0.04	-	-	-	2
10	45-1, 44	PdCu	PdCu	**Wt.%**	**55.7**	**4.8**	**2.0**	**29.5**	**5.4**	-	**0.7**	-	-	-	**98.1**
				F. c.	0.93	0.04	0.02	0.82	0.17	-	0.02	-	-	-	2
11	45-2, 4	(Pd,Pt)Cu	(Pd,Pt)Cu	**Wt.%**	**47.1**	**15.3**	-	**30.4**	**6.4**	-	-	-	-	-	**99.2**
				F. c.	0.79	0.14	-	0.86	0.21	-	-	-	-	-	2
12	45-1, 55	VSL+(Pd,Pb,Cu,Au)	VSL	**Wt.%**	**70.8**	-	-	**14.0**	**0.6**	-	-	-	-	**13.1**	**98.5**
				F. c.	11.73	-	-	3.88	0.19	-	-	-	-	7.20	23
13	45-1, 56	VSL	VSL	**Wt.%**	**71.2**	-	-	**14.2**	**0.8**	-	-	-	-	**12.7**	**99.4**
				F. c.	11.81	-	-	3.94	0.25	-	-	-	-	6.99	23
14	45-2, 3	VSL+KTH	VSL	**Wt.%**	**71.8**	-	-	**14.1**	**0.4**	-	-	-	-	**13.3**	**99.5**
				F. c.	11.80	-	-	3.88	0.13	-	-	-	-	7.20	23

Table 6 continued: Chemical composition and formulas of Au-Pd-Cu-Ag alloys, Pt-Fe-Pd alloy, Pd-Pt-Cu alloy, unnamed mineral phase PdCu, vasilite and vysotskite in PGM-grains of the heavy concentrates (sample 90-23A, 808)

An.	Grain	Association of minerals in the grain	Mineral		Pd	Pt	Au	Cu	Fe	Ni	Zn	Pb	Te	S	Total
15	75-1, 5	VSL+BORN+CP	VSL	**Wt.%**	**63.8**	**-**	**-**	**15.4**	**6.0**	**-**	**-**	**-**	**-**	**13.4**	**98.6**
				F. c.	10.08	-	-	4.08	1.81	-	-	-	-	7.03	23
16	75-1, 18	VSL+KTH+BORN+ACT	VSL	**Wt.%**	**72.3**	**-**	**-**	**14.1**	**0.3**	**-**	**-**	**-**	**-**	**13.0**	**99.7**
				F. c.	11.93	-	-	3.89	0.10	-	-	-	-	7.09	23
17	75-1, 26	VSL+BORN+CHC+ CHL+MT	VSL	**Wt.%**	**70.5**	**1.0**	**-**	**14.1**	**0.7**	**-**	**-**	**-**	**-**	**12.9**	**99.2**
				F. c.	11.68	0.09	-	3.91	0.22	-	-	-	-	7.09	23
18	45-1, 10	VYS+CHC+BORN	VYS	**Wt.%**	**71.8**	**3.6**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**22.9**	**98.3**
				F. c.	0.96	0.03	-	-	-	-	-	-	-	1.01	2
19	45-1, 62	VYS+BORN	VYS	**Wt.%**	**74.0**	**-**	**-**	**-**	**-**	**1.2**	**-**	**-**	**-**	**-**	**99.5**
				F. c.	0.94	-	-	-	-	0.03	-	-	-	-	2
20	75-1, 4	VYS+ILM	VYS	**Wt.%**	**70.1**	**-**	**-**	**-**	**0.7**	**3.1**	**-**	**-**	**-**	**24.3**	**98.2**
				F. c.	0.89	-	-	-	0.02	0.07	-	-	-	1.02	2

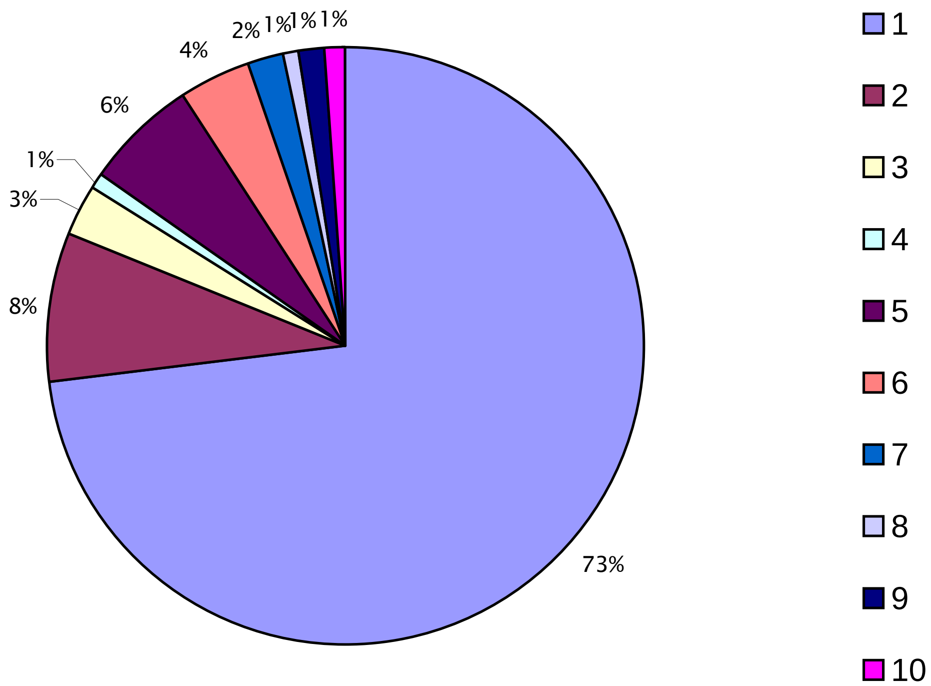

Fig. 1. PGE, Au and Ag minerals relative contents of the sample 90-23A, 808.
1: zvyagintsevite, 2: guanglinite, 3: arsenopalladinite, 4: palladoasenide, 5: vasilite, 6: vysotskit, , 7: Au-minerals (bogdanovite+Au-Cu-Pd-Ag-alloys), 8: uunamed PdCu, 9: Pt-minerals (sperrylite, Pt-Fe-Pd-Cu-alloys), 10: others.

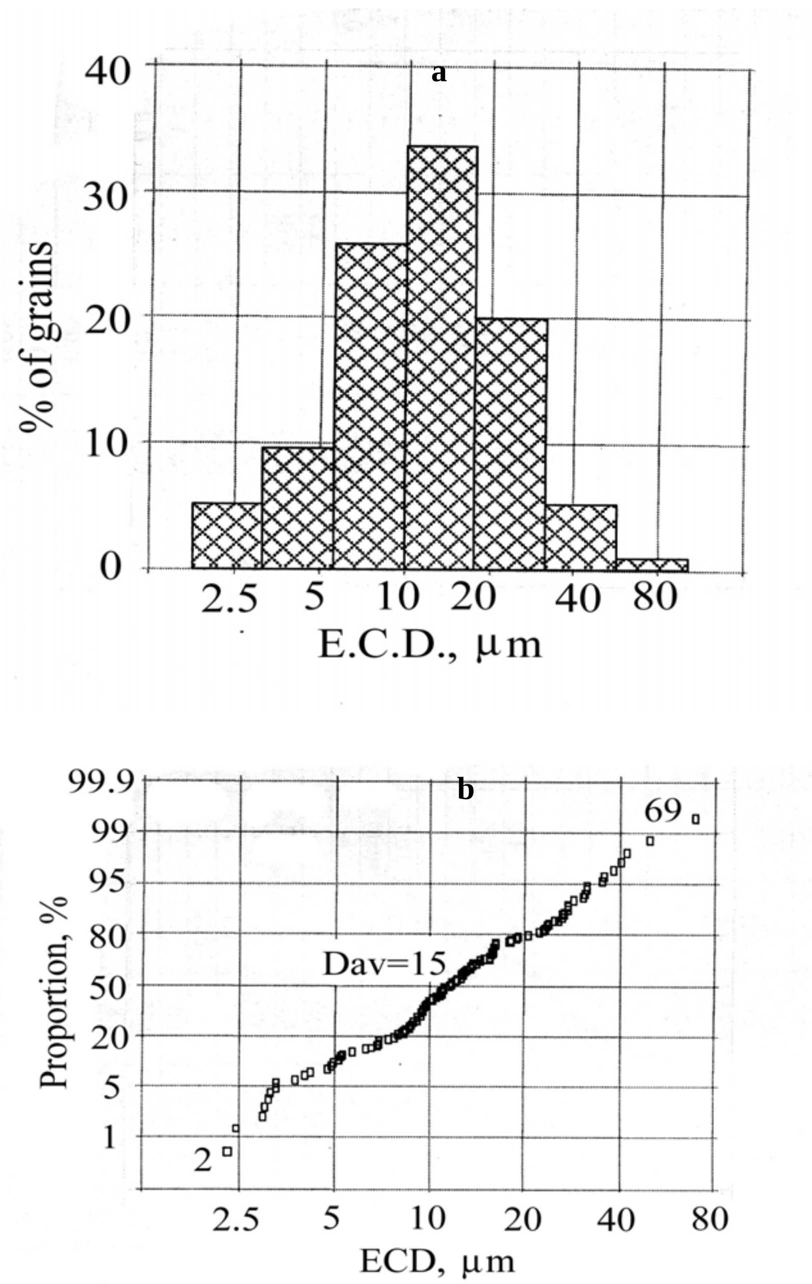

Fig. 2. Grain sizes of precious metal mineral grains (N=116), extracted in the heavy concentrates of the sample 90-23A, 808.
a: histogram, b: lognormal probability plot.

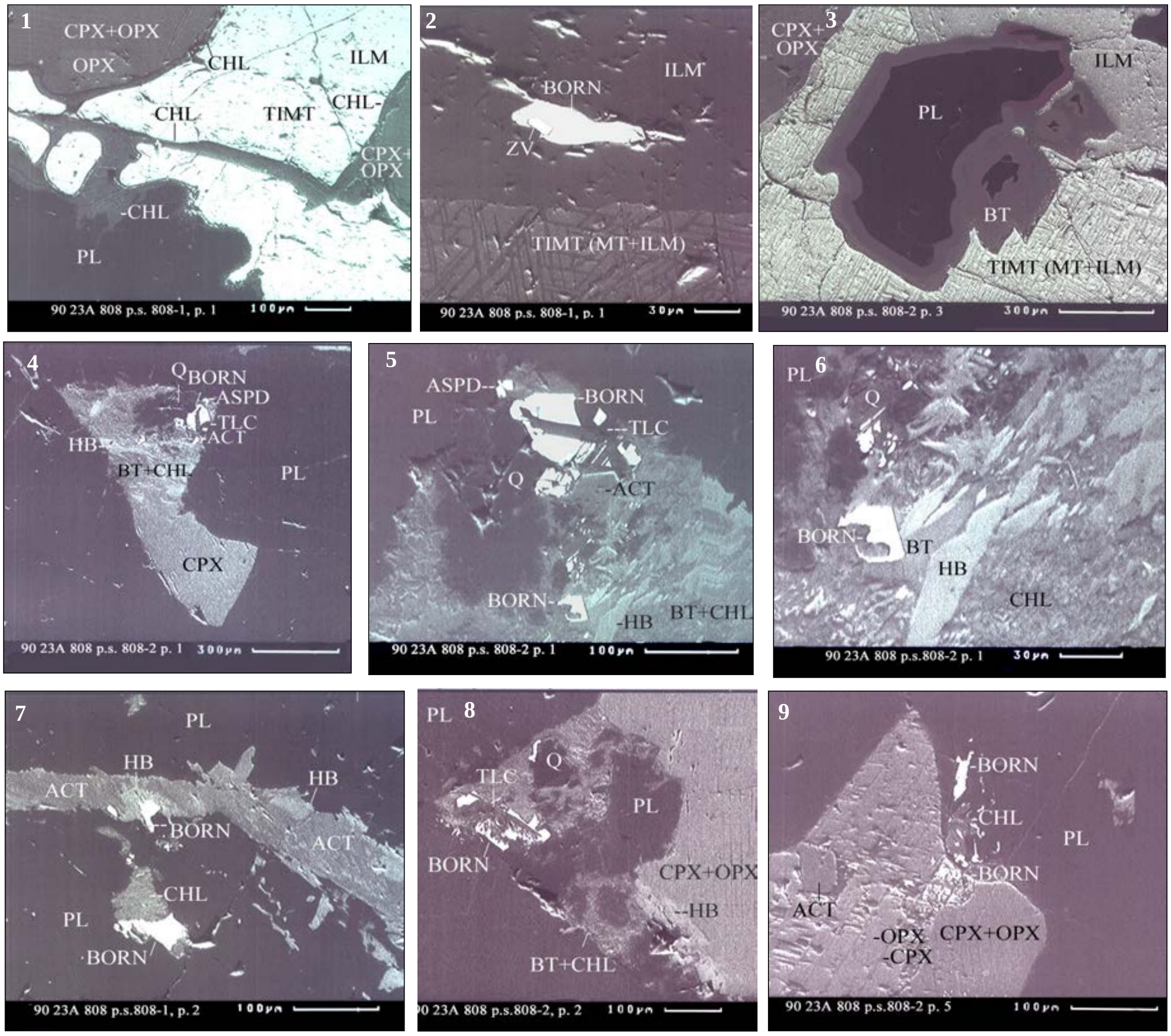

Plate 1: Relationships of rock-forming minerals, Fe-Ti-oxides, sulphides and PGMs in oxide-rich tholeiitic gabbros, the sample 90-23A, 808 (1-9); polished sections of grains, extracted in the heavy concentrates; 2: part of 1; 5 and 6: parts of 4; SEM-image (BIE), polished sections #90 23A, 808-1 and 808-2.

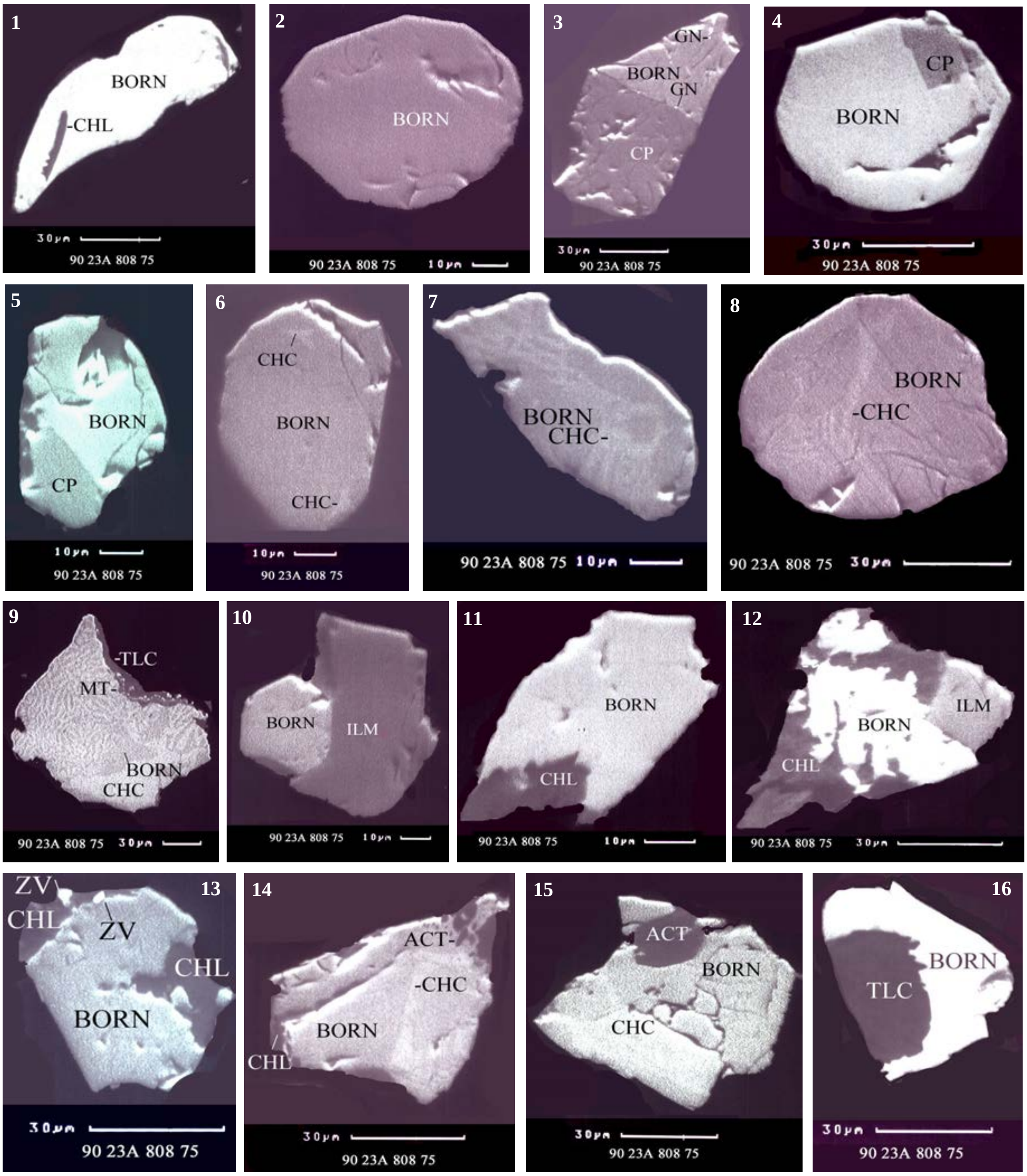

Plate 2. Sulphide mineralisation grains and globules from oxide-rich tholeiitic gabbros, the sample 90-23A, 808 (1-16); polished sections of grains, extracted in the heavy concentrates; SEM-image (BIE).

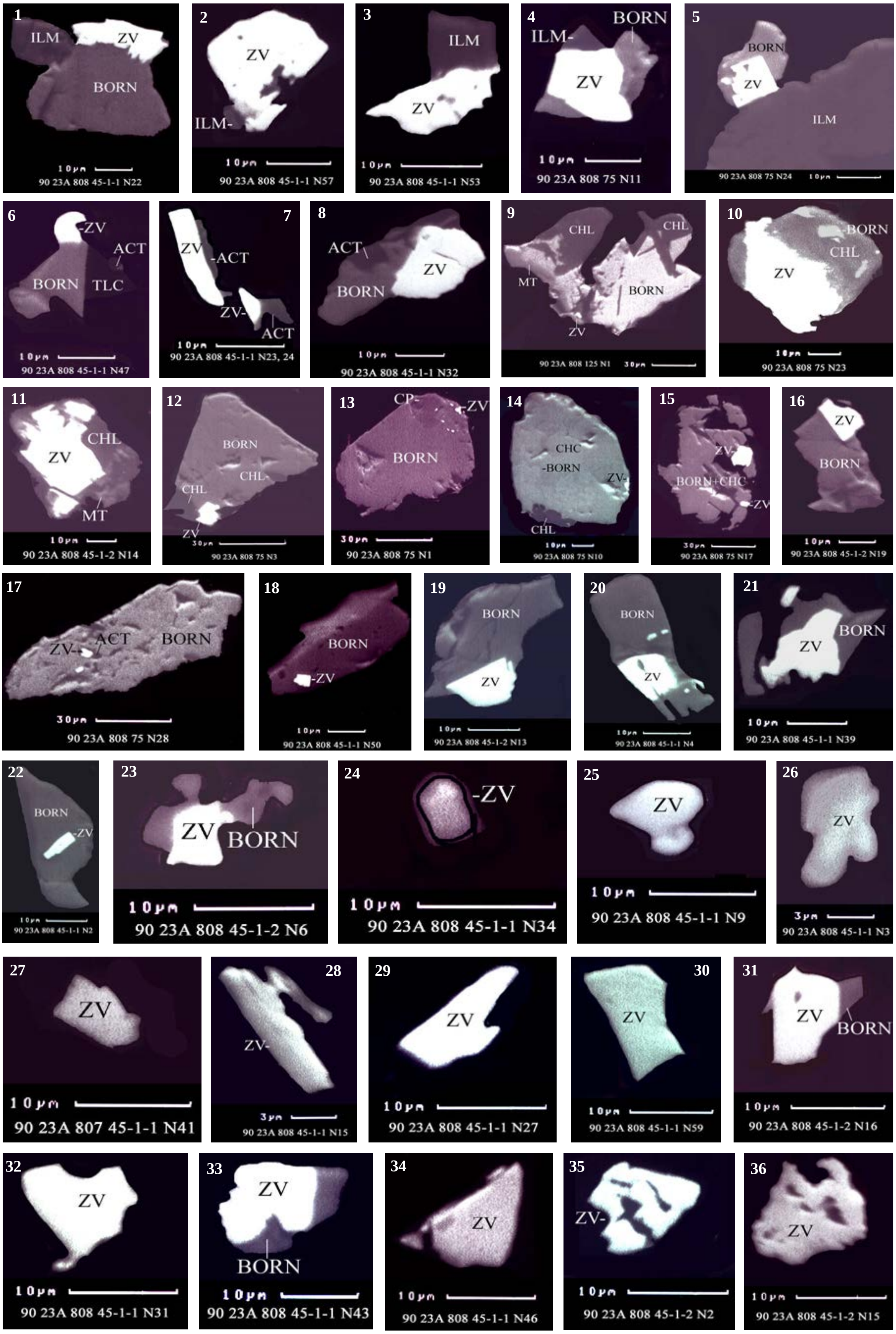

Plate 3. Grains of zvyagintsevite, extracted in heavy concentrates of the sample 90-23A, 808 (1-65); polished sections; SEM-image (BIE).

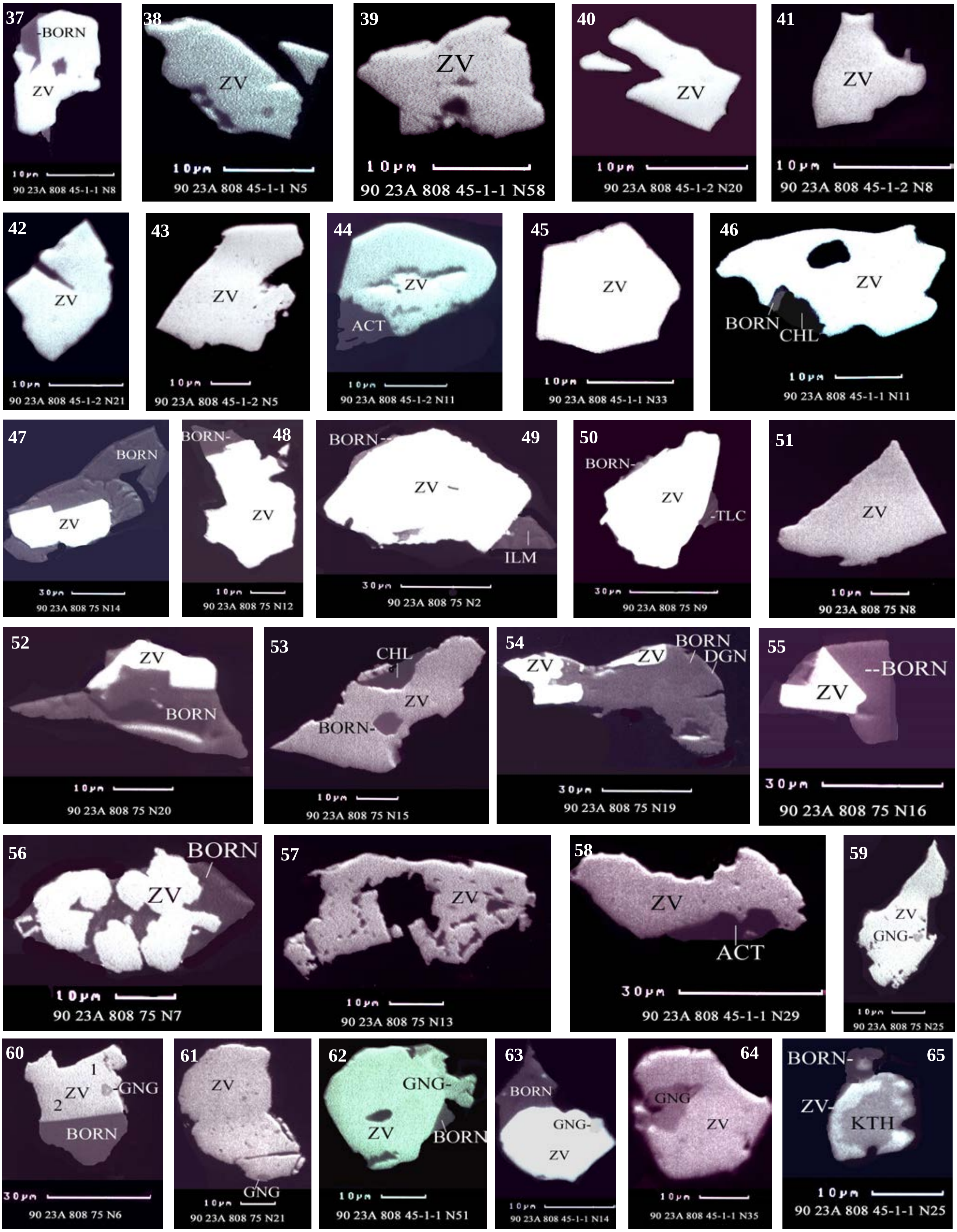

Plate 3 continued. Grains of zvyagintsevite, extracted in heavy concentrates of the sample 90-23A, 808 (1-65); polished sections; SEM-image (BIE).

Plate 4. Grains of arsenopalladinite, guanglinite and palladoarsenide, extracted in heavy concentrates of the sample 90-23A, 808 (1-23); polished sections: SEM-image (BIE).

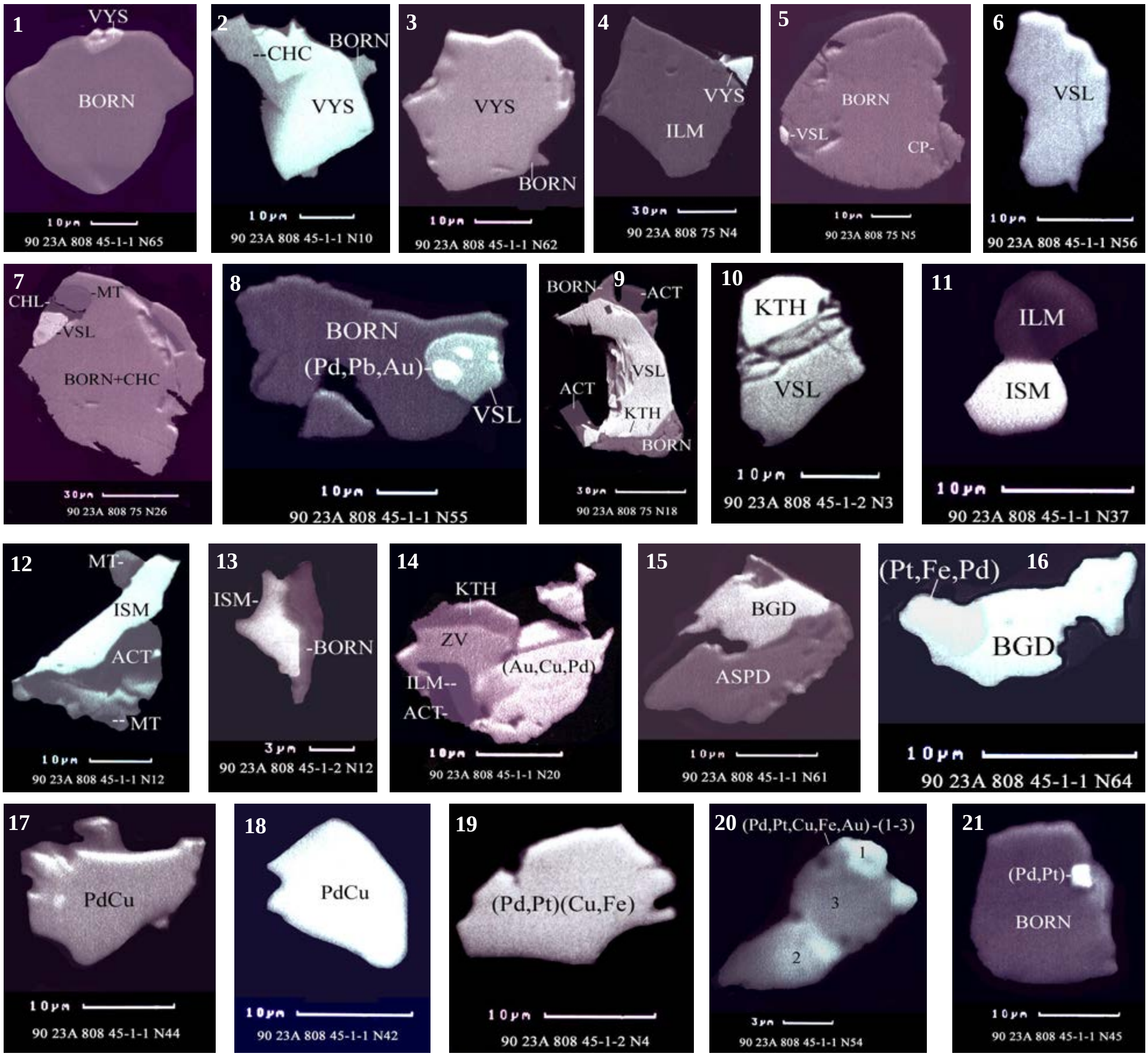

Plate 5. Grains of vysotskite, vasilite, keithconnite, isomertieite, Au-Cu-Pd-alloy, bogdanovite, Pt-Fe-Pd-alloy, unnamed mineral phase PdCu and Pd-Pt-Cu-alloy, extracted in heavy concentrates of the sample 90-23A, 808 (1-21); polished sections; SEM-image (BIE).