DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2003/47

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

Part 1: sample 90-23A, 807

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

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Contents

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. 88:7:5. The report presents the results of mineralogical investigations of sample 90-23A 807 (core 90-23A from 807 to 808 meters) from the most palladium-rich one-meter interval in the main Pd-level in the mineralisation.

The non-magnetic heavy concentrates of sample 90-23A 807 (0.76 kg) were subjected to separation using HS-01 Hydroseparator technology. From the concentrates enriched in platinum group and Au-minerals were prepared polished thin section. The thin sections were investigated under the scanning electron microscope and the electron micro probe. The magnetic concentrates contain no precious metal grains, except for rare grains inter-grown with Fe-Ti-oxides.

The sample was found to contain 165 precious metal grains, including 155 grains of platinum group minerals (PGMs) and 10 grains of Au-minerals. The dominant PGM is zviagintsevite (Pd_3Pb, 58%), followed by guanglinite (Pd3As; 12%) and arsenopalladinite (Pd_8As_3; 11%). The grain size of PGMs and Au-minerals varies between 2 and 51 μm with an average of 17 μm. Despite the low concentrations of Pt in the investigated sample (140 ppb), two Pt minerals - (Pt,Fe,Pd,Cu)-alloy and sperrylite - were identified in the concentrates. This documents the high sensitivity (100 ppb) of the hydroseparator technology.

The HS-concentrates contain spherical sulphide grains identified as sulphide droplets composed of one or more of the Cu-sulphides bornite, chalcopyrite, chalcosine and digenite. Some of these melt droplets contain grains or crystals of PGMs. However most of the PGMs and Au-minerals are intergrown with anhedral Cu-sulphides and H_2O-bearing silicates and Fe-Ti oxides.

Based on the petrographic observations the primary paragenesis (probably magmatic) consisted of sulphide droplets with grains and crystals of mainly Pd-arsenides. Most of the identified PGMs grains are composed of zviagintsevite, often in close association with H_2O-bearing phases. Very often zviagintsevite is euhedral and well crystallised

The coexistence of zviagintsevite with a hydrous re-equilibration paragenesis suggests that the entire PGM and Au-mineral paragenesis, possibly except the Pd-Arsenides, represents a re-equlibration paragenesis. It is suggested to be 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.

Introduction

This report is the first in a series that describe the mineralogy of 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 & 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-1. Mounts with concentrate have been studied using electron microscopy and electron microprobe. The report gives descriptions of the analytical techniques, 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 of 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. Pd-levels above 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 >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 in the Skaergaard intrusion. It 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, e.i. the base of the macro-rythmic layer. 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 807

Sample 90-23A 807 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 807 collects the 1 m interval with the highest Pd concentration in the Pd5 level between 807 and 808 m. The average Pd concentration between 807m and 808m is 2.8 g/t Pd and an average of combined PGE plus Au of 3.2 g/t.

The recovery between 807 and 808m is c. 80 %. 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.

Additional electron microprobe data

During a Ph.D. study Henrik Rasmussen (GEUS) collected a suite of microprobe analyses from a thin section at 807.03 meters (thin section # 90-23A 807.03). The data is shown in the appendix. In the appendix names of phases are suggested purely on the basis of their compositions.

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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.

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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, 807 (0.76 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 140 ppb Pt, 2800 ppb Pd and 270 ppb Au in that particular core interval. In addition, one thin section (90-23 807.03) was provided for optical investigation.

Analytical techniques

Sample preparation
Successful studies of accessory minerals have been carried out using a hydroseparation technique (Rudashevsky et al., 2001b and c) on rocks, ores, and industrial products (Rudashevsky et al., 1995, 1998, 2001a, e and f, 2002). The hydroseparation process relies on the successful liberation of mineral grains in powdered material. Grinding should be carried out with caution to ensure a balance between the maximum liberation and minimum fragmentation of the primary crystals of the accessory minerals. Particular care must be taken to avoid contamination (cross contamination between sample and contamination with particles from the mill).

The sample was crushed and desintegrated in a vibration grinder (Pulverizette-9) with a 100 ml steel mill. The chemical composition of the mill is known and mill particles can easily be recognised. Optimal liberation has been achieved by repeated grinding of the sample in small portions for short time intervals (15-20 sec) followed by sieving to remove the fine fraction. The whole volume of the sample was crushed -0.5 mm. After complete grinding, the sample was passed through standard sieves on the "Retsch classifier: -45, 45-75, 75-125, 125-180 and 180-500 microns. Sieves were cleaned in an ultrasonic chamber.

Each fraction was subjected to wet magnetic separation by hand before the application of the fractions to hydroseparation. Wet magnetic separation was necessary due to the high concentration of the magnetic phases in the fractions.

Hydroseparation

All concentrates free of magnetic phases (-45 microns (110 g), 45-75 microns (60 g), 75-125 microns (75 g)) as well as the magnetic -45 micron fraction were subjected to hydroseparation using hydroseparator HS-01. This technique (see reference, see Rudashevsky et al., 2001 a, b and c) concentrates all high density phases in a process that copies the formation of black sands of beaches (Rudashevsky et al., 2002)).

By correct setting of the parametres, hydroseparation concentrates all very dense phases almost independently of grain size. 7-10 mg of concentrate was obtained from each powder sample listed above. These concentrates form the basis for the mineralogical investigation.

As documented in this and the following reports the hydroseparation techniques concentrates PGE grains down to <2 micron size. As documented in the reports the recovered PGE phases sum up to bulk concentrations comparable to the assays. This suggests that most of the PGE phases in the samples were liberated and recovered.

Mounting of the sample

Each heavy mineral concentrate, as well as one sample from the coarse fraction of the primary rock (180-500 microns) was mounted in a plastic block and polished to allow optical examination and microprobe analyses.

Microscopic and microprobe investigation

Backscatter (BEI), scanning electron (SEI) images and microprobe analyses were obtained using Camscan-4 scanning electronic microscope with a Link AN-10000 energy-dispersive spectrometer and a Microspec-4DV wavelength-dispersive spectrometer. Microprobe analyses were performed using a 30 kV accelerating voltage and counting times of 50 - 100 seconds. Standards used for the analyses included pure metals: Fe, Ni, Cu, Sn, Sb, Mn, Ti, V, Pt, Pd, Au, Ag, synthetic compounds: InAs for As, PbTe for Pb and Te, Al_2O_3 for Al, and chlor-apatite for Cl; and natural minerals: diopside for Si, Ca and Mg; sanidine for K and Na; and pyrite for S. Matrix corrections were carried out by standard ZAF procedure.

The parageneses of the noble metal-bearing minerals and their relationships to the ore-forming and other accessory minerals the the main rock forming minerals are documented to the extend possible in the types of samples used in the present investigation.

Grain size investigation

Size parameters were calculated from the "effective diameter" of all studied grains. The size of a grain is defined as the diameter of the circle inscribed within the square that encloses the grain.

Results

Rock forming minerals and sulphide mineralogy

Silicates and oxides

The silicates and oxides related to sulphides and PGE phases are: 1) *plagioclase*, An_{44-45} (Table 1, analyses 1, and 2); 2) monoclinic ferrous *pyroxene*, Mg# 0.55 (Table 1, analyses 3 and 4); and 3) Fe-Ti oxides including *ilmenite* (Table 1, analyses 5, 6 and 7) and *magnetite* (Table 1, analyses 12 and 13).

The ilmenite contains 0.9 -1.1 % MnO and 0.3 - 0.5 % V_2O_3 with Fe_2O_3 calculated to 1.3 - 3.2 %. The magnetite in the concentrate has 4.6-5.5 % TiO_2, 1.3-1.8 % V_2O_3 and 1.1-2.9 % Al_2O_3.

Sulphides

Despite of the high concentrations of PGE (~3 ppm), these rocks are relatively poor in sulphides - the content of sulphides of Cu and Fe is less than 0.1 %. The aggregates of sulphides of <0.1 mm in size occur as inclusions between rock-forming minerals and are mostly associated with accumulations of oxides. As observed in the polished sections, the shapes of the sulphides are usually irregular, sometimes with rounded or droplet-like outline. They are closely intergrown with H2O-bearing minerals - ampiboles and chlorite, as well as with quartz (Plate 1, #1).

The heavy nonmagnetic concentrates are ilmenite-rich products (>90 % ilmenite) enriched in grains of sulphides and precious metal minerals.

Cu-Fe sulphides occur as grains of irregular shapes and as numerous spherical sulphide particles, up to 0.1 mm large (Plate 1, #6, 7, 9, 12 and 13). The dominant sulphides minerals are:

Bornite: Plate 1, #1-13; Table 2, analyses 1-4, 6, 8, 10, 12 and 13.
Chalcopyrite: Plate 1, #2, 7, 9, 12; Table 1, analyses 7, 9 and 11.

Chalcosine group minerals - *digenite and chalcosine* (Plate 1, #3, 4, 5 and 10; Table 1, analyses 5 and 14) vary in aboundance. Characteristic exsolution textures are observed in a number of bornite grains and chalcosine group minerals (e. g., Plate 1, #5). In addition to Cu and Fe sulphides are observed rare grains of *galena, arsenopyrite* (Plate 1, #14, 15 and 16) and *sphalerite.*

Inclusions of H2O-bearing minerals occur in sulphide aggregates. These include:

hornblende:	Plate 1, #4; Table 1, analysis 21.
actinolite:	Plate 1, #10; Table 1, analyses 23 and 24.
chlorite :	Plate 1, #1 and 11; Table 1, analyses 25-28).
ferrous talc:	Plate 1, #6; Table 1, analysis 29.
biotite:	Plate 1, #3; Table 1, analyses 17 and 19.

Intergrowths of Cu-Fe sulphides and oxide phases include:

Ilmenite:	Plate 1, #s 9 and 11.
magnetite:	Plate 1, #s 2 and 10: Table 1, analysis 15.
Baddelleyite:	Plate 1, #2.

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

Recovery

With the scanning electron microscope, only one PGM grain and four fine grains of Pd-arsenides (2-4 micron) were observed as inclusions in plagioclase in the polished thin section (90-23 807.3) and in the coarse fraction (180-500 micron) of disintegrated rock.

In contrast, the heavy mineral concentrates yielded a wide range of minerals including 155 PGE-rich minerals as well as 10 grains of Au and Ag minerals (Table 3). The dominant precious metal minerals are:

1) *zvyagintsevite* (103 grains),
2) *Pd-arsenides* (21 grains of *guanglinite*, 13 grains of *arsenopalladinite* and 1 grain of *palladoarsenide*) and
3) *Au-Cu-Ag alloys* (12 grains of *Au-Pd-Cu* and 4 grains of *Au-Ag*).

Other identified phases include 8 grains of *keithconnite*, 6 grains of *vasilite*, 3 grains of *Pt-alloys*, 4 grains of *sperrylite*, 2 grains of *native palladium*, 2 grains of *atokite*, 2 grains of *vysotskite*, 1 grain of *native silver* and 1 grain of *polybasite* (Table 3). A total of 15 precious metal minerals were identified in the sample.

No magnetic PGM phases were found in the heavy concentrate of the magnetic -45 micron fraction. The sample, however, contained 5 grains of zvyagintsevite, including one grain that was intergrown with a large grain of magnetite (Plate 4, #7).

Grain sizes

For this wide selection of precious metal minerals and phases grain sizes vary from around 3 to 51 microns, with an average of 17 micron (Table 3; Fig. 1). It should be emphasised that the majority of the grains (as shown by SEI), are well preserved and have preserved their primary shape and size (Plates 2-4). The grains have not been broken during the production of the concentrate.

Most of the liberated grains of PGMs and Au-Ag minerals are concentrated in the -45 micron fraction. Grains of PGMs and Au minerals determined in a coarser fractions (45-75 and 75-125 microns) are found in intergrowths with Cu-Fe-sulpides and rock forming minerals (e. g., Plate 1, #6-13; Plate 2, #1-5, 9-18, 83, 84 and 101). The PGMs and Au-minerals in these intergrowths are smaller than the average grain size of the fractions (Plate 2, #44, 60 and 82; Plate 3, #1, 16 and 25).

The deviation of grains <10 micron from the the log-normal distribution in Fig. 1b is probably caused by errors in grain size estimates. Diametres of grains enclosed in Cu-Fe sulphides (Plate1, #6-13) will tend to be underestimated, as only a part of an enclosed grain would be exposed on the polished surface of the investigated sample.

Based on the number of observed grains and the average grain size, the volume ratios (Table 3 and Fig. 2) of the dominant groups of precious metal minerals are as show below.

Mineral group	%
<u>Zvyagintsevite</u>	58
Pd-arsenites	25
Au-Pd-Cu and Au-Ag alloys	8
others	9

Petrography

<u>*Observations*</u>

The investigations of the thin section and the concentrates show that PGM and Au-Ag mineral phases occur as:

monomineralic grains: Plate 2, #43-48, 50 and 52-80; Plate 3, #6-11, 13 and 22-28; Plate 4 6, #13, 19 and 20-25.

in intergrowths with Cu-Fe-sulphides, including sulphide droplets: Plate 1, #6-13; Plate 2, #1-7, 10-42, 83-85, 88-94, 96, 97, 100 and 101; Plate 3, #1, 3-5, 16, 17, 19, 20,21, 29 and 31; Plate 4, #1, 2, 6, 15-17 and 26-30.

with H2O-bearing silicates such as:

chlorite (Plate 1, #10 and 11; Plate 2, #4, 5, 7, 8, 25, 28 and 98; Plate 3, #12 and 16; Plate 4, #1);

actinolite (Plate 1, #10; Plate 2, #9, 20, 38 and 100; Plate 3, #4: Plate 4, #1, 14 and 16); *hornblende* (Plate 3, #15 and 18); talc (Plate 1, #6);

biotite (Plate 2, #76)

with rock-forming minerals such as:

magnetite (Plate 1, #10 and 13; Plate 2, #7 and 81; Plate 3, #12 and 16; Plate 4, #1);

ilmenite (Plate 1, #9 and 11; Plate 2, #6, 7 and 98; Plate 4, #2, 10, 11, 15 and 18)
plagioclase (Plate 2, #76).

Some polymineral intergrowths of different combinations of PGMs, Au-Cu-Pd and Au-Ag alloys are also observed in Plate 1, #9; Plate 2, #82-101; Plate 3, #14, 21 and 29-33; Plate 4, #2-9, 11, 12, 14, 16, 17 and 29.

Native palladium, native silver and polibasite have only been observed as individual mo-nomineral grains in Plate 4, #21-24.

The paragenesis

As is shown by the many examples of well preserved micro-droplets of Cu-Fe sulphides (e. g. Plate 1, #6-13), the grains of PGMs and Au minerals, as a rule, have crystallised at the rim of sulphide droplets and aggregates. The droplets and aggregates are commonly related to H_2O-bearing silicate phases and fine, euhedral magnetite crystals in the matrix or intercumulus material in the of the gabbroic cumulate. It should, however, be noted that rare Pd-arsenite grains and precious metal phases (see also Bird et al., 1991) are found in the rims of cumulus plagioclase.

Table 1 and 2 give the chemical composition of Cu-Fe sulphides (Table 2, analyses 6-15), H_2O-bearing silicates (Table 1, analyses 18, 20, 22-25 and 27) and magnetite (Table 1, analyses 14 and 16). All minerals and phase have charateristic compositons, irrespectively of the mineral and phase association.

This is taken to indicate that the precious metals are part of a re-equilibrated paragenesis of Cu-Fe sulphides (bornite, chalcopyrite, chalcosine and digenite), PGMs, Au-Pd-Cu, Au-Ag alloys (Table 3), H_2O-bearing silicates (hornblende, actinolite, chlorite, biotite and ferrous talc) and magnetite.

Description and chemistry of PGMs and Au-minerals

Zvyagintsevite

Description

Zvyagintsevite is present in the heavy concentrate as anhedral grains and euhedral crystals. Individual grains vary from 3 to 34 microns. The average grain size is 18 micron (Table 3, Fig. 2). Most of the grains are single crystals or fragments of crystals (Plate 2, #1-82). The most common inclusion in zvyagintsevite grains is guanglinite (Plate 2, #83-93). Very characteristic are intergrowths of zvyagintsevite grains with grains of Au-Pd-Cu alloys and keithconnite (Plate 2, #98-100; Plate 3, #3-5, 9 and 14). Rare inclusions of atokite (Plate 2, #95 and 96) and Pt-alloy (Plate 2, #94), as well intergrowths of vasilite (Plate 2, #101) and vysotskite (Plate 3, #4) with zvyagintsevite are also observed.

Mineral chemistry

The chemical composition zvyagintsevite varies from near-stoichiometric Pd_3Pb (Table 4, analyses 1-2, 4-5, 7, 8, 11-12, 15, 17-18, 21-23, and 46) to the varieties with substitutions of Pt, Au, Cu, Fe, Sn, As, and Te.

Pd can be partly replaced by:

- Pt: up to 4.3 %, Table 4, analysis 24.
- Au: up to 7.3 %, Table 4, analysis 43.
- Cu: up to 1.5 %, Table 4, analysis 65.
- Fe: up to 1.7 %, Table 4, analysis 51.

Pb can be partly replaced by:

- Sn: up to 10.4 %, Table 4, analysis 14.
- As: up to 5.4 %, Table 4, analysis 67.
- Te: up to 6 %, Table 4, analysis 67.

Some very zoned and heterogeneous crystals of zvyagintsevite are also observed (Plate 2, 82; Table 4, analysis 57-59; Plate 2, 84 and 85; Table 4, analysis 66-68).

Pd-arsenides

Description

Pd-arsenides are represented by 3 minerals. The most common is guanglinite, less common is arsenopalladinite, and palladoarsenide is rare (Table 3; Fig. 2). Grain sizes of guanglinite vary from 10 to 29 microns, with an average of 18 microns (Table 3, Plate 3, #15-32). Arsenopalladinite (Table 3; Plate 3, #1-13) and palladoarsenide (Table 3; Plate 3, #33) tend to form the larger grains, up to 51 microns.

Pd-arsenides mostly form anhedral grains (Plate 3, #2, 3 and 5-33), but arsenopalladinite sometimes also occurs as euhedral crystals (Plate 3, #1 and 4).

Arsenopalladinite is associated with *no* other PGM phase than guanglinite (Plate 3, #1-14: Table 5, analyses 20 and 34).

Guanglinite, on the contrary, is in the heavy concentrate found as:

1) individual PGM grains (Plate 3, #15-20 and 22-28).
2) grains with fine inclusions of sperrylite (Plate 3, #29-32).
3) associated with zvyagintsevite (Plate 3, #21).
3) as inclusions in zvyagintsevite grains (Plate 3, #83-94).

Palladoarsenide occurs with Au-rich Au-Ag alloy (Plate 3, #33).

<u>*Mineral chemistry*</u>

The microprobe analyses of Pd-arsenides are calculated as:

guanglinite :	Pd_3As (Table 5, analyses 1-26).
arsenopalladinite:	Pd_8As_3 (Table 5, analyses 27-39).
palladoarsenide:	Pd_2As (Table 5, analysis 40).

The chemical compositions of these Pd-arsenides vary from the stoichiometric guanglinite (Table 5, analyses 6 and 20) and arsenopalladinite (Table 5, analysis 36) to the isomorphic compositions with the following substitutions:

Guanglinite:	Pt up to 2.1 %; Table 5, analysis 2.
	Cu up to 2.9 %; Table 5, analysis 22.
	Fe up to 1.0 %; Table 5, analysis 22.
	Sn up to 7.5 %; Table 5, analysis 13.
	Pb up to 11.3 %; Table 5, analysis 1.
	Te up to 11.3 %; Table 5, analysis 3.
	Sb up to 3.9 %; Table 5, analysis 18.
Arsenopalladinite:	Pt up to 2.4 %; Table 5, analysis 28.
	Cu up to 3.4 %; Table 5, analysis 29.
	Fe up to 1.0 %; Table 5, analysis 33.
	Sn up to 6.2 %; Table 5, analysis 30.
	Te up to 8.9 %; Table 5, analysis 30.
	Sb up to 2.2 %; Table 5, analysis 30.
Palladoarsenide:	Cu 0.5 %; Table 5, analysis 40.

Au minerals

Description

Au minerals belong to two groups of alloys. They only form anhedral grains and include:

1) Au-Pd-Cu alloys (Table 3; Plate 4, #1-17)
2) Pd-Ag alloys (Fig. 4, #33; Plate 3, #8-20, Table 3).

(Au-Pd-Cu)-alloys are usually closely related to keithconnite (e. g., Plate 2, #99 and 100; Plate 4, #2-4, 6-8, 11,12, 14, 16 and 17) and zviagintsevite (e. g., Plate 2, #99 and 100; Plate 3, #3-5, 9, and 14), as well as with vasilite (Plate 4, #6) and vysotskite (Plate 4, #4). Grains of Au-Pd-Cu alloys occur sometimes in sulphide droplets that also contain grains of PGE phases, but direct relationship seems to exist between Au.Pd-Cu alloys and PGE (e. g., Plate 4, #1,10 and 13). The grain sizes of Au-Pd-Cu alloys varies from 6 to 20 μm, with an average of 13 micron.

(Au-Ag)-alloys are represented by three monomineral grains (Plate 3, #18-20). They range fromfrom 12 to 41 μm with an average of 25 μm. One grain is an intergrowth between (Au,Ag) and palladoarsenide (Plate 3, #33).

Mineral chemistry

(Au-Pd-Cu)-alloys show a wide compositional range. They have compositions similar to several of the mineral found in the Au-Cu system (Table 3):

1) *(Au, Pd)$_3$Cu* – bogdanovite (Table 6, analyses 9-11, 13,14 and 17).
2) *(Au,Pd)Cu* - tetraauricupride (Table 6, analysis 12).
3) *disordered (Au,Pd,Cu) alloy* (Table 6, analyses 1-8, 15 and 16).

Substitutions are common in all of these minerals:

Au may be substituded by:	Ag, up to 8.1 % (Table 6, analysis 33).
Pd may be substituded by:	Pt, up to 3.5 % (Table 6, analysis 2).
Cu may be substituded by:	Fe (up to 1.2 % (Table 6 analysis 17).

”Primary” (Au,Cu,Pd) alloys may show exsolution textures of *(Au,Pd)$_3$Cu* and *(Au,Pd)Cu* (Plate 4, #11 and 12). Grains of bogdanovite may be chemically zoned (e. g., Plate 4, #4; Table 6, analyses 13 and 14).

Au-Ag alloys correspond to compositions of *native gold* (Table 6, analyses 18 and 19) and the unnamed mineral phase *Au$_3$Ag* (Table 6, analyses 20 and 21).

Other precious metal phases

A small number of grains of other precious metal phases have been observed Besides the above-mentioned minerals and phases. They can be divided into two groups:

Group I phases show no paragenetic relationship to any other precious metal phases. They include:

1) *native palladium* (Plate 4, #23 and 24; Table 6, analyses 24 and 25).
2) *native silver* (Plate 4, #6 and 21; Table 6, analysis 22).
3) *polybasite* (Plate 4, #22; Table 6, analysis 33).

Group II minerals are closely associated with the main PGE minerals (zvyagintsevite and guanglinite) and Au - alloys (Au,Pd,Cu). They include:

1) *atokite* (Plate 2, #95 and 96; Plate 3, analyses 41, and 42).
2) *(Pt,Fe,Pd,Cu) alloy* (Plate 2, #94 and Plate 4, #25: Table 6, analysis 23).
3) *sperrylite* (Ålate 3, #29-32, Table 5, analyses 50 and 51).
4) *keithconnite* (Plate 1, #9; Plate 2, #98-100; Plate 4, #2,-4, 6, -8, 11, 12, 14, 17 and 29; Table 5, analyses 43-49; Table 3).
5) *vasilite* (Plate 1, #12; Fig. 4, #101; Plate 4, #6 and 26-29; Table 6, analyses 26-30).
6) *vysotskite* (Plate 1, #13; Plate n4, #4 and 30; Table 6, analyses 31 and 32).

Order of crystallisation

The observations do in part allow the reconstruction of the order crystallisation in the sulphide and precious metal mineral paragenesis of sample 90-23A, 807.

The earliest precious metal phases crystallised in sulphide droplets were Pd-arsenides (arsenopalladinite, guanglinite and probably palladoarsenide), Pt-minerals (Pt-alloy and sperrylite) and atokite. Several of these occur as inclusions in zvyagintsevite. In consecutive order, zvyagintsevite is followed by Au-Pd-Cu-Ag alloys, keithconnite and Pd-sulphides (vasilite and vysotskite).

The possibility exists, that the early (high temperature) Pd-arsenides crystallised idependently of the formation of sulphide droplets. Pd-arsenites have a wide distribution in the gabbros and occur, without coexisting sulphide in liquidus plagioclase.

Summary

The conclusions that may be suggested from the investigations are:

1) 15 different species of precious metal minerals and phases have been identified in the investigated sample (90-23A, 807).

2) Based on the observations the primary paragenesis (probably magmatic has been reconstructed. The earliest PGE phase seems to have been Pd-arsenides. They are in turn followed by zvyagintsevite, alloys and PGE sulphides.

3) Despite the low concentrations of Pt in the investigated sample (140 ppb), two Pt minerals - (Pt,Fe,Pd,Cu)-alloy and sperrylite - were identified in the concentrates. This shows the high sensitivity (100 ppb) of the hydroseparation technology and proves the application of this technology in the study of low concentration accessory mineral phases.

4) The whole-rock Pd:Au:Pt ratio is 90:8:4. Based on a balance between the phases (zvyagintsevite, Pd-arsenides, Au-Pd-Cu-Ag alloys other PGMs and Pt-minerals (see Table 3) the Pd:Au:Pt ratio found to be 90:9:1 and very close to the assay ratio. This suggests that the recovery of precious metal phases and minerals is representative for the mineralogy of the sample.

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List of abbreveviations

Abbreveviations used in figures and tables.

Rock-forming minerals

PL	= plagioclase
CPX	= monoclinic pyroxene
ILM	= ilmenite
MT	= magnetite
ACT	= actinolite
HBL	= hornblende
BT	= biotite
CHL	= chlorite
TLC	= talc
BDL	= baddelleyite
Q	= quartz
AP	= apatite

Sulphides

BORN	= bornite
CP	= chalcopyrite
CHC	= chalcosine
DGN	= digenite
GN	= galena
ARSP	= arsenopyrite

Precious metal minerals

ZV	= zviagintsevite
ARSPD	= arsenopalladinite
GNG	= guanglinite
PLDAS	= palladoarsenide
KTH	= keithconnite
AT	= atokite
VSL	= vasilite
VYS	= vysotskite
SP	= sperrylite
PLBS	= polybasite
(Au,Pd)Cu	= tetraauricupride
$(Au,Pd)_3Cu$	= unnamed new phase
(Pt,Fe,Pd,Cu)	= Pt-alloy
(Au,Pd,Cu), (Au,Ag,Pd,Cu) etc.	= alloys of Au, Pd, Cu and Ag
Ag and (Au,Ag)	= native silver and alloys of Au and Ag
Pd	= native palladium

Table 1. *Chemical composition and formulas of silicates and oxides of oxide-rich tholeiitic gabbros (sample 90-23A, 807)*

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	P.s.	PL+CPX+ILM+MT	PL	**Wt.%**	**56.1**	**-**	**26.8**	**-**	**0.58**	**-**	**-**	**-**	**9.1**	**6.9**	**0.42**	**-**	**99.90**
				F. c.	2.54	-	1.43	-	0.03	-	-	-	0.44	0.60	0.02	-	O=8
2	P. s.	PL+CPX+ILM+MT	PL	**Wt.%**	**56.8**	**-**	**27.1**	**-**	**0.52**	**-**	**-**	**-**	**9.5**	**5.7**	**0.31**	**-**	**99.93**
				F. c.	2.55	-	1.44	-	0.02	-	-	-	0.46	0.50	0.02	-	O=8
3	P. s.	PL+CPX+ILM+MT	CPX	**Wt.%**	**52.5**	**0.66**	**0.61**	**-**	**-**	**16.9**	**0.42**	**11.9**	**18.9**	**-**	**-**	**-**	**101.89**
				F. c.	1.98	0.02	0.03	-	-	0.53	0.01	0.66	0.73	-	-	-	ΣK=4
4	P. s.	PL+CPX+ILM+MT	CPX	**Wt.%**	**50.8**	**0.75**	**0.72**	**-**	**4.0**	**13.7**	**0.38**	**11.6**	**17.9**	**0.95**	**-**	**-**	**100.80**
				F. c.	1.94	0.02	0.03	-	0.11	0.42	0.01	0.66	0.73	0.07	-	-	ΣK=4
5	P. s.	PL+CPX+ILM+MT	ILM	**Wt.%**	**-**	**51.0**	**-**	**0.49**	**3.2**	**44.7**	**0.95**	**-**	**-**	**-**	**-**	**-**	**100.34**
				F. c.	-	0.97	-	0.01	0.06	0.94	0.02	-	-	-	-	-	ΣK=2
6	P. s.	PL+CPX+ILM+MT	ILM	**Wt.%**	**-**	**51.1**	**-**	**0.39**	**3.2**	**45.6**	**1.1**	**-**	**-**	**-**	**-**	**-**	**101.39**
				F. c.	-	0.97	-	0.01	0.06	0.94	0.02	-	-	-	-	-	ΣK=2
7	P. s.	PL+CPX+ILM+MT	ILM	**Wt.%**	**-**	**51.7**	**-**	**0.25**	**1.3**	**46.9**	**0.86**	**-**	**-**	**-**	**-**	**-**	**101.01**
				F. c.	-	0.98	-	0.01	0.02	0.97	0.02	-	-	-	-	-	ΣK=2
8	45-M, 1	ZV+MT+ILM	ILM	**Wt.%**	**-**	**51.1**	**-**	**-**	**3.2**	**46.2**	**1.0**	**-**	**-**	**-**	**-**	**-**	**101.5**
				F. c.	-	0.97	-	-	0.06	0.95	0.02	-	-	-	-	-	ΣK=2
9	120, 6	ILM+BORN+DGN +HB	ILM	**Wt.%**	**-**	**51.7**	**-**	**0.50**	**2.7**	**45.3**	**0.80**	**-**	**-**	**-**	**-**	**-**	**101.0**
				F. c.	-	0.97	-	0.01	0.06	0.95	0.02	-	-	-	-	-	ΣK=2
10	120, G	ZV+MT+CHL+ILM	ILM	**Wt.%**	**-**	**52.0**	**-**	**0.40**	**2.7**	**45.8**	**0.90**	**-**	**-**	**-**	**-**	**-**	**101.8**
				F. c.	-	0.97	-	0.01	0.05	0.95	0.02	-	-	-	-	-	ΣK=2
11	120, 2	KTH+$(Au,Pd)_3Cu$+ BORN+CP+ILM	ILM	**Wt.%**	**-**	**51.2**	**-**	**0.60**	**3.8**	**43.4**	**0.80**	**1.0**	**-**	**-**	**-**	**-**	**100.8**
				F. c.	-	0.96	-	0.01	0.07	0.90	0.02	0.04	-	-	-	-	ΣK=2
12	P. s.	PL+CPX+ILM+MT	MT	**Wt.%**	**-**	**5.5**	**2.9**	**1.3**	**54.6**	**37.2**	**-**	**-**	**-**	**-**	**-**	**-**	**101.5**
				F. c.	-	0.15	0.13	0.04	1.52	1.16	-	-	-	-	-	-	ΣK=3
13	P. s.	PL+CPX+ILM+MT	MT	**Wt.%**	**-**	**4.6**	**1.1**	**1.8**	**57.3**	**36.5**	**-**	**-**	**-**	**-**	**-**	**-**	**101.3**
				F. c.	-	0.13	0.05	0.05	1.64	1.13	-	-	-	-	-	-	ΣK=3

Table 1 continued. *Chemical composition and formulas of silicates and oxides of oxide-rich tholeiitic gabbros (sample 90-23A, 807)*

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	45 M, 1	ZV+MT+ILM	MT	**Wt.%**		**4.7**	**1.4**	**1.7**	**57.4**	**34.1**	**0.30**						**99.6**
				F. c.		0.14	0.06	0.05	1.65	1.09	0.01						ΣK=3
15	120, F	BORN+MT+CHL	MT	**Wt.%**		**4.4**	**3.3**	**1.6**	**53.2**	**36.5**	**-**						**99.0**
				F. c.		0.13	0.14	0.05	1.52	1.16							ΣK=3
16	45-2, 87	ZV+MT	MT	**Wt.%**		**3.0**	**1.0**	**1.7**	**60.2**	**32.1**		**1.4**					**99.4**
				F. c.		0.09	0.05	0.05	1.72	1.02		0.07					ΣK=3
17	P. s.	BORN+BT	BT	**Wt.%**	**29.7**	**3.7**	**11.4**	**1.3**		**21.4**		**7.1**			**7.6**		**82.2**
				F. c.	2.72	0.26	1.23	0.09		1.64		0.97			0.89		O=11
18	45-2, 93	ARSPD+BT	BT	**Wt.%**	**32.8**	**6.1**	**15.6**		**5.3**	**18.6**		**10.0**			**4.9**	**0.3**	**93.5**
				F. c.	2.54	0.35	1.43		0.31	1.21		1.16			0.48	0.04	O=11
19	120, j	BORN+DGN+BT	BT	**Wt.%**	**35.9**	**1.9**	**13.5**		**4.2**	**10.3**		**18.3**			**8.7**	**0.3**	**93.1**
				F. c.	2.73	0.11	1.21		0.24	0.65		2.07			0.85	0.04	O=11
20	45-2, 83	GNG+HB	HB	**Wt.%**	**45.4**	**1.1**	**9.8**		**6.0**	**20.4**	**0.5**	**4.0**	**10.7**		**0.5**	**0.4**	**98.8**
				F. c.	6.87	0.13	1.75		0.68	2.59	0.07	0.91	1.74		0.09	0.10	O=23
21	120, 6	BORN+DIG+HB	HB	**Wt.%**	**49.5**	**0.5**	**5.8**	**0.24**	**11.8**			**18.0**	**12.2**		**0.26**		**98.3**
				F. c.	6.94	0.05	0.97	0.03	1.25			3.77	1.84		0.05		O=23
22	45-2, 18	(Au,Cu,Pd)+KTH+ ZV+ACT	ACT	**Wt.%**	**54.3**		**1.0**		**6.3**	**8.2**		**16.0**	**12.1**				**97.9**
				F. c.	7.76		0.17		0.68	0.98		3.41	1.86				O=23
23	120, D	(Au,Cu,Pd)+BORN +DGN+ACT	ACT	**Wt.%**	**51.0**	**0.3**	**1.3**	**1.2**	**9.2**	**11.6**		**12.2**	**11.5**				**98.3**
				F. c.	7.48	0.03	0.22	0.14	1.02	1.42		2.68	1.81				O=23
24	120, E	$(Au,Pd)_3Cu$+BORN+ DGN+ACT	ACT	**Wt.%**	**51.4**	**0.3**	**1.0**	**1.2**	**7.2**	**13.5**		**12.1**	**11.9**				**98.6**
				F. c.	7.54	0.03	0.18	0.14	0.80	1.66		2.65	1.87				O=23
25	120, G	ZV+BORN+CHL+ ILM	CHL	**Wt.%**	**23.5**	**4.7**	**15.4**	**0.5**		**32.0**		**12.9**					**89.0**
				F. c.	1.28	0.19	0.99	0.02		1.47		1.06					O=7
26	120, A	BORN+DGN+CHL	CHL	**Wt.%**	**25.8**		**14.9**		**5.4**	**29.0**		**13.5**					**88.6**
				F. c.	1.41		0.96		0.22	1.32		1.09					O=7

Table 1 continued. *Chemical composition and formulas of silicates and oxides of oxide-rich tholeiitic gabbros (sample 90-23A, 807)*

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
27	120, 3	ZV+BORN+CHL	CHL	**Wt.%**	**26.1**	**-**	**16.4**	**-**	**4.0**	**28.3**	**-**	**14.0**					**89.0**
				F. c.	1.40	-	1.04	-	0.16	1.27	-	1.13					O=7
28	120, F	BORN+MT+CHL	CHL	**Wt.%**	**33.0**	**0.3**	**13.4**	**0.9**	**-**	**12.7**	**-**	**28.7**					**89.0**
				F. c.	1.60	0.01	0.77	0.04	-	0.51		2.07					O=7
29	120, B	ZV+BORN+TLC	TLC	**Wt.%**	**60.7**	**-**	**-**	**-**	**-**	**15.5**		**21.8**					**98.0**
				F. c.	4.00	-	-	-	-	0.85		2.15					O=11

P.s. – polished section, f.c. – formula coefficient; FeO and Fe_2O_3 – are calculated 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, 807)*

An.	Object	Association of minerals	Mineral		Cu	Fe	S	Total
1	P. s.	BORN+CPX+PL+ILM +MT	BORN	**Wt.%**	**63.6**	**11.9**	**25.1**	**100.6**
				F. c.	5.01	1.07	3.92	10
2	P. s.	BORN+CPX+PL+ILM +MT+CHL+Q	BORN	**Wt.%**	**63.0**	**11.5**	**25.2**	**99.7**
				F. c.	5.00	1.04	3.96	10
3	P. s.	BORN+CPX+PL+ILM +MT+Q	BORN	**Wt.%**	**63.6**	**11.2**	**25.7**	**100.5**
				F. c.	5.00	1.00	4.00	10
4	120, 4	BORN+CHC	BORN	**Wt.%**	**63.7**	**11.4**	**24.9**	**100.0**
				F. c.	5.05	1.03	3.92	10
5	120, 4	“	CHC	**Wt.%**	**77.6**	**1.2**	**19.7**	**98.5**
				F. c.	1.97	0.03	1.00	3
6	120, 2	KTH+$(Au,Pd)_3Cu$+ BORN+CP	BORN	**Wt.%**	**63.0**	**11.9**	**24.4**	**99.3**
				F. c.	5.05	1.08	3.87	10
7	120, 2	“	CP	**Wt.%**	**34.2**	**31.1**	**34.2**	**99.5**
				F. c.	1.00	1.03	1.97	4
8	120, 7	BORN+CP	BORN	**Wt.%**	**62.6**	**11.9**	**25.0**	**99.5**
				F. c.	4.98	1.08	3.94	0.02
9	120, 7	“	CP	**Wt.%**	**33.9**	**30.3**	**34.1**	**98.3**
				F. c.	1.00	1.01	1.99	4
10	120, 9	VSL+BORN+CP	BORN	**Wt.%**	**62.4**	**11.4**	**25.3**	**99.1**
				F. c.	4.97	1.04	3.99	10
11	120, 9	“	CP	**Wt.%**	**34.4**	**30.3**	**34.1**	**98.8**
				F. c.	1.01	1.01	1.98	4
12	75, 2	ZV+BORN	BORN	**Wt.%**	**62.1**	**11.9**	**25.7**	**99.7**
				F. c.	4.92	1.07	4.01	10
13	120, 3	ZV+BORN+DGN	BORN	**Wt.%**	**62.0**	**11.8**	**25.2**	**99.0**
				F. c.	4.95	1.07	3.98	10
14	120, 3	“	DGN	**Wt.%**	**73.4**	**3.6**	**21.2**	**98.2**
				F. c.	8.60	0.49	4.91	14

P. s. – polished section, f. c. – formula coefficient...

Table 3. *PGE, Au and Ag minerals of heavy concentrates of the sample 90-23A, 807*

N	Mineral	General formula	Number of grains	Grain size, μm			Vol.%
				min	max	average	
1	Zvyagintsevite	$(Pd,Au,Pt)_3(Pb,Sn)$	103	3	34	18	58
2	Guanglinite	$(Pd,Pt)_3(As,Sn,Pb,Te,Pb)$	21(12*)	10	29	18	12
3	Arsenopalladinite	$(Pd,Cu)_8As_3$	13	7	51	22	11
4	Palladoarsenide	$(Pd,Cu)_2As$	1	-	-	40	2
5	Alloys of Au, Pd, Cu	(Au,Pd,Cu,Pt,Ag) $(Au,Pd)_3Cu$ (Au,Pd)Cu	12	6	20	13	4
6	Alloys of Au, Ag	(Au,Ag) Au_3Ag	3(1*)	12	41	25	4
7	Native palladium	Pd	2	20	37	29	3
8	Keithconnite	$Pd_{3-x}(Te,Pb,As,Sn)$	(8*)	4	10	8	2
9	Vasilite	$(Pd,Cu,Fe)_{16}S_7$	5(1*)	6	17	11	2
10	Atokite	Pd3(Sn,Pb)	1(1*)	3	9	6	<1
11	Vysotskite	(Pd,Pt,Ni,Cu)S	1(1*)	6	10	8	<1
12	Pt-alloy	(Pt,Fe,Pd,Cu)	1(2*)	2	8	6	<1
13	Sperrylite	$PtAs_2$	(4*)	1	5	3	<1
14	Native silver	Ag	1	-	-	25	<1
15	Polybasite	$Ag_{16}Sb_2S_{11}$	1	-	-	24	<1
	Total		165	3	51	17	100

*As inclusions in grains of other precious metal minerals.

Table 4. *Chemical composition and formulas of zvyagintsevite in PGM grains from heavy concentrates of the sample 90-23A, 807*

An.	Grain	Association of minerals in the grain		Pd	Pt	Au	Cu	Fe	Pb	Sn	As	Te	Total
1	45-1, 3	ZV	**Wt.%**	**59.6**	**-**	**-**	**-**	**-**	**40.2**	**-**	**-**	**-**	**99.8**
			F. c.	2.97	-	-	-	-	1.03	-	-	-	4
2	45-1, 10	ZV+GNG+BORN	**Wt.%**	**60.9**	**-**	**-**	**-**	**-**	**39.5**	**-**	**-**	**-**	**100.4**
			F. c.	3.00	-	-	-	-	1.00	-	-	-	4
3	45-1, 13	ZV+BORN	**Wt.%**	**57.6**	**-**	**2.5**	**0.9**	**-**	**37.0**	**-**	**-**	**-**	**98.0**
			F. c.	2.90	-	0.07	0.08	-	0.95	-	-	-	4
4	45-1, 14	ZV	**Wt.%**	**60.1**	**-**	**-**	**-**	**-**	**39.7**	**-**	**-**	**-**	**99.8**
			F. c.	2.99	-	-	-	-	1.01	-	-	-	4
5	45-1,15	ZV	**Wt.%**	**58.7**	**3.7**	**-**	**-**	**-**	**37.3**	**-**	**-**	**-**	**99.7**
			F. c.	2.94	0.10	-	-	-	0.96	-	-	-	4
6	45-1, 19	ZV+GNG+BORN	**Wt.%**	**55.6**	**3.4**	**4.2**	**0.8**	**-**	**35.1**	**-**	**-**	**-**	**99.1**
			F. c.	2.81	0.09	0.12	0.06	-	0.91	-	-	-	4
7	45-1, 21	ZV	**Wt.%**	**59.6**	**-**	**-**	**-**	**-**	**38.4**	**-**	**-**	**-**	**98.0**
			F. c.	3.00	-	-	-	-	1.00	-	-	-	4
8	45-1, 22	ZV	**Wt.%**	**61.0**	**-**	**-**	**-**	**-**	**38.8**	**-**	**-**	**-**	**99.8**
			F. c.	3.01	-	-	-	-	0.99	-	-	-	4
9	45-1, 23	ZV+AT	**Wt.%**	**38.7**	**-**	**1.2**	**-**	**-**	**58.8**	**-**	**-**	**-**	**98.7**
			F. c.	2.97	-	0.03	-	-	1.00	-	-	-	4
10	45-1, 24	ZV+GNG+BORN	**Wt.%**	**58.5**	**-**	**-**	**0.8**	**-**	**39.4**	**-**	**-**	**-**	**98.7**
			F. c.	2.92	-	-	0.07	-	1.01	-	-	-	4
11	45-1, 25	ZV	**Wt.%**	**59.6**	**-**	**-**	**-**	**-**	**40.1**	**-**	**-**	**-**	**99.7**
			F. c.	2.97	-	-	-	-	1.03	-	-	-	4
12	45-1, 26	ZV+PL	**Wt.%**	**61.1**	**-**	**-**	**-**	**-**	**38.2**	**-**	**-**	**-**	**99.3**
			F. c.	3.03	-	-	-	-	0.97	-	-	-	4
13	45-1, 27	ZV+KTH1+KTH2+(Au,Cu,Pd)	**Wt.%**	**60.1**	**1.9**	**3.8**	**-**	**-**	**27.5**	**5.9**	**-**	**-**	**99.2**
			F. c.	2.91	0.05	0.10	-	-	0.68	0.26	-	-	4
14	45-1, 28	ZV+GNG+(Au,Cu,Pd)+BORN+ACT	**Wt.%**	**62.4**	**1.2**	**3.2**	**-**	**-**	**22.0**	**10.4**	**-**	**-**	**99.2**
			F. c.	2.91	0.03	0.08	-	-	0.53	0.44	-	-	4
15	45-1, 31	ZV+BORN+ACT	**Wt.%**	**58.2**	**-**	**-**	**-**	**-**	**40.8**	**-**	**-**	**-**	**99.0**
			F. c.	2.94	-	-	-	-	1.06	-	-	-	4

Table 4 continued. *Chemical composition and formulas of zvyagintsevite in PGM grains from heavy concentrates of the sample 90-23A, 807*

An.	Grain	Association of minerals in the grain		Pd	Pt	Au	Cu	Fe	Pb	Sn	As	Te	Total
16	45-1, 34	ZV	**Wt.%**	**58.4**	**2.1**	**-**	**-**	**-**	**38.5**	**-**	**-**	**-**	**99.0**
			F. c.	2.94	0.06	-	-	-	1.00	-	-	-	4
17	45-1, 35	ZV+BORN	**Wt.%**	**61.5**	**-**	**-**	**-**	**-**	**37.9**	**-**	**-**	**-**	**99.4**
			F. c.	3.04	-	-	-	-	0.96	-	-	-	4
18	45-1, 36	ZV	**Wt.%**	**59.5**	**-**	**-**	**-**	**-**	**38.5**	**-**	**-**	**-**	**98.0**
			F. c.	3.00	-	-	-	-	1.00	-	-	-	4
19	45-1, 37	ZV	**Wt.%**	**58.9**	**-**	**-**	**0.7**	**-**	**39.1**	**-**	**-**	**-**	**98.7**
			F. c.	2.94	-	-	0.06	-	1.00	-	-	-	4
20	45-2, 1	ZV	**Wt.%**	**57.0**	**1.3**	**2.2**	**-**	**-**	**39.7**	**-**	**-**	**-**	**100.2**
			F. c.	2.87	0.04	0.06	-	-	1.03	-	-	-	4
21	45-2, 3	ZV+BORN	**Wt.%**	**59.1**	**-**	**-**	**-**	**-**	**39.5**	**-**	**-**	**-**	**98.6**
			F. c.	2.98	-	-	-	-	1.02	-	-	-	4
22	45-2, 6	ZV	**Wt.%**	**59.7**	**-**	**-**	**-**	**-**	**39.5**	**-**	**-**	**-**	**99.2**
			F. c.	2.99	-	-	-	-	1.01	-	-	-	4
23	45-2, 9	ZV	**Wt.%**	**59.3**	**-**	**-**	**-**	**-**	**39.2**	**-**	**-**	**-**	**98.5**
			F. c.	2.99	-	-	-	-	1.01	-	-	-	4
24	45-2, 11	ZV+GNG+(Pt,Fe,Pd,Cu)+BORN	**Wt.%**	**57.8**	**4.3**	**-**	**-**	**-**	**37.4**	**-**	**-**	**-**	**99.5**
			F. c.	2.91	0.12	-	-	-	0.97	-	-	-	4
25	45-2, 16	ZV	**Wt.%**	**56.7**	**3.0**	**3.3**	**-**	**-**	**38.9**	**-**	**-**	**-**	**101.9**
			F. c.	2.83	0.08	0.09	-	-	1.00	-	-	-	4
28	45-2, 18	(Au,Cu,Pd)+KTH+ZV+HB	**Wt.%**	**54.0**	**3.0**	**3.6**	**-**	**-**	**37.8**	**-**	**-**	**-**	**98.4**
			F. c.	2.81	0.08	0.10	-	-	1.01	-	-	-	4
29	45-2, 20	ZV+BORN	**Wt.%**	**60.6**	**-**	**6.2**	**-**	**-**	**28.1**	**4.8**	**-**	**-**	**99.7**
			F. c.	2.93	-	0.16	-	-	0.70	0.21	-	-	4
30	45-2, 21	ZV	**Wt.%**	**58.2**	**-**	**1.3**	**-**	**-**	**39.1**	**-**	**-**	**-**	**98.6**
			F. c.	2.95	-	0.03	-	-	1.02	-	-	-	4
31	45-2, 23	ZV+GNG+BORN	**Wt.%**	**61.1**	**-**	**1.6**	**0.9**	**-**	**29.3**	**5.9**	**-**	**-**	**98.8**
			F. c.	2.92	-	0.04	0.07	-	0.72	0.25	-	-	4
32	45-2, 26	ZV	**Wt.%**	**58.4**	**1.9**	**2.9**	**-**	**-**	**36.1**	**-**	**-**	**-**	**99.3**
			F. c.	2.93	0.05	0.08	-	-	0.94	-	-	-	4

Table 4 continued. *Chemical composition and formulas of zvyagintsevite in PGM grains from heavy concentrates of the sample 90-23A, 807*

An.	Grain	Association of minerals in the grain		Pd	Pt	Au	Cu	Fe	Pb	Sn	As	Te	Total
33	45-2, 29	(Au,Cu,Pd)+ZV	**Wt.%**	**54.2**	**3.2**	**6.4**	**-**	**-**	**35.6**	**-**	**-**	**-**	**99.4**
			F. c.	2.79	0.09	0.18	-	-	0.94	-	-	-	4
34	45-2, 30	ZV+BORN	**Wt.%**	**57.6**	**-**	**-**	**1.3**	**0.7**	**39.7**	**-**	**-**	**-**	**99.3**
			F. c.	2.82	-	-	0.11	0.07	1.00	-	-	-	4.00
35	45-2, 32	ZV	**Wt.%**	**56.0**	**1.7**	**2.1**	**-**	**0.5**	**38.4**	**-**	**-**	**-**	**98.7**
			F. c.	2.84	0.05	0.06	-	0.05	1.00	-	-	-	4
36	45-2, 36	ZV	**Wt.%**	**58.1**	**1.8**	**-**	**-**	**0.5**	**37.6**	**-**	**-**	**-**	**98.0**
			F. c.	2.93	0.05	-	-	0.04	0.98	-	-	-	4
37	45-2, 37	ZV+KTH+(Au,Pd,Cu)	**Wt.%**	**56.7**	**1.5**	**3.8**	**-**	**0.7**	**33.5**	**-**	**1.9**	**-**	**98.1**
			F. c.	2.81	0.04	0.10	-	0.07	0.85	-	0.13	-	4
38	45-2, 38	ZV+GNG	**Wt.%**	**56.2**	**1.2**	**1.9**	**-**	**0.7**	**39.7**	**-**	**-**	**-**	**99.7**
			F. c.	2.82	0.04	0.05	-	0.07	1.02	-	-	-	4
39	45-2, 40	ZV+BORN+CP	**Wt.%**	**59.5**	**-**	**-**	**0.4**	**0.4**	**38.7**	**-**	**-**	**-**	**99.0**
			F. c.	2.94	-	-	0.03	0.04	0.99	-	-	-	4
40	45-2, 41	ZV+BORN	**Wt.%**	**58.3**	**-**	**1.3**	**0.5**	**0.4**	**37.5**	**-**	**-**	**-**	**98.0**
			F. c.	2.91	-	0.04	0.05	0.04	0.96	-	-	-	4
41	45-2, 43	ZV	**Wt.%**	**57.4**	**-**	**1.7**	**-**	**0.6**	**39.4**	**-**	**-**	**-**	**99.1**
			F. c.	2.88	-	0.05	-	0.05	1.02	-	-	-	4
42	45-2, 46	ZV+CHL	**Wt.%**	**58.4**	**-**	**-**	**-**	**0.5**	**40.4**	**-**	**-**	**-**	**99.3**
			F. c.	2.91	-	-	-	0.05	1.04	-	-	-	4
43	45-2, 48	ZV+$(Au,Pd)_3Cu$	**Wt.%**	**51.8**	**3.6**	**7.3**	**0.6**	**-**	**35.8**	**-**	**-**	**-**	**99.1**
			F. c.	2.69	0.10	0.21	0.05	-	0.95	-	-	-	4
44	45-2, 49	ZV	**Wt.%**	**60.2**	**-**	**1.3**	**-**	**-**	**37.6**	**-**	**-**	**-**	**99.1**
			F. c.	3.00	-	0.04	-	-	0.96	-	-	-	4
45	45-2, 51	ZV+BORN	**Wt.%**	**56.9**	**1.0**	**2.2**	**-**	**0.4**	**38.3**	**-**	**-**	**-**	**98.8**
			F. c.	2.88	0.03	0.06	-	0.04	0.99	-	-	-	4
46	45-2, 52	ZV	**Wt.%**	**58.8**	**-**	**-**	**-**	**-**	**40.3**	**-**	**-**	**-**	**99.1**
			F. c.	2.96	-	-	-	-	1.04	-	-	-	4

Table 4 continued. *Chemical composition and formulas of zvyagintsevite in PGM grains from heavy concentrates of the sample 90-23A, 807*

An.	Grain	Association of minerals in the grain		Pd	Pt	Au	Cu	Fe	Pb	Sn	As	Te	Total
47	45-2, 54	ZV+GNG+BORN	**Wt.%**	**59.0**	**-**	**1.9**	**-**	**0.9**	**37.7**	**-**	**-**	**-**	**99.5**
			F. c.	2.91	-	0.05	-	0.08	0.96	-	-	-	4
48	45-2, 55	ZV+BORN	**Wt.%**	**57.8**	**-**	**-**	**0.5**	**0.5**	**41.0**	**-**	**-**	**-**	**99.8**
			F. c.	2.87	-	-	0.04	0.05	1.04	-	-	-	4
49	45-2, 58	ZV	**Wt.%**	**59.0**	**-**	**1.8**	**-**	**-**	**38.2**	**-**	**-**	**-**	**99.0**
			F. c.	2.97	-	0.05	-	-	0.98	-	-	-	4
50	45-26 59	ZV	**Wt.%**	**57.7**	**1.9**	**1.2**	**-**	**-**	**38.0**	**-**	**-**	**-**	**98.8**
			F. c.	2.93	0.05	0.03	-	-	0.99	-	-	-	4
51	45-2, 60	ZV	**Wt.%**	**58.0**	**-**	**-**	**-**	**1.7**	**38.5**	**-**	**-**	**-**	**98.2**
			F. c.	2.86	-	-	-	0.16	0.98	-	-	-	4
52	45-2, 63	ZV+GNG	**Wt.%**	**55.6**	**2.6**	**3.8**	**-**	**-**	**36.3**	**-**	**-**	**-**	**98.3**
			F. c.	2.86	0.07	0.11	-	-	0.96	-	-	-	4
53	45-2, 64	ZV+BORN	**Wt.%**	**57.3**	**1.6**	**2.9**	**-**	**-**	**37.2**	**-**	**-**	**-**	**99.0**
			F. c.	2.91	0.04	0.08	-	-	0.97	-	-	-	4
54	45-2, 67	(Au,Pd)Cu+(Au,Pd)$_3$Cu+KTH+VYS +ZV	**Wt.%**	**52.6**	**-**	**9.4**	**0.9**	**-**	**33.8**	**-**	**1.3**	**-**	**98.0**
			F. c.	2.68	-	0.26	0.08	-	0.89	-	0.09	-	4
55	45-2, 71	ZV	**Wt.%**	**59.3**	**-**	**1.2**	**-**	**-**	**37.5**	**-**	**-**	**-**	**98.0**
			F. c.	3.00	-	0.03	-	-	0.97	-	-	-	4
56	45-2, 73	ZV+BORN+ILM	**Wt.%**	**59.4**	**-**	**1.4**	**0.5**	**-**	**38.0**	**-**	**-**	**-**	**99.3**
			F. c.	2.95	-	0.04	0.04	-	0.97	-	-	-	4
57	75, 1	ZV(zon:1,2)+ZV3(incl.): zone 1 (center)	**Wt.%**	**62.2**	**-**	**2.9**	**-**	**-**	**27.4**	**6.4**	**-**	**-**	**98.9**
			F. c.	2.98	-	0.07	-	-	0.68	0.27	-	-	4
58	75, 1	ZV zone 2 (rim)	**Wt.%**	**58.0**	**-**	**2.7**	**-**	**-**	**38.6**	**-**	**-**	**-**	**99.3**
			F. c.	2.93	-	0.07	-	-	1.00	-	-	-	4
59	75, 1	ZV (incl.)	**Wt.%**	**67.7**	**-**	**-**	**-**	**-**	**18.2**	**2.9**	**5.3**	**4.0**	**98.1**
			F. c.	2.99	-	-	-	-	0.41	0.12	0.33	0.15	4
60	75, 2	ZV+BORN	**Wt.%**	**59.1**	**-**	**-**	**0.4**	**-**	**39.9**	**-**	**-**	**-**	**99.4**
			F. c.	2.95	-	-	0.03	-	1.02	-	-	-	4

Table 4 continued. *Chemical composition and formulas of zvyagintsevite in PGM grains from heavy concentrates of the sample 90-23A, 807*

An.	Grain	Association of minerals in the grain		Pd	Pt	Au	Cu	Fe	Pb	Sn	As	Te	Total
61	75, 3	ZV+BORN	**Wt.%**	**58.3**	**-**	**1.4**	**-**	**-**	**39.0**	**-**	**-**	**-**	**98.7**
			F. c.	2.95	-	0.04	-	-	1.01	-	-	-	4
62	75, 4	ZV	**Wt.%**	**57.8**	**-**	**1.7**	**-**	**0.4**	**39.2**	**-**	**-**	**-**	**99.1**
			F. c.	2.91	-	0.05	-	0.03	1.01	-	-	-	4
63	75, 5	ZV+BORN	**Wt.%**	**59.5**	**-**	**-**	**0.6**	**0.04**	**39.0**	**-**	**-**	**-**	**99.5**
			F. c.	2.93	-	-	0.05	0.04	0.98	-	-	-	4
64	75, 8	ZV+BORN	**Wt.%**	**58.0**	**-**	**1.2**	**-**	**-**	**39.7**	**-**	**-**	**-**	**98.9**
			F. c.	2.94	-	0.03	-	-	1.03	-	-	-	4
65	75, 15	ZV+VSL+BORN	**Wt.%**	**58.8**	**-**	**-**	**1.5**	**0.5**	**37.4**	**-**	**-**	**-**	**98.2**
			F. c.	2.89	-	-	0.13	0.04	0.94	-	-	-	4
66	75, 12	ZV (zoned)+BORN: ZV (matrix)	**Wt.%**	**58.4**	**-**	**1.1**	**0.4**	**-**	**38.9**	**-**	**-**	**-**	**98.8**
			F. c.	2.94	-	0.03	0.03	-	1.00	-	-	-	4
67	75, 12	ZV(zone 1)	**Wt.%**	**68.4**	**-**	**-**	**-**	**-**	**16.2**	**2.3**	**5.4**	**6.0**	**98.3**
			F. c.	2.99	-	-	-	-	0.36	0.09	0.34	0.22	4
68	75, 12	ZV (zone 2)	**Wt.%**	**62.3**	**-**	**1.2**	**-**	**-**	**33.4**	**2.5**	**-**	**-**	**99.4**
			F. c.	3.03	-	0.03	-	-	0.83	0.11	-	-	4
69	75, 17	ZV+AT+BORN	**Wt.%**	**58.6**	**-**	**-**	**0.5**	**0.4**	**39.6**	**-**	**-**	**-**	**99.1**
			F. c.	2.91	-	-	0.04	0.04	1.01	-	-	-	4
70	120, 3	ZV+BORN+CHC+CHL	**Wt.%**	**63.2**	**-**	**-**	**0.7**	**0.5**	**26.7**	**7.5**	**-**	**-**	**98.6**
			F. c.	2.95	-	-	0.05	0.04	0.64	0.31	-	-	4
71	120, 4	ZV+BORN	**Wt.%**	**58.8**	**-**	**-**	**0.6**	**-**	**39.1**	**-**	**-**	**-**	**98.5**
			F. c.	2.95	-	-	0.05	-	1.00	-	-	-	4

Table 5. *Chemical composition and formulas of guanglinite, arsenopalladinite, palladoarsenide, atokite, keithconnite and sperrylite in PGM grains from heavy concentrates of the sample 90-23A, 807*

An.	Grain	Association of minerals in the grain	Mineral		Pd	Pt	Cu	Fe	As	Sn	Pb	Te	Sb	Total
1	45-1, 10	ZV+GNG (incl)+BORN	GNG	**Wt.%**	**69.6**	**-**	**0.4**	**-**	**6.5**	**7.3**	**11.3**	**3.8**	**-**	**98.9**
				F. c.	2.93	-	0.03	-	0.39	0.28	0.24	0.13	-	4
2	45-1, 12	GNG+BORN+HB	GNG	**Wt.%**	**78.2**	**2.1**	**-**	**-**	**18.7**	**-**	**-**	**-**	**-**	**99.0**
				F. c.	3.00	0.04	-	-	1.00	-	-	-	-	4
3	45-1, 19	ZV+GNG (incl.)+BORN	GNG	**Wt.%**	**71.7**	**-**	**0.4**	**-**	**6.7**	**4.7**	**5.2**	**11.3**	**-**	**100.0**
				F. c.	2.92	-	0.03	-	0.39	0.17	0.11	0.39	-	4
4	45-1, 24	ZV+GNG (incl.)+BORN	GNG	**Wt.%**	**76.3**	**-**	**0.4**	**-**	**14.8**	**-**	**7.8**	**-**	**-**	**99.3**
				F. c.	2.99	-	0.03	-	0.83	-	0.16	-	-	4
5	45-1, 28	ZV+GNG+(Au,Cu,Pd)+ ACT+BORN	GNG	**Wt.%**	**74.6**	**-**	**-**	**-**	**8.4**	**5.0**	**-**	**10.3**	**-**	**98.3**
				F. c.	3.00	-	-	-	0.48	0.18	-	0.34	-	4
6	45-2, 5	GNG	GNG	**Wt.%**	**79.2**	**-**	**-**	**-**	**19.8**	**-**	**-**	**-**	**-**	**99.0**
				F. c.	2.95	-	-	-	1.05	-	-	-	-	4
7	45-2, 7	GNG	GNG	**Wt.%**	**80.0**	**-**	**-**	**-**	**15.1**	**3.6**	**-**	**-**	**-**	**98.7**
				F. c.	3.06	-	-	-	0.82	0.12	-	-	-	4
8	45-2, 8	GNG	GNG	**Wt.%**	**81.2**	**-**	**-**	**-**	**16.3**	**2.4**	**-**	**-**	**-**	**99.9**
				F. c.	3.05	-	-	-	0.87	0.08	-	-	-	4
9	45-2, 11	ZV+GNG+(Pt,Fe,Pd,Cu) +BORN	GNG	**Wt.%**	**73.3**	**-**	**0.7**	**-**	**9.2**	**1.2**	**5.1**	**9.8**	**-**	**99.3**
				F. c.	2.95	-	0.05	-	0.53	0.05	0.09	0.33	-	4
10	45-2, 15	GNG	GNG	**Wt.%**	**76.2**	**1.8**	**-**	**-**	**16.0**	**3.8**	**-**	**-**	**-**	**99.8**
				F. c.	2.97	0.04	-	-	0.86	0.13	-	-	-	4
11	45-2, 17	GNG+SP+BORN	GNG	**Wt.%**	**79.2**	**-**	**-**	**-**	**16.2**	**3.6**	**-**	**-**	**-**	**99.0**
				F. c.	3.01	-	-	-	0.87	0.12	-	-	-	4
12	45-2, 22	GNG+SP+BORN	GNG	**Wt.%**	**76.2**	**1.7**	**-**	**0.5**	**17.6**	**3.1**	**-**	**-**	**-**	**99.1**
				F. c.	2.88	0.04	-	0.03	0.94	0.11	-	-	-	4
13	45-2, 23	GNG+ZV+BORN	GNG	**Wt.%**	**75.7**	**-**	**1.3**	**0.6**	**12.1**	**7.5**	**-**	**1.3**	**-**	**98.5**
				F. c.	2.91	-	0.09	0.04	0.66	0.26	-	0.04	-	4
14	45-2, 27	GNG+BORN	GNG	**Wt.%**	**78.1**	**-**	**-**	**0.6**	**15.4**	**3.7**	**-**	**1.2**	**-**	**99.0**
				F. c.	2.96	-	-	0.04	0.83	0.13	-	0.4	-	4

Table 5 continued. *Chemical composition and formulas of guanglinite, arsenopalladinite, palladoarsenide, atokite, keithconnite and sperrylite in PGM grains from heavy concentrates of the sample 90-23A, 807*

An.	Grain	Association of minerals in the grain	Mineral		Pd	Pt	Cu	Fe	As	Sn	Pb	Te	Sb	Total
15	45-2, 34	GNG	GNG	**Wt.%**	**77.9**	**-**	**-**	**0.5**	**17.6**	**-**	**-**	**-**	**3.6**	**99.6**
				F. c.	2.91	-	-	0.04	0.93	-	-	-	0.12	4
16	45-2, 45	GNG+SP	GNG	**Wt.%**	**78.0**	**-**	**-**	**0.4**	**17.3**	**3.5**	**-**	**-**	**-**	**99.2**
				F. c.	2.93	-	-	0.03	0.93	0.11	-	-	-	4
17	45-2, 54	ZV+GNG+BORN	GNG	**Wt.%**	**76.8**	**-**	**-**	**0.8**	**16.0**	**3.2**	**2.4**	**-**	**-**	**99.2**
				F. c.	2.92	-	-	0.06	0.86	0.11	0.05	-	-	4
18	45-2, 62	GNG	GNG	**Wt.%**	**78.0**	**-**	**-**	**0.7**	**16.1**	**-**	**-**	**-**	**3.9**	**98.7**
				F. c.	2.95	-	-	0.05	0.87	-	-	-	0.13	4
19	45-2, 63	ZV+GNG (incl)	GNG	**Wt.%**	**77.6**	**1.7**	**-**	**-**	**13.8**	**3.9**	**2.5**	**-**	**-**	**99.5**
				F. c.	3.02	0.04	-	-	0.76	0.13	0.05	-	-	4
20	45-2, 65	GNG+ARSPD	GNG	**Wt.%**	**81.3**	**-**	**-**	**0.6**	**17.8**	**-**	**-**	**-**	**-**	**99.7**
				F. c.	3.02	-	-	0.04	0.94	-	-	-	-	4
21	45-2, 66	GNG+BORN	GNG	**Wt.%**	**79.4**	**-**	**0.7**	**0.3**	**16.8**	**2.3**	**-**	**-**	**-**	**99.5**
				F. c.	2.96	-	0.05	0.02	0.89	0.08	-	-	-	4
22	45-2, 69	GNG+SP	GNG	**Wt.%**	**75.1**	**-**	**2.9**	**1.0**	**20.3**	**-**	**-**	**-**	**-**	**99.3**
				F. c.	2.72	-	0.17	0.07	1.04	-	-	-	-	4
23	45-2, 75	GNG+BORN	GNG	**Wt.%**	**76.6**	**-**	**-**	**0.8**	**17.2**	**3.7**	**-**	**-**	**-**	**100.1**
				F. c.	2.91	-	-	0.05	0.92	0.12	-	-	-	4
24	45-2, 82	GNG	GNG	**Wt.%**	**76.8**		**-**	**-**	**16.0**	**3.8**	**-**	**-**	**-**	**99.8**
				F. c.	2.89		-	-	0.86	0.13	-	-	-	4
25	45-2, 83	GNG+ACT	GNG	**Wt.%**	**77.7**	**-**	**-**	**0.4**	**17.2**	**1.4**	**-**	**-**	**2.0**	**98.7**
				F. c.	2.94	-	-	0.03	0.92	0.04	-	-	0.07	4
26	75, 16	GNG	GNG	**Wt.%**	**76.6**	**-**	**-**	**0.6**	**15.1**	**1.9**	**4.5**	**-**	**-**	**98.7**
				F. c.	2.97	-	-	0.04	0.83	0.07	0.09	-	-	4
27	45-1, 16	ARSPD	ARSPD	**Wt.%**	**75.5**	**-**	**3.3**	**-**	**22.1**	**-**	**-**	**-**	**-**	**100.9**
				F. c.	7.39	-	0.54	-	3.07	-	-	-	-	11
28	45-1, 17	ARSPD+BORN+HB	ARSPD	**Wt.%**	**75.4**	**2.4**	**0.4**	**-**	**20.7**	**-**	**-**	**-**	**-**	**98.9**
				F. c.	7.76	0.13	0.07	-	3.03	-	-	-	-	11

Table 5 continued. *Chemical composition and formulas of guanglinite, arsenopalladinite, palladoarsenide, atokite, keithconnite and sperrylite in PGM grains from heavy concentrates of the sample 90-23A, 807*

An.	Grain	Association of minerals in the grain	Mineral		Pd	Pt	Cu	Fe	As	Sn	Pb	Te	Sb	Total
29	45-2, 19	ARSPD	ARSPD	**Wt.%**	**75.2**	**-**	**3.4**	**-**	**21.1**	**-**	**-**	**-**	**-**	**99.7**
				F. c.	7.47	-	0.56	-	2.97	-	-	-	-	11
30	45-2, 35	ARSPD+BORN	ARSPD	**Wt.%**	**71.0**	**-**	**1.7**	**0.7**	**9.1**	**6.2**	**-**	**8.9**	**2.2**	**99.8**
				F. c.	7.58	-	0.30	0.15	1.38	0.59	-	0.80	0.20	11
31	45-2, 56	ARSPD	ARSPD	**Wt.%**	**75.1**	**-**	**2.8**	**-**	**21.0**	**-**	**-**	**-**	**-**	**99.1**
				F. c.	7.54	-	0.47	-	2.99	-	-	-	-	11
32	45-2, 57	ARSPD	ARSPD	**Wt.%**	**74.4**	**-**	**3.1**	**0.4**	**21.2**	**-**	**-**	**-**	**-**	**99.1**
				F. c.	7.41	-	0.51	0.08	3.00	-	-	-	-	11
33	45-2, 61	ARSPD	ARSPD	**Wt.%**	**75.8**	**-**	**-**	**1.0**	**17.8**	**3.6**	**-**	**-**	**-**	**98.2**
				F. c.	7.85	-	-	0.20	2.62	0.33	-	-	-	11
34	45-2, 65	GNG+ARSPD	ARSPD	**Wt.%**	**74.6**	**-**	**3.2**	**0.5**	**20.8**	**-**	**-**	**-**	**-**	**99.1**
				F. c.	7.43	-	0.53	0.10	2.94	-	-	-	-	11
35	45-2, 72	ARSPD	ARSPD	**Wt.%**	**76.6**	**-**	**-**	**0.5**	**18.0**	**3.7**	**-**	**-**	**-**	**98.9**
				F. c.	7.91	-	-	0.11	2.64	0.34	-	-	-	11
36	45-2, 76	ARSPD	ARSPD	**Wt.%**	**79.9**	**-**	**-**	**-**	**20.7**	**-**	**-**	**-**	**-**	**100.6**
				F. c.	8.04	-	-	-	2.96	-	-	-	-	11
37	45-2, 77	ARSPD	ARSPD	**Wt.%**	**77.2**	**-**	**-**	**0.5**	**19.1**	**2.9**	**-**	**-**	**-**	**99.7**
				F. c.	7.88	-	-	0.10	2.76	0.26	-	-	-	11
38	45-2, 80	ARSPD	ARSPD	**Wt.%**	**75.6**		**1.5**	**0.6**	**21.6**	**-**	**-**	**-**	**-**	**99.3**
				F. c.	7.56		0.25	0.11	3.08	-	-	-	-	11
39	120, 1	ARSPD+BORN	ARSPD	**Wt.%**	**74.7**	**-**	**3.2**	**-**	**21.4**	**-**	**-**	**-**	**-**	**99.3**
				F. c.	7.44	-	0.53	-	3.03	-	-	-	-	11
40	45-1, 1	PLDAS+(Au,Ag)	PLDAS	**Wt.%**	**75.6**	**-**	**0.5**	**-**	**23.8**	**-**	**-**	**-**	**-**	**99.9**
				F. c.	2.06	-	0.02	-	0.92	-	-	-	-	3
41*	45-1, 23	AT+ZV	AT	**Wt.%**	**72.7**	**-**	**-**	**-**	**-**	**25.4**	**-**	**-**	**-**	**99.9**
				F. c.	3.01	-	-	-	-	0.95	-	-	-	4

Table 5 continued. *Chemical composition and formulas of guanglinite, arsenopalladinite, palladoarsenide, atokite, keithconnite and sperrylite in PGM grains from heavy concentrates of the sample 90-23A, 807*

An.	Grain	Association of minerals in the grain	Mineral		Pd	Pt	Cu	Fe	As	Sn	Pb	Te	Sb	Total
42*	75, 17	ZV+AT+BORN	AT	**Wt.%**	**70.8**	**1.3**	**0.8**	**0.6**	**-**	**16.0**	**9.2**	**-**	**-**	**100.0**
				F. c.	3.02	0.03	0.05	0.05	-	0.61	0.20	-	-	4
43	45-1, 6	(Au,Cu,Pd)+KTH+ACT +BORN+CP	KTH	**Wt.%**	**67.7**	**-**	**-**	**-**	**-**	**-**	**5.9**	**26.3**	**-**	**99.9**
				F. c.	2.92	-	-	-	-	-	0.13	0.95	-	4
44	45-1, 27	(Au,Pd,Cu)+KTH1+ KTH2+ZV	KTH1	**Wt.%**	**68.3**	**-**	**-**	**-**	**-**	**2.7**	**-**	**28.0**	**-**	**99.0**
				F. c.	2.91	-	-	-		0.10	-	0.99	-	4
45	45-1, 27	“	KTH2	**Wt.%**	**71.8**	**-**	**-**	**-**	**5.7**	**5.8**	**-**	**15.7**	**-**	**99.0**
				F. c.	2.93	-	-	-	0.33	0.21	-	0.53	-	4
46	45-2, 18	(Au,Cu,Pd)+KTH+ZV	KTH	**Wt.%**	**67.4**	**-**	**-**	**-**	**-**	**-**	**7.8**	**24.5**	**-**	**99.7**
				F. c.	2.94	-	-	-	-	-	0.17	0.89	-	4
47	45-2, 37	ZV+KTH+(Au,Cu,Pd)	KTH	**Wt.%**	**68.7**	**-**	**-**	**1.1**	**2.4**	**-**	**4.9**	**22.0**	**-**	**99.1**
				F. c.	2.89	-	-	0.09	0.14	-	0.11	0.77	-	4
48	45-2, 47	(Au,Pd)$_3$Cu+KTH	KTH	**Wt.%**	**66.9**	**-**	**-**	**0.6**	**-**	**-**	**4.1**	**27.2**	**-**	**99.1**
				F. c.	2.88	-	-	0.05	-	-	0.09	0.98	-	4
49	45-2, 67	(Au,Pd)Cu+(Au,Pd)$_3$Cu+ KTH+VYS+ZV	KTH	**Wt.%**	**66.8**	**-**	**-**	-	-	-	**6.2**	**26.1**	**-**	**99.1**
				F. c.	2.91	-	-	-	-	-	0.14	0.95	-	4
50	45-2, 22	GNG+SP (incl.)+BORN	SP	**Wt.%**	**-**	**56.3**	**-**	**-**	**43.7**	**-**	**-**	**-**	**-**	**100.0**
				F. c.	-	0.99	-	-	2.01	-	-	-	-	3
51**	45-2, 69	GNG+SP	SP	**Wt.%**	**-**	**54.5**	**-**	**0.8**	**42.3**	**-**	**-**	**-**	**-**	**98.2**
				F. c.	-	0.95	-	0.05	1.94	-	-	-	-	3

*Au was detemined in atokite too: 1.8% (f. c. 0.04) in the an. 41 and 1.3% (f. c. 0.03) in the an. 42 (included in sum of analyses);
**0.6 % S was determined in sperrylite too (f. c. 0.06) (included in sum of analysis).

Table 6. *Chemical composition and formulas of native precious metals, their alloys and sulphides in precious metal mineral grains from heavy concentrates of the sample 90-23A, 807*

An.	Grain	Association of minerals in the grain	Mineral		Pd	Pt	Au	Ag	Cu	Fe	Ni	S	Sb	Total
1	45-1, 6	(Au,Cu,Pd)+KTH+ ACT+BORN+CP	(Au,Pd,Cu)	**Wt.%**	**14.2**	**-**	**77.0**	**-**	**8.2**	**-**	**-**	**-**	**-**	**99.4**
				F. c.	0.20	-	0.60	-	0.20	-	-	-	-	1
2	45-1, 11	KTH+(Au,Pd,Cu)+ BORN	(Au,Pd,Cu)	**Wt.%**	**17.3**	**3.5**	**67.8**	**0.9**	**9.5**	**-**	**-**	**-**	**-**	**99.0**
				F. c.	0.24	0.03	0.50	0.01	0.22	-	-	-	-	1
3	45-1, 27	(Au,Pd,Cu)+KTH1+ KTH2+ZV	(Au,Pd,Cu)	**Wt.%**	**8.1**	**-**	**84.8**	**1.9**	**4.8**	**-**	**-**	**-**	**-**	**99.6**
				F. c.	0.13	-	0.72	0.03	0.13	-	-	-	-	1
4	45-2, 12	(Au,Pd,Cu)+ILM+ BORN	(Au,Pd,Cu)	**Wt.%**	**8.6**	**-**	**82.8**	**3.6**	**3.6**	**-**	**-**	**-**	**-**	**98.6**
				F. c.	0.14	-	0.70	0.06	0.10	-	-	-	-	1
5	45-2, 18	(Au,Cu,Pd)+KTH+ZV +ACT	(Au,Cu,Pd)	**Wt.%**	**9.6**	**2.0**	**81.7**	**-**	**6.3**	**-**	**-**	**-**	**-**	**99.6**
				F. c.	0.15	0.02	0.67	-	0.16	-	-	-	-	1
6	45-2, 29	(Au,Cu,Pd) +ZV	(Au,Cu,Pd)	**Wt.%**	**7.7**	**-**	**82.2**	**2.7**	**5.3**	**1.0**	**-**	**-**	**-**	**98.9**
				F. c.	0.12	-	0.68	0.04	0.13	0.03	-	-	-	1
7	45-2, 33	(Au,Ag,Pd,Cu)	(Au,Ag,Pd, Cu)	**Wt.%**	**5.4**	**-**	**83.1**	**8.1**	**1.2**	**0.9**	**-**	**-**	**-**	**98.7**
				F. c.	0.09	-	0.72	0.13	0.03	0.03	-	-	-	1
8	45-2, 42	(Au,Pd,Cu)+ILM	(Au,Pd,Cu)	**Wt.%**	**9.1**	**-**	**83.2**	**1.4**	**5.1**	**0.7**	**-**	**-**	**-**	**99.5**
				F. c.	0.14	-	0.69	0.02	0.13	0.02	-	-	-	1
9	45-2, 47	$(Au,Pd)_3Cu$+KTH	$(Au,Pd)_3Cu$	**Wt.%**	**11.9**	**1.1**	**74.4**	**-**	**11.4**	**0.5**	**-**	**-**	**-**	**99.3**
				F. c.	0.66	0.03	2.21	-	1.05	0.05	-	-	-	4
10	45-2, 48	ZV+$(Au,Pd)_3Cu$	$(Au,Pd)_3Cu$	**Wt.%**	**6.7**	**-**	**80.8**	**2.4**	**9.5**	**-**	**-**	**-**	**-**	**99.4**
				F. c.	0.39	-	2.55	0.13	0.93	-	-	-	-	4
11	45-2, 50	$(Au,Pd)_3Cu$+KTH	$(Au,Pd)_3Cu$	**Wt.%**	**7.7**	**-**	**82.2**	**-**	**9.1**	**0.4**	**-**	**-**	**-**	**99.4**
				F. c.	0.45	-	2.61	-	0.89	0.05	-	-	-	4
12	45-2, 67	(Au,Pd)Cu+$(Au,Pd)_3Cu$+ KTH+VYS+ZV	(Au,Pd)Cu	**Wt.%**	**24.1**	**-**	**47.3**	**-**	**26.4**	**0.9**	**-**	**-**	**-**	**98.7**
				F. c.	0.50	-	0.53	-	0.93	0.04	-	-	-	2
13	45-2, 67	“	$(Au,Pd)_3Cu$, zone 1	**Wt.%**	**23.7**	**-**	**62.8**	**-**	**12.9**	**0.7**	**-**	**-**	**-**	**100.1**
				F. c.	1.18	-	1.69	-	1.07	0.06	-	-	-	4
14	45-2, 67	“	$(Au,Pd)_3Cu$, zone 2	**Wt.%**	**10.6**	**-**	**77.4**	**-**	**10.6**	**0.4**	**-**	**-**	**-**	**99.0**
				F. c.	0.62	-	2.43	-	0.91	0.04	-	-	-	4

Table 6 continued. *Chemical composition and formulas of native precious metals, their alloys and sulphides in precious metal mineral grains from heavy concentrates of the sample 90-23A, 807*

An.	Grain	Association of minerals in the grain	Mineral		Pd	Pt	Au	Ag	Cu	Fe	Ni	S	Sb	Total
15	45-2, 68	(Au,Ag,Pd,Cu)	(Au,Ag,Pd, Cu)	**Wt.%**	**4.9**	-	**85.3**	**5.5**	**2.1**	**0.9**	-	-	-	**98.7**
				F. c.	0.08	-	0.74	0.09	0.06	0.03	-	-	-	1
16	45-2, 70	VSL+(Au,Pd,Cu)+KTH+ BORN	(Au,Pd,Cu)	**Wt.%**	**19.9**	**1.1**	**68.7**		**8.0**	**0.5**	-	-	-	**98.2**
				F. c.	0.28	0.01	0.52		0.19	0.01	-	-	-	1
17	120, 2	$(Au,Pd)_3Cu$+KTH+ BORN+CP+ILM	(Au,Pd)3Cu	**Wt.%**	**15.4**	-	**72.2**	-	**10.2**	**1.2**	-	-	-	**99.0**
				F. c.	0.83	-	2.10	-	0.94	0.13	-	-	-	4
18	45-1, 1	PLDAS+(Au,Ag)	(Au,Ag)	**Wt.%**	-	-	**75.7**	**23.5**	-	-	-	-	-	**99.2**
				F. c.	-	-	0.64	0.36	-	-	-	-	-	1
19	45-1, 9	(Au,Ag)+ILM	(Au,Ag)	**Wt.%**	-	-	**88.3**	**10.1**	-	-	-	-	-	**98.4**
				F. c.	-	-	0.83	0.17	-	-	-	-	-	1
20	45-2, 44	Au_3Ag	Au_3Ag	**Wt.%**	-	-	**82.8**	15.8	-	-	-	-	-	**98.6**
				F. c.	-	-	2.97	**1.03**	-	-	-	-	-	4
21	45-2, 53	Au_3Ag	Au_3Ag	**Wt.%**	-	-	**82.7**	**16.3**	-	-	-	-	-	**99.0**
				F. c.	-	-	2.94	1.06	-	-	-	-	-	4
22	45-2, 91	Ag	Ag	**Wt.%**	-	-	-	**99.8**	-	-	-	-	-	**99.8**
				F. c.	-	-	-	1.00	-	-	-	-	-	1
23	45-2, 4	(Pt,Fe,Pd,Cu)	(Pt,Fe,Pd, Cu)	**Wt.%**	**10.4**	**75.3**	-	-	**2.2**	**11.8**	-	-	-	**99.7**
				F. c.	0.13	0.53	-	-	0.05	0.29	-	-	-	1
24	45-1, 20	Pd	Pd	**Wt.%**	**99.0**		-	-	**0.5**	-	-	-	-	**99.5**
				F. c.	0.99		-	-	0.01	-	-	-	-	1
25	45-1, 33	Pd	Pd	**Wt.%**	**99.2**	-	-	-	-	-	-	-	-	**99.2**
				F. c.	1.00	-	-	-	-	-	-	-	-	1
26	45-2, 14	VSL+KTH+BORN	VSL	**Wt.%**	**71.8**	-	-	-	**13.7**	**0.6**	-	**12.2**	-	**98.3**
				F. c.	12.12	-	-	-	3.86	0.20	-	6.82	-	23
27	45-2, 24	VSL+BORN	VSL	**Wt.%**	**65.4**	-	-	-	**18.7**	**1.5**	-	**12.7**	-	**98.3**
				F. c.	10.61	-	-	-	5.08	0.46	-	6.84	-	23
28	45-2, 70	VSL+(Au,Cu,Pd)+KTH+ BORN	VSL	**Wt.%**	**72.3**	-	-	-	**14.0**	-	-	-	-	**98.9**
				F. c.	12.08	-	-	-	3.92	-	-	-	-	23

Table 6 continued. *Chemical composition and formulas of native precious metals, their alloys and sulphides in precious metal mineral grains from heavy concentrates of the sample 90-23A, 807*

An.	Grain	Association of minerals in the grain	Mineral		Pd	Pt	Au	Ag	Cu	Fe	Ni	S	Sb	Total
29	75, 15	VSL+ZV+BORN	VSL	**Wt.%**	**72.6**	**-**	**-**	**-**	**14.5**	**-**	**-**	**12.7**	**-**	**99.8**
				F. c.	12.01	-	-	-	4.02	-	-	6.97	-	23
30	120, 9	VSL+BORN+CP	VSL	**Wt.%**	**70.0**	**-**	**-**	**-**	**15.5**	**1.1**	**-**	**13.2**	**-**	**99.8**
				F. c.	11.35	-	-	-	4.21	0.35	-	7.08	-	23
31	45-2, 67	(Au,Pd)Cu+$(Au,Pd)_3Cu$+ KTH+VYS+ZV	VYS	**Wt.%**	**59.4**	**16.0**	**-**	**-**	**3.0**	**-**	**-**	**21.4**	**-**	**99.8**
				F. c.	0.82	0.12	-	-	0.07	-	-	0.99	-	2
32	120, c	VYS+BORN	VYS	**Wt.%**	**73.3**	**-**	**-**	**-**	**-**	**-**	**3.1**	**23.7**	**-**	**100.1**
				F. c.	0.93	-	-	-	-	-	0.07	1.00	-	2
33	45-2, 25	PLBS	PLBS	**Wt.%**	**-**	**-**	**-**	**73.6**	**-**	**-**	**-**	**15.3**	**10.7**	**99.6**
				F. c.	-	-	-	15.86	-	-	-	11.09	2.04	29

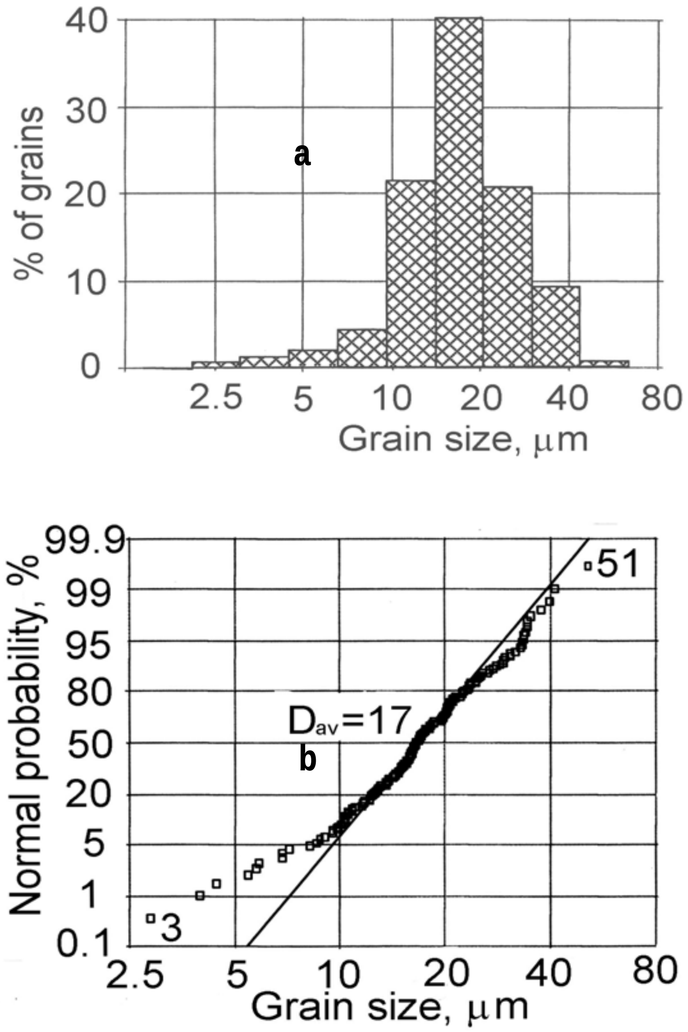

Fig. 1. *Grain sizes of precious metal mineral grains (N=165), extracted in the heavy concentrates of the sample 90-23A, 807 a -histogram, b - lognormal probability plot*

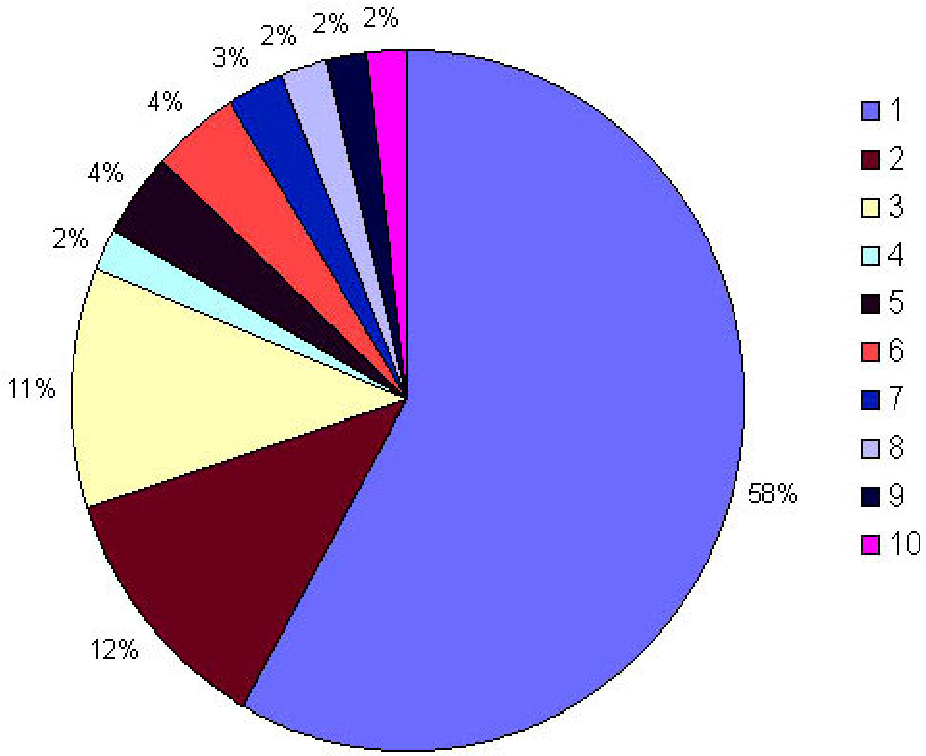

Fig. 2. *PGE, Au and Ag minerarals relative contents of the sample 90-23A, 807. 1: zvyagintsevite, 2: guanglinite, 3: arsenopalladinite, 4: palladoarsenide, 5: alloys of Au, Pd and Cu, 6: alloys of Au and Ag, 7: native palladium, 8: keithconnite, 9: vasilite, 10: other minerals.*

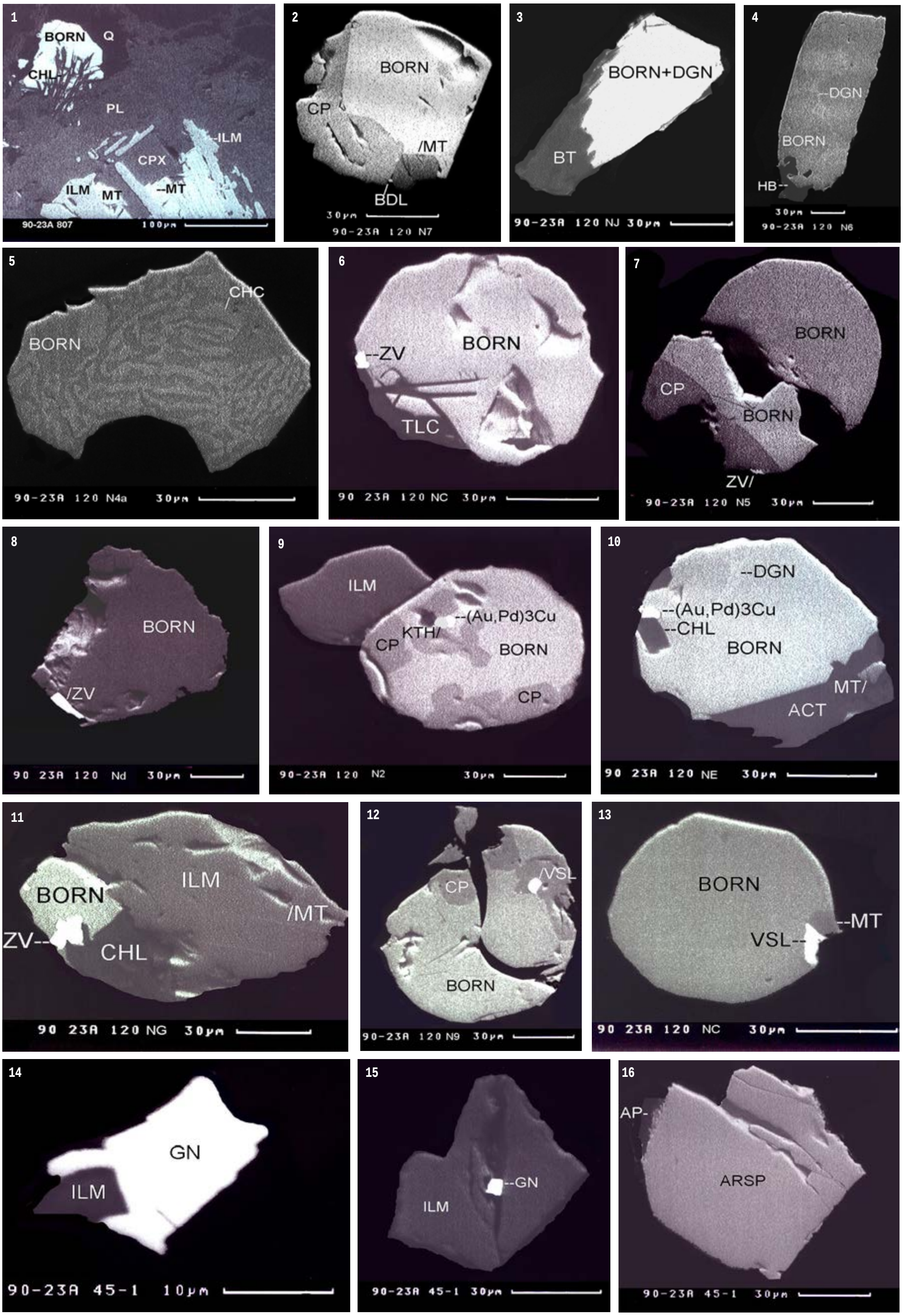

Plate 1. *Sulphide mineralization of oxide-rich tholeiitic gabbros, sample 90-23A, 807; polished section, SEM-image (BIE). 1: polished section of the rock, 2-16: grains, extracted in heavy concentrates.*

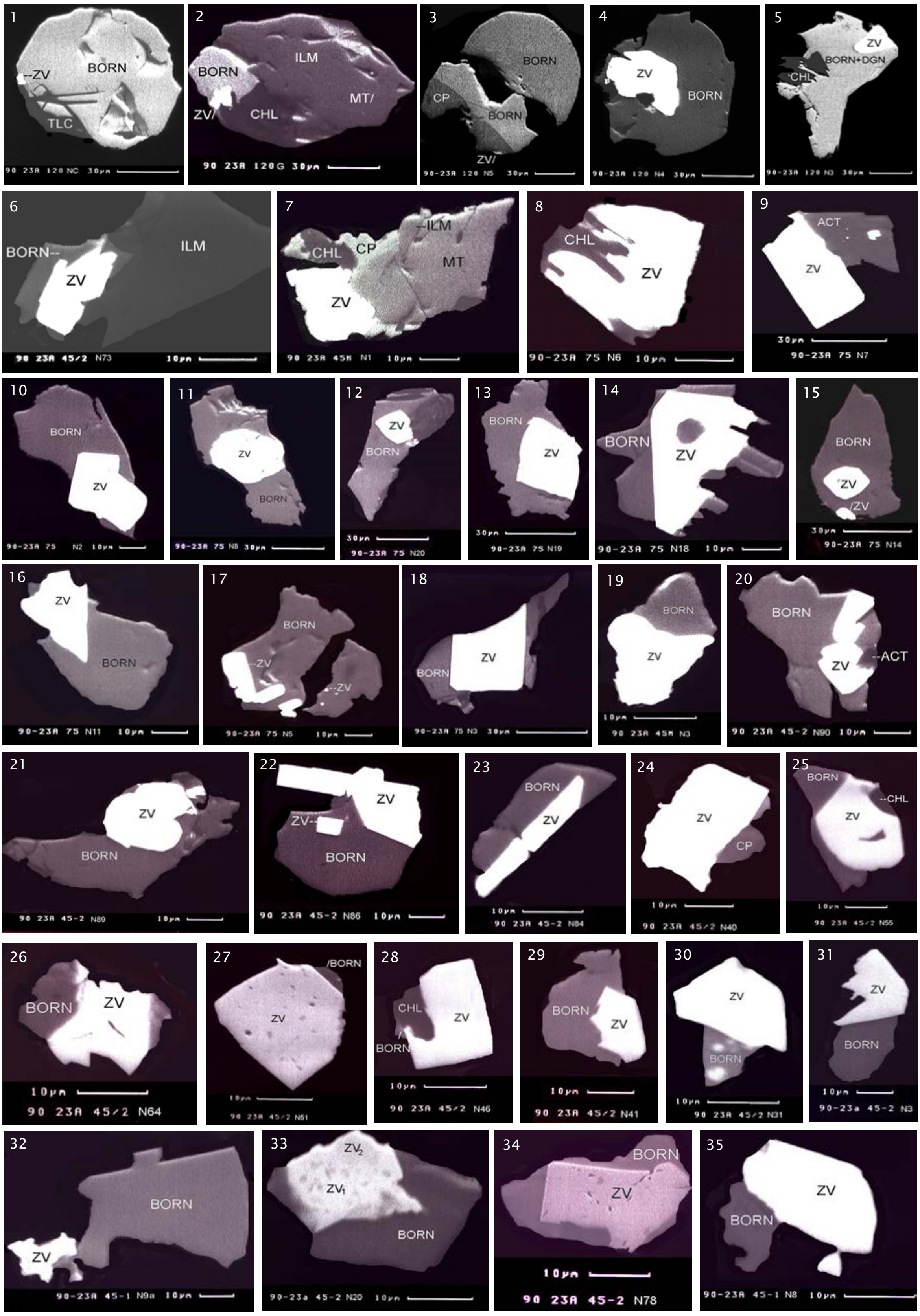

Plate 2. *Grains of zviagintsevite, extracted in heavy concentrates of the sample 90-23A, 807 (1-101); polished section, SEM-image (BIE).*

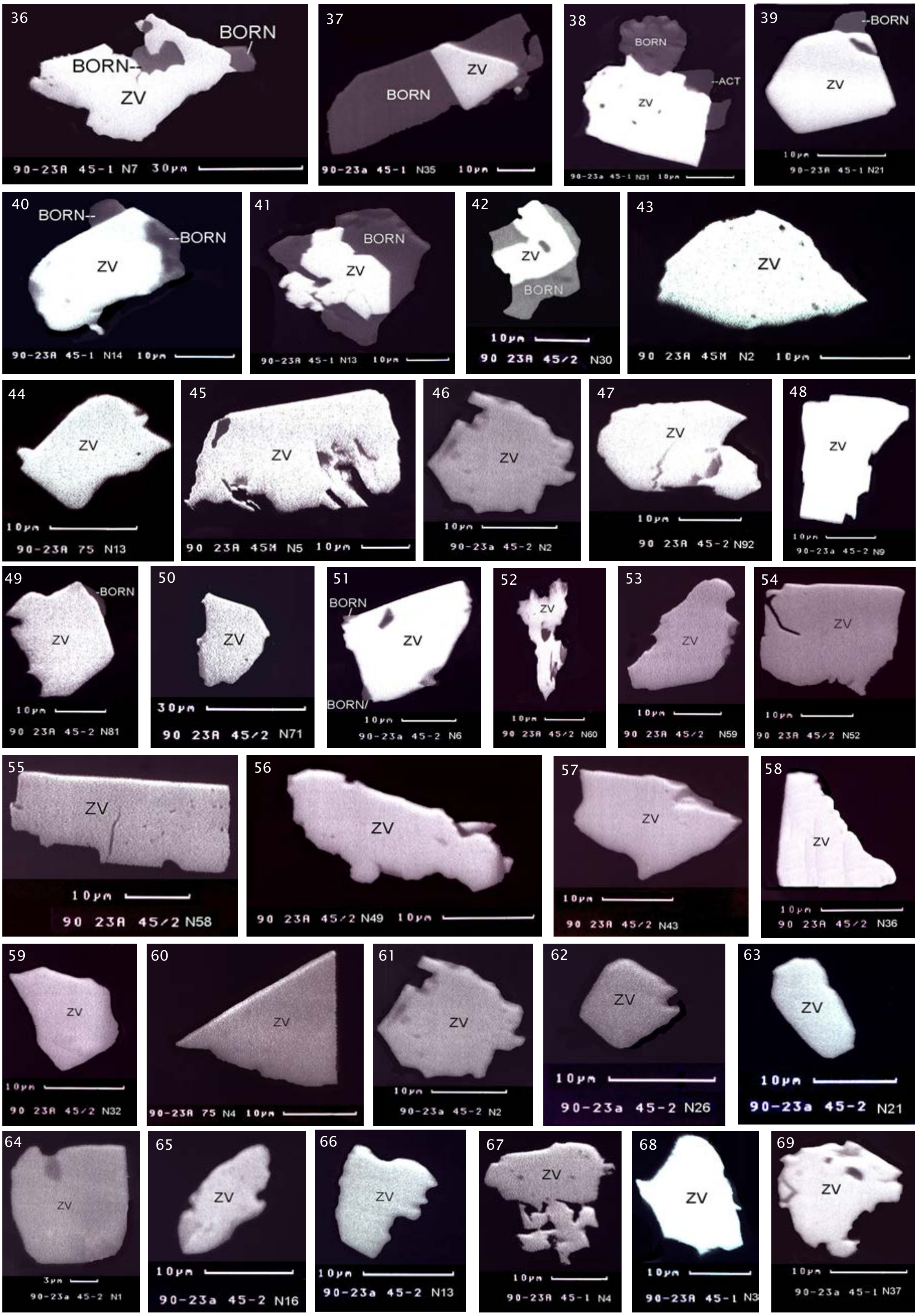

Plate 2 continued. *Grains of zviagintsevite, extracted in heavy concentrates of the sample 90-23A, 807 (1-101); polished section, SEM-image (BIE).*

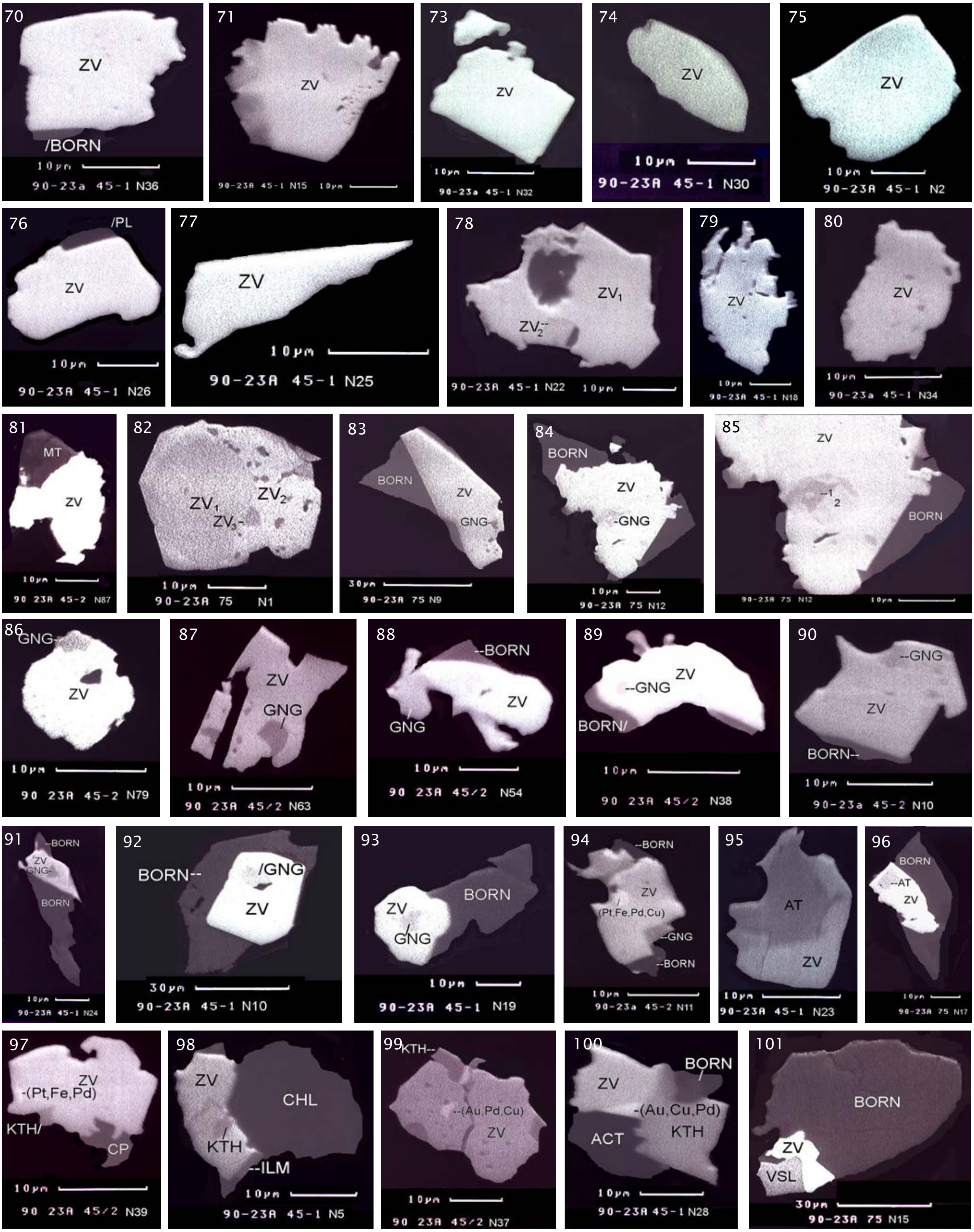

Plate 2 continued. *Grains of zviagintsevite, extracted in heavy concentrates of the sample 90-23A, 807 (1-101); polished section, SEM-image (BIE).*

Plate 3. *Grains of arsenides of Pd, extracted in heavy concentrates of the sample 90-23A, 807 (1-33); polished section, SEM-image (BIE).*

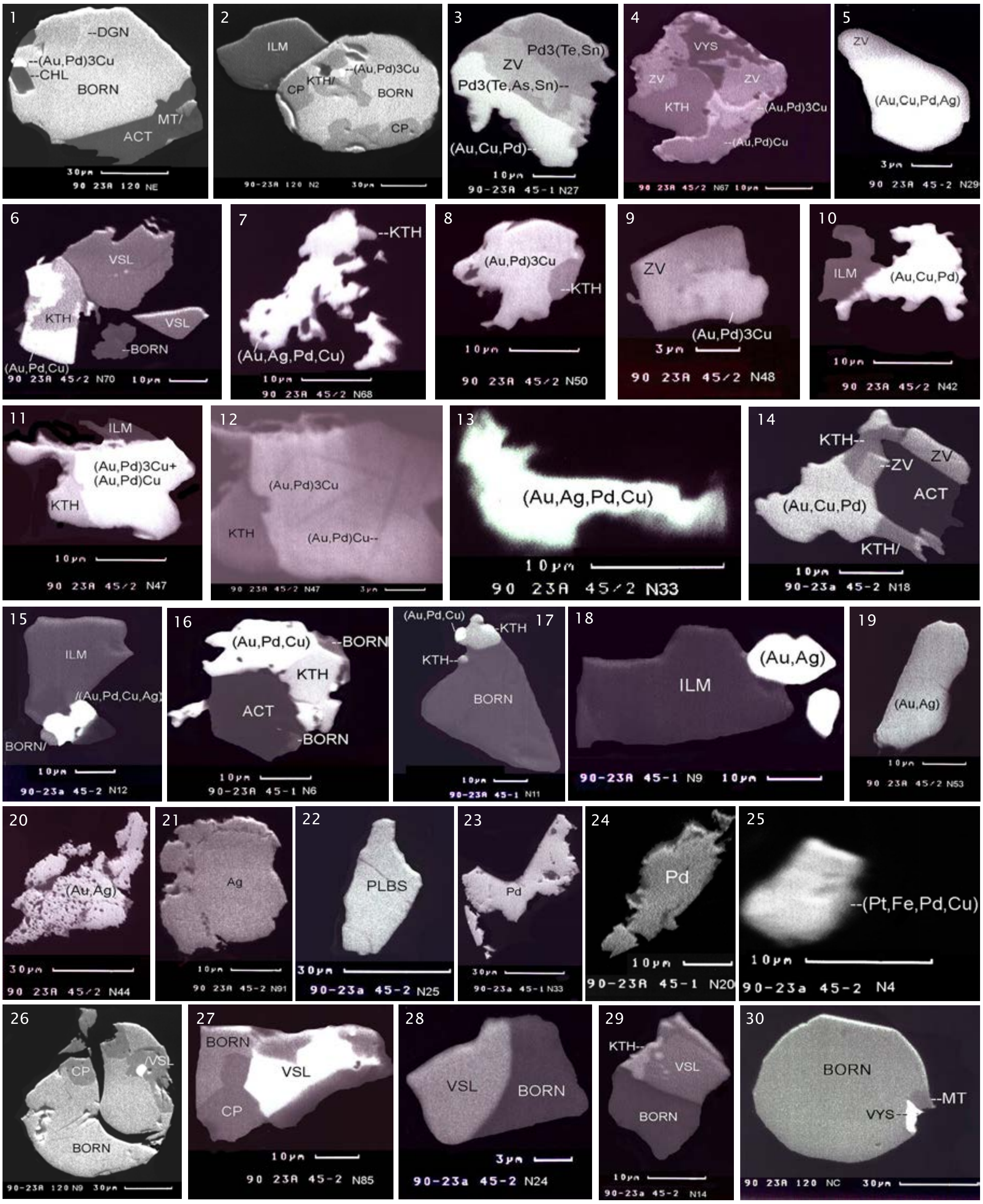

Plate 4. *Grains of native precious metals, their alloys and sulphides, extracted in heavy concentrates of the sample 90-23A, 807 (1-30); polished section, SEM-image (BIE).*

Sample 90-23A 807.03

Electron microprobe analyses of sulphides and PGE phases

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

Cu-sulphides

FILE ID1	Pd level	ID2	260794	phase	Cu	Fe	S	Au	Pd	Pt	Pb	Sn	Bi	Zn	Te	Sb	As	Ag	Ni	TOTAL
23A-807.03	Pd5	Sulphide	5Sa	Chalcopyrite	34,24	30,03	35,32	0,07	0,02	0,05	n.a	0,06	n.a.	n.a.	0,01	0,01	0,01	0,01	0,01	99,85
23A-807.03	Pd5	Sulphide	6Sc	Chalcopyrite	34,96	29,98	34,28	0,01	0,02	0,16	n.a	0,03	n.a.	n.a.	0,01	0,03	0,01	0,01	0,01	99,51
23A-807.03	Pd5	Sulphide	6Sd	Chalcopyrite	36,03	28,68	33,89	0,01	0,03	0,01	n.a	0,02	n.a.	n.a.	0,01	0,01	0,01	0,01	0,01	98,71
23A-807.03	Pd5	Sulphide	8Sb	Chalcopyrite	37,09	28,00	33,26	0,07	0,01	0,01	n.a	0,01	n.a.	n.a.	0,01	0,01	0,01	0,01	0,01	98,50
											n.a									
23A-807.03	Pd5	Sulphide	1Sa	bornite	58,47	11,06	24,07	0,10	0,02	0,16	n.a	0,01	n.a.	n.a.	0,01	0,02	0,01	0,01	0,01	93,95
23A-807.03	Pd5	Sulphide	1Sb	bornite	56,65	11,16	24,40	0,31	0,05	0,01	n.a	0,01	n.a.	n.a.	0,01	0,02	0,01	0,22	0,01	92,85
23A-807.03	Pd5	Sulphide	3Sa	bornite	61,67	11,89	25,86	0,07	0,01	0,09	n.a	0,01	n.a.	n.a.	0,03	0,01	0,01	0,01	0,01	99,66
23A-807.03	Pd5	Sulphide	3Sb	bornite	61,81	11,92	25,66	0,01	0,03	0,13	n.a	0,04	n.a.	n.a.	0,05	0,01	0,01	0,21	0,03	99,91
23A-807.03	Pd5	Sulphide	4Sb	bornite	61,41	11,29	25,24	0,02	0,01	0,09	n.a	0,01	n.a.	n.a.	0,02	0,01	0,01	0,22	0,03	98,37
23A-807.03	Pd5	Sulphide	6Sa	bornite	62,50	11,50	25,69	0,18	0,01	0,04	n.a	0,01	n.a.	n.a.	0,01	0,03	0,01	0,19	0,02	100,20
23A-807.03	Pd5	Sulphide	6Sb	bornite	63,65	11,61	26,19	0,06	0,07	0,08	n.a	0,03	n.a.	n.a.	0,01	0,04	0,01	0,01	0,04	101,80
23A-807.03	Pd5	Sulphide	7Sa	bornite	62,46	11,78	25,07	0,01	0,07	0,15	n.a	0,01	n.a.	n.a.	0,01	0,01	0,01	0,01	0,01	99,60
23A-807.03	Pd5	Sulphide	7Sb	bornite	62,57	11,68	25,25	0,13	0,03	0,01	n.a	0,03	n.a.	n.a.	0,01	0,01	0,01	0,01	0,01	99,75
23A-807.03	Pd5	Sulphide	8Sa	bornite	60,32	13,49	25,55	0,01	0,01	0,07	n.a	0,02	n.a.	n.a.	0,03	0,01	0,01	0,01	0,01	99,55
23A-807.03	Pd5	Sulphide	9Sb	bornite	63,06	11,78	25,05	0,03	0,03	0,13	n.a	0,01	n.a.	n.a.	0,03	0,03	0,01	0,01	0,01	100,19
23A-807.03	Pd5	Sulphide	10Sa	bornite	61,65	11,93	25,04	0,18	0,06	0,13	n.a	0,01	n.a.	n.a.	0,03	0,02	0,01	0,01	0,01	99,08
23A-807.03	Pd5	Sulphide	10Sb	bornite	60,95	12,00	25,50	0,01	0,10	0,04	n.a	0,05	n.a.	n.a.	0,01	0,01	0,01	0,01	0,01	98,71
23A-807.03	Pd5	Sulphide	4Sa	bornite	59,64	11,20	24,94	0,01	0,92	0,01	n.a	0,06	n.a.	n.a.	0,01	0,01	0,01	0,01	0,01	96,84

PGE phases

FILE ID1	Pd level	ID2	260794	phase	Cu	Fe	S	Au	Pd	Pt	Pb	Sn	Bi	Zn	Te	Sb	As	Ag	Ni	TOTAL
23A-807.03	Pd5	PGM	8PGM1	Atokite	1,96	2,00	0,05	0,59	66,10	5,38	n.a.	17,06	n.a.	n.a.	1,19	0,36	5,97	0,01	0,01	100,67
23A-807.03	Pd5	PGM/Pb	6PGM2	Atokite	0,37	0,52	0,01	3,12	65,34	0,21	n.a.	20,70	n.a.	n.a.	0,01	0,06	0,01	0,01	0,01	90,37
23A-807.03	Pd5	PGM/Pb	4PGM1	"Atokite"	0,54	0,98	0,01	1,15	59,74	0,58	n.a.	14,06	n.a.	n.a.	0,01	0,01	0,04	0,01	0,01	77,15
23A-807.03	Pd5	PGM/Pb	6PGM3	Zvyagintsevite	0,33	0,66	0,01	3,00	55,41	0,30	n.a.	9,34	n.a.	n.a.	0,01	0,01	0,01	0,01	0,01	69,10
23A-807.03	Pd5	PGM/Pb	6PGM1	Zvyagintsevite	0,21	0,68	0,01	3,00	51,69	0,17	n.a.	3,44	n.a.	n.a.	0,04	0,01	0,01	0,01	0,01	59,28

Sample 90-23A 807.03

Electron microprobe analyses of sulphides and PGE phases

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

Cu-sulphides

FILE ID1	Pd level	ID2	260794	phase	Cu	Fe	S	Au	Pd	Pt	Pb	Sn	Bi	Zn	Te	Sb	As	Ag	Ni	TOTAL
23A-807.03	Pd5	Sulphide	5Sa	Chalcopyrite	34,24	30,03	35,32	0,07	0,02	0,05	n.a	0,06	n.a.	n.a.	0,01	0,01	0,01	0,01	0,01	99,85
23A-807.03	Pd5	Sulphide	6Sc	Chalcopyrite	34,96	29,98	34,28	0,01	0,02	0,16	n.a	0,03	n.a.	n.a.	0,01	0,03	0,01	0,01	0,01	99,51
23A-807.03	Pd5	Sulphide	6Sd	Chalcopyrite	36,03	28,68	33,89	0,01	0,03	0,01	n.a	0,02	n.a.	n.a.	0,01	0,01	0,01	0,01	0,01	98,71
23A-807.03	Pd5	Sulphide	8Sb	Chalcopyrite	37,09	28,00	33,26	0,07	0,01	0,01	n.a	0,01	n.a.	n.a.	0,01	0,01	0,01	0,01	0,01	98,50
											n.a									
23A-807.03	Pd5	Sulphide	1Sa	bornite	58,47	11,06	24,07	0,10	0,02	0,16	n.a	0,01	n.a.	n.a.	0,01	0,02	0,01	0,01	0,01	93,95
23A-807.03	Pd5	Sulphide	1Sb	bornite	56,65	11,16	24,40	0,31	0,05	0,01	n.a	0,01	n.a.	n.a.	0,01	0,02	0,01	0,22	0,01	92,85
23A-807.03	Pd5	Sulphide	3Sa	bornite	61,67	11,89	25,86	0,07	0,01	0,09	n.a	0,01	n.a.	n.a.	0,03	0,01	0,01	0,01	0,01	99,66
23A-807.03	Pd5	Sulphide	3Sb	bornite	61,81	11,92	25,66	0,01	0,03	0,13	n.a	0,04	n.a.	n.a.	0,05	0,01	0,01	0,21	0,03	99,91
23A-807.03	Pd5	Sulphide	4Sb	bornite	61,41	11,29	25,24	0,02	0,01	0,09	n.a	0,01	n.a.	n.a.	0,02	0,01	0,01	0,22	0,03	98,37
23A-807.03	Pd5	Sulphide	6Sa	bornite	62,50	11,50	25,69	0,18	0,01	0,04	n.a	0,01	n.a.	n.a.	0,01	0,03	0,01	0,19	0,02	100,20
23A-807.03	Pd5	Sulphide	6Sb	bornite	63,65	11,61	26,19	0,06	0,07	0,08	n.a	0,03	n.a.	n.a.	0,01	0,04	0,01	0,01	0,04	101,80
23A-807.03	Pd5	Sulphide	7Sa	bornite	62,46	11,78	25,07	0,01	0,07	0,15	n.a	0,01	n.a.	n.a.	0,01	0,01	0,01	0,01	0,01	99,60
23A-807.03	Pd5	Sulphide	7Sb	bornite	62,57	11,68	25,25	0,13	0,03	0,01	n.a	0,03	n.a.	n.a.	0,01	0,01	0,01	0,01	0,01	99,75
23A-807.03	Pd5	Sulphide	8Sa	bornite	60,32	13,49	25,55	0,01	0,01	0,07	n.a	0,02	n.a.	n.a.	0,03	0,01	0,01	0,01	0,01	99,55
23A-807.03	Pd5	Sulphide	9Sb	bornite	63,06	11,78	25,05	0,03	0,03	0,13	n.a	0,01	n.a.	n.a.	0,03	0,03	0,01	0,01	0,01	100,19
23A-807.03	Pd5	Sulphide	10Sa	bornite	61,65	11,93	25,04	0,18	0,06	0,13	n.a	0,01	n.a.	n.a.	0,03	0,02	0,01	0,01	0,01	99,08
23A-807.03	Pd5	Sulphide	10Sb	bornite	60,95	12,00	25,50	0,01	0,10	0,04	n.a	0,05	n.a.	n.a.	0,01	0,01	0,01	0,01	0,01	98,71
23A-807.03	Pd5	Sulphide	4Sa	bornite	59,64	11,20	24,94	0,01	0,92	0,01	n.a	0,06	n.a.	n.a.	0,01	0,01	0,01	0,01	0,01	96,84

PGE phases

23A-807.03	Pd5	PGM	8PGM1	Atokite	1,96	2,00	0,05	0,59	66,10	5,38	n.a.	17,06	n.a.	n.a.	1,19	0,36	5,97	0,01	0,01	100,67
23A-807.03	Pd5	PGM/Pb	6PGM2	Atokite	0,37	0,52	0,01	3,12	65,34	0,21	n.a.	20,70	n.a.	n.a.	0,01	0,06	0,01	0,01	0,01	90,37
23A-807.03	Pd5	PGM/Pb	4PGM1	"Atokite"	0,54	0,98	0,01	1,15	59,74	0,58	n.a.	14,06	n.a.	n.a.	0,01	0,01	0,04	0,01	0,01	77,15
23A-807.03	Pd5	PGM/Pb	6PGM3	Zvyagintsevite	0,33	0,66	0,01	3,00	55,41	0,30	n.a.	9,34	n.a.	n.a.	0,01	0,01	0,01	0,01	0,01	69,10
23A-807.03	Pd5	PGM/Pb	6PGM1	Zvyagintsevite	0,21	0,68	0,01	3,00	51,69	0,17	n.a.	3,44	n.a.	n.a.	0,04	0,01	0,01	0,01	0,01	59,28