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SHORT NOTE

Rhodarsenide, $(Rh,Pd)_2As$, a new mineral

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Abstract: The new mineral rhodarsenide, ideally $(Rh, Pd)_2As$, has been found in concentrates from placers of the Srebrnica river, near the village Veluce in Central Serbia. The associated platinum-group minerals are PGE alloys, Rh-Ir sulpharsenides and sperrylite. Rhodarsenide is present as inclusions (up to 80 × 100 µm) in Pt-Fe and Ru-Os-Ir alloys. In reflected light it is brownish; pleochroism and anisotropy are weak to distinct. Maximum and minimum reflectance values in air for standard wavelengths (470, 546, 589 and 650 nm) are 46.3/45.5, 48.4/47.6, 49.5/48.2 and 51.2/49.8, respectively; values measured in oil are 38.2/32.9 (470), 39.8/35.7 (546),40.4/36.4 (589) and 40.5/36.6 (650). Vickers micro-indentation hardness (VHN_{25}) is 493-585 kg/mm^2. Chemical compositions of individual grains of rhodarsenide vary between Rh 38.53-60.81, Pd 12.10-34.67, Pt 0.00-2.38, Ir 0.09-0.48, Fe 0.00-0.10, Cu 0.08-0.46, As 23.42-27.96, Sb 0.09-1.60, and Te 0.08-1.20 wt.%, corresponding to: $(Rh_{1.67}Pd_{0.34})_{\Sigma 2.01}$ $As_{0.99}$ and $(Rh_{1.07}Pd_{0.94}Pt_{0.03})_{\Sigma 2.04}$ $(As_{0.91}Sb_{0.04}Te_{0.01})_{\Sigma 0.96}$. The X-ray powder-diffraction pattern was indexed for an orthorhombic cell with a = 5.866 Å; b = 3.893 Å; c = 7.302 Å; a: b: c = 1.507: 1: 1.875; V = 166.7 Å^3. For Z = 4, the calculated density is 11.32 g/cm^3. The three strongest lines in the X-ray pattern are 2.237 (10), 2.067 (8) and 2.426 (7) Å.

Key-words: rhodarsenide, new mineral, PGM placers, Central Serbia.

Introduction

Rhodarsenide, ideally $(Rh,Pd)_2As$, is a new platinum-group mineral (PGM) discovered in PGM-bearing placers of the Srebrnica river, near Veluce, in Central Serbia. The mineralogy of the placers has recently been described by Krstć & Tarkian (1997). They contain a wide variety of PGM consisting of PGE alloys, sulphides, arsenides, sulpharsenides, tellurides, and antimonides. The PGM associated with rhodarsenide are Pt-Fe alloys, Ru-Os-Ir alloys, hollingworthite, irarsite, and sperrylite. The source rocks of the placers are chromitites of the Veluce ophiolite complex, in which most of the PGM precipitated from a silicate melt under magmatic conditions (Krstć & Tarkian, 1997).

The new mineral and its name have been approved by the Commission on New Minerals and Mineral Names of the International Mineralogical Association (No. 96-030). The mineral name is for the composition (Rh > Pd)$_2$As. Type material is deposited in the Mineralogical Museum ot the University of Hamburg.

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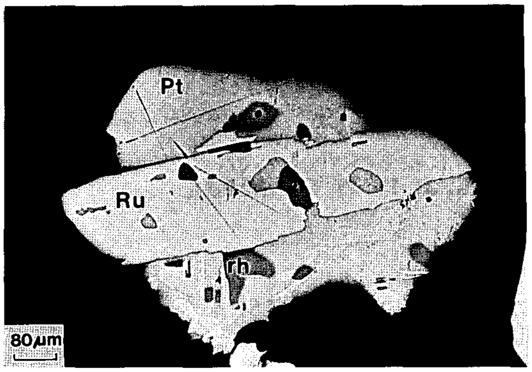

Fig. 1. Photomicrograph of rhodarsenide inclusions (rh) in Pt-Fe-alloy (Pt) and Ru-Os-Ir alloy (Ru). Reflected light.

Physical and optical properties

Rhodarsenide occurs as irregular inclusions in Pt-Fe- and Ru-Os-Ir alloys. The size of individual grains varies between 10 × 70 and 80 × 100 µm (Fig. 1). Vickers microhardness VHN (25 g load) is on average 515 (6 indentations), and the range is 493-585 kg/mm². Accordingly, it is harder than palladoarsenide Pd_2As (VHN_{20} = 277-357, Begizov *et al.*, 1974) and palladobismutharsenide, $Pd_{10}As_4Bi$ (VHN_{25} = 373-483, Cabri *et al.*, 1976), but softer than cherepanovite, RhAs (VHN_{50} = 726-754, Rudashevsky *et al.*, 1985).

In reflected light, rhodarsenide is brownish with a pale-green tinge. Pleochroism is weak in air but distinct (from brownish to greenish) in oil immersion. The anisotropism is moderate to distinct, from dark brown to greenish grey.

A computerized Zeiss MPM microphotometer and a WTiC standard (*R*₅₈₉ in air = 49.5 %, *R*₅₈₉ in oil = 35.5 %) were used for reflectance measurements (Table 1 and Fig. 2). The reflectance

Table 1. Reflectance date of rhodarsenide.

λnm	R_1 (air)	R_2 (air)	R_1 (oil)	R_2 (oil)
400	41.8	39.4	35.2	30.5
420	43.2	41.1	35.7	31.1
440	44.5	42.8	36.6	31.7
460	45.9	44.5	37.9	32.5
470	**46.3**	**45.5**	**38.2**	**32.9**
480	47.2	46.2	38.7	33.9
500	48.6	47.9	39.3	34.5
520	49.2	48.1	39.3	35.1
540	49.9	48.4	39.8	35.6
546	**48.4**	**47.6**	**39.8**	**35.7**
560	49.7	48.3	40.1	36.1
580	49.5	48.3	40.4	36.5
589	**49.5**	**48.2**	**40.4**	**36.4**
600	50.2	49.3	40.5	36.4
620	51.0	50.3	40.7	36.6
640	51.0	50.2	40.5	36.5
650	**51.2**	**49.8**	**40.5**	**36.6**
660	51.0	50.0	40.5	36.8
680	52.0	50.8	40.6	36.8
700	53.2	51.6	40.5	36.6

Colour values (C illuminant)

	x	y	Y%	Pe%	λd
R_1 (air)	0.318	0.327	49.6	5.1	574
R_2 (air)	0.319	0.328	48.4	5.7	574
R_1 (oil)	0.317	0.325	39.9	4.0	574
R_2 (oil)	0.320	0.329	35.8	5.9	574

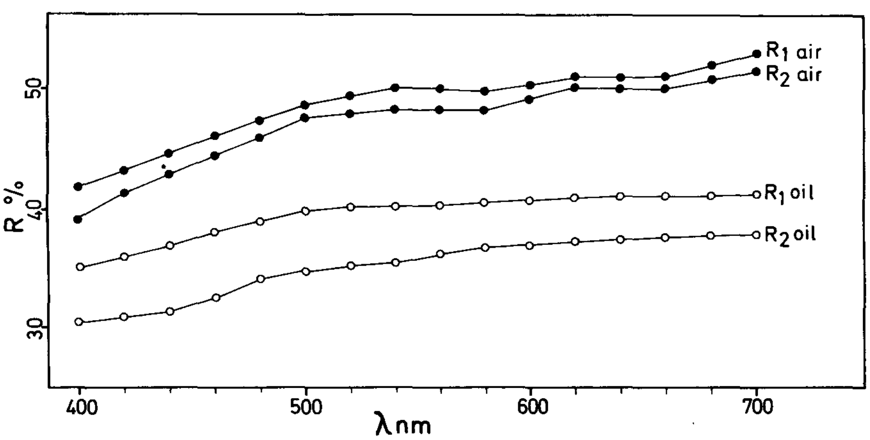

Fig. 2. Reflectance spectra for rhodarsenide in air and oil.

Table 2. Representative electron-microprobe analyses of rhodarsenide (wt.%).

No.	1	2	3	4	5	6
Rh	60.81	57.63	57.18	42.01	40.34	38.53
Pd	12.65	15.74	12.10	29.88	30.70	34.67
Pt	0.49	1.78	2.38	-	1.95	1.90
Ir	-	0.20	-	-	0.09	0.48
Fe	-	-	-	-	-	0.10
Cu	0.08	-	0.19	-	0.46	-
As	26.04	24.00	27.96	25.74	23.37	23.42
Sb	0.09	0.67	0.15	1.60	1.08	1.55
Te	-	-	0.08	-	1.20	0.50
Total	100.16	100.02	100.04	99.23	99.19	101.15
		Atomic proportions (Σatoms = 3)				
Rh	1.67	1.60	1.57	1.17	1.14	1.07
Pd	0.34	0.42	0.32	0.81	0.84	0.94
Pt	-	0.03	0.04	-	0.03	0.03
Ir	-	-	-	-	-	-
Fe	-	-	-	-	-	-
Cu	-	-	0.01	-	0.02	-
Σ Me	2.01	2.05	1.94	1.98	2.03	2.04
As	0.99	0.93	1.06	0.98	0.91	0.91
Sb	-	0.02	-	0.04	0.03	0.04
Te	-	-	-	-	0.03	0.01
Σ	0.99	0.95	1.06	1.02	0.97	0.96
Rh/Rh+Pd	0.83	0.79	0.83	0.59	0.57	0.53

curves of rhodarsenide resemble those of palladoarsenide (Begizov *et al.*, 1974) and cherepanovite (Rudashevsky *et al.*, 1985). However, the reflectance values of rhodarsenide (average at 589 nm = 49 %) lie between those reported for palladoarsenide (53 %) and cherepanovite (46 %). Reflectance spectra for palladobismutharsenide appear to be different, though data given by Cabri *et al.* (1976) are for the four standard wavelengths (R_{589}: ≈ 54 %) only.

Chemical composition

Several grains of rhodarsenide were analyzed using a Cameca Camebax Microbeam wavelength-dispersive electron microprobe at the Department of Mineralogy and Petrology, University of Hamburg. The operating conditions were 20 kV and 20 nA. The following X-ray lines were used: Rh$L\alpha$, Pd$L\beta$, Pt$L\alpha$, Ir$L\alpha$, Fe$K\alpha$, Cu$K\alpha$, As$K\alpha$, Sb$L\alpha$, Te$L\alpha$. Pure elements (Rh, Pt, Ir, Fe, Cu) as well as synthetic PdBiTe, GaAs, and Sb_2S_3 were used as standards. Corrections were applied using the computer program "PAP" (Pouchou & Pichoir, 1991).

Representative analyses of rhodarsenide are given in Table 2. Platinum is present as a minor element (up to 3 wt. %) in most analyses. Ir was detected in some analyses, however, in amounts less than 0.5 wt. %. Arsenic is partly replaced by Sb (up to 3 wt. %) and Te (up to 1.5 wt. %). The composition is close to stoichiometric Me_2As, with variation of Rh/Rh+Pd from 0.83 to 0.53. Accordingly the ideal formula is $(Rh,Pd)_2As$ for the mineral. The only PGM comparable with this composition is an unnamed mineral with the formula $(Rh,Pd)_{5-x}(As,Te)_2$ or ideally $Rh_5Pd_5As_4$ (without additional data) described by Johan *et al.* (1991) in isoferroplatinum nuggets from Milverton, Australia. However, the chemical formula of this mineral reported by Johan *et al.*, (1991) shows considerable deviation from the 2:1 stoichiometry.

Analyses of palladoarsenides from the type locality (Begizov *et al.*, 1974), the Stillwater complex (Cabri *et al.*, 1975; Volborth *et al.*, 1986) and from Lac des Iles, Ontario (Cabri & Laflamme, 1979) do not show any Rh. In addition, palladobismutharsenide (Cabri *et al.*, 1976) is devoid of Rh. However, significant variation of Rh/Rh+Pd ratios in rhodarsenide implies an extensive solid-solution between Pd_2As (palladoarsenide) and Rh_2As, whereas the latter was known as a synthetic phase only (Quesnel & Heyding, 1962).

Table 3. Comparison of X-ray data of rhodarsenide and synthetic β–Rh_2As.

Rhodarsenide				Synthetic β-Rh_2As (Quesnel & Heyding, 1962)		
$I_{est.}$	$d_{meas.}$	$d_{calc.}$	hkl	I	d	hkl
7	2.426	2.425	112	80	2.424	112
4	2.348	2.343	210	40	2.343	210
				20	2.289	202
				20	2.248	103
10	2.237	2.231	211	100	2.232	211
8	2.067	2.064	013	40	2.071	013
6	1.935	1.945	020,113	80	1.947	020
				20	1.894	301
5	1.860	1.873	203	20	1.878	203
3	1.828	1.825	004	18	1.832	004
				6	1.751	104
				20	1.731	302
1	1.694	1.699	311	14	1.703	311
		1.688	213	18	1.692	213
1	1.610	1.622	220			
				6	1.598	114
2	1.548	1.550	204			
				14	1.487	222
1	1.475	1.472	123	20	1.475	123
				14	1.445	401
1	1.426	1.419	313	14	1.423	313
		1.417	105			
3	1.384	1.379	320			
				14	1.374	410
1	1.351	1.355	321	25	1.358	321
1	1.337	1.334	304	14	1.337	304
		1.331	115,024			
3	1.306	1.307	205	14	1.314	205
1	1.300	1.298	124			
1	1.291	1.290	322	35	1.296	322
2	1.278	1.278	031			
1	1.268	1.267	314	35	1.268	314
1	1.258	1.256	403			
				8	1.247	131
1	1.218	1.217	006			
1	1.212	1.212	224	6	1.216	224
				18	1.201	323

X-ray data

Single-crystal studies of rhodarsenide could not be performed on the material available. Thus, three crystals analysed by electron microprobe were studied using a Rigaku microdiffractometer (Cr*K*α). The X-ray pattern obtained is presented in Table 3. With the exception of some reflections the data are different from those of palladoarsenide (monoclinic) (Begizov *et al.*, 1974) and of synthetic Pd_2As (Saini *et al.*, 1964; Bälz & Schubert, 1969). The latter has been reported as monoclinic (α-form), hexagonal (β-form) and orthorhombic phases. The X-ray data of rhodarsenide show more similarity to those reported for the synthetic equivalent of palladobismutharsenide (Cabri *et al.*, 1976), although only the strongest line (2.237) coincides.

The X-ray pattern of rhodarsenide is, however, in good agreement with that obtained for synthetic β–Rh_2As (orthorhombic, a = 5.89; b = 3.89; c = 7.32 Å) by Quesnel & Heyding (1962, Table 3). Thus the pattern was indexed for an orthorhombic cell by analogy with that of synthetic β–Rh_2As. Refinement of the data yielded for rhodarsenide: a = 5.866(5) Å; b = 3.893 (2) Å; c = 7.302(4) Å; a: b: c = 1.507: 1: 1.875; V = 166.7 Å^3. For Z = 4, the density calculated for a composition (Table 2, analysis No. 4) is 11.32 g/cm³.

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