Oulankaite, a new platinum-group mineral from the Lukkulaisvaara layered intrusion, northern Karelia, Russia

Article *in* European Journal of Mineralogy · March 1996

1 author:

A. Y. Barkov
Cherepovets State University

Eur. J. Mineral.
1996, **8**, 311-316

Oulankaite, a new platinum-group mineral from the Lukkulaisvaara layered intrusion, northern Karelia, Russia

ANDREW YU. BARKOV[1,2], YURII P. MEN'SHIKOV[2], VICTOR D. BEGIZOV[3] and ANDREW I. LEDNEV[2]

[1] Department of Geosciences and Astronomy, University of Oulu, FIN-90570 Oulu, Finland

[2] Geological Institute, Kola Science Centre, Russian Academy of Sciences, 14, Fersman Street, 184200 Apatity, Russia

[3] Moscow Geological Prospecting Institute, 23 Mikluho-Maklai Street, 117485 Moscow, Russia

Abstract: Oulankaite, ideally $(Pd,Pt)_5(Cu,Fe)_4SnTe_2S_2$, is a new mineral species, occurring in pegmatoidal, plagioclase-bearing pyroxenite hosted by a microgabbronorite in the Early Proterozoic Lukkulaisvaara mafic-ultramafic layered intrusion, Oulanka complex, northern Karelia, Russia. The mineral name is for the Oulanka river. The associated minerals include base-metal sulphides (chalcopyrite, bornite, millerite, pentlandite *etc.*), various platinum-group minerals, and an unnamed rhenium-rich sulphide. Typically, oulankaite forms platy inclusions (up to 0.2 x 0.1 mm) in chalcopyrite. Oulankaite is an opaque mineral. In reflected light *in air* it is distinctly to strongly bireflectant and pleochroic from yellowish-rose to violet-rose. The anisotropy is typically strong from yellowish-white to bluish-grey. Reflectance data measured *in air* are [R_1 and R_2 % (λ nm)]: 41.6 and 36.2 (470); 48.7 and 41.0 (546); 51.7 and 43.1 (589); 54.0 and 44.6 (650). Reflectance data measured *in oil* are 29.1 and 23.5 (470); 35.2 and 29.5 (546); 37.1 and 30.8 (589); 39.4 and 33.8 (650). Vickers micro-indentation hardness is 156-334, the average is 221 kg/mm^2 ($VHN_{20;40}$). The mean of three microprobe analyses gave Pd 41.60, Pt 2.85, Cu 17.53, Fe 2.51, Sn 9.73, Te 21.32, S 4.84, a total of 100.38 wt.%, corresponding to: $(Pd_{4.86}Pt_{0.18})_{\Sigma 5.04}(Cu_{3.43}Fe_{0.56})_{\Sigma 3.99}Sn_{1.02}Te_{2.08}S_{1.88}$ (on the basis of Σ atoms = 14). The X-ray powder diffraction pattern was indexed for a tetragonal cell with a = 9.044(3) Å, c = 4.937(3) Å, $c:a$ = 0.5459, V = 403.8(5) Å^3. For Z = 2, the calculated density is 10.27(1) g/cm^3. The strongest five lines in the X-ray powder pattern are [d in Å (I) (hkl)]: 2.472(10) (311,002); 2.260 (9) (400); 2.022 (6) (420); 1.361 (4) (541); 1.129 (5) (800,533,651).

Key-words: oulankaite, new mineral, platinum-group mineral, Lukkulaisvaara, Karelia, Russia.

Introduction

Oulankaite, ideally $(Pd,Pt)_5(Cu,Fe)_4SnTe_2S_2$, is a new platinum-group mineral found in the Early Proterozoic (*ca.* 2440 Ma; Barkov, 1992) Lukkulaisvaara mafic-ultramafic layered intrusion in the Oulanka complex. The intrusion is situated in the Russian Karelia, relatively adjacent (*ca.* 50 km) to the border between Russia and Finland. The Oulanka complex is a part of an extensive intrusion belt known in Finland as the Tornio-Näränkävaara belt (*e.g.*, Alapieti *et al.*, 1990). Some geological and mineralogical features of the Lukkulaisvaara intrusion were

0935-1221/96/0008-0311 $ 1.50

described by Lavrov (1979), Barkov (1992), Barkov *et al.* (1995a), Barkov *et al.* (1995b), and Barkov *et al.* (1995c).

The new mineral and its name have been approved by the Commission on New Minerals and Mineral Names (90-055), International Mineralogical Association.

Previously, oulankaite was reported as an incompletely characterized phase from the same ore deposit in Lukkulaisvaara (Begizov & Batashev, 1981; Grokhovskaya & Laputina, 1989; Barkov *et al.*, 1994).

The mineral name is for the *Oulanka* (*Olanga* in the Russian spelling of the name) river, which is near the ore deposit.

Type material is deposited at the Fersman Museum, Moscow.

Occurrence and associated minerals

Oulankaite occurs exclusively within sulphide-rich podiform and stringer-like segregations (< 0.5 m in thickness) of pegmatoidal plagioclase-bearing pyroxenite hosted by a sill of microgabbronorite. The primary mineral chemistry of the segregations is indistinguishable from that of the host microgabbronorite (*e.g.*, Barkov *et al.*, 1995a). The pegmatoidal rocks show different extents of alteration, but their primary texture and relics of igneous minerals are typically well preserved. It is of particular interest to note that a quite unusual, highly aluminous mineralization (*e.g.*, staurolite, tschermakite, corundum *etc.*) was identified in the oulankaite-bearing meta-pyroxenite, which normally contains from 4 to 5 wt.% of Al_2O_3 only (Barkov *et al.*, in prep.). It should be noted that the meta-pyroxenite is spatially associated with slightly altered pyroxenite and the fresh microgabbronorite.

Sulphide minerals account for up to 25 vol. % of the pegmatitic pyroxenite. There are significant variations in the proportions of the sulphide minerals, typically occurring interstitially to orthopyroxene. However, sulphides may also be included within enstatite. Sulphide veinlets observed are considered to be of secondary origin. Chalcopyrite, bornite and millerite are three principal sulphides, but pentlandite may also be present in significant amounts. Members of the linnaeite mineral group, various platinum-group minerals, sphalerite, galena, pyrite and molybdenite are among the accessory minerals. The platinum-group minerals are telargpalite,

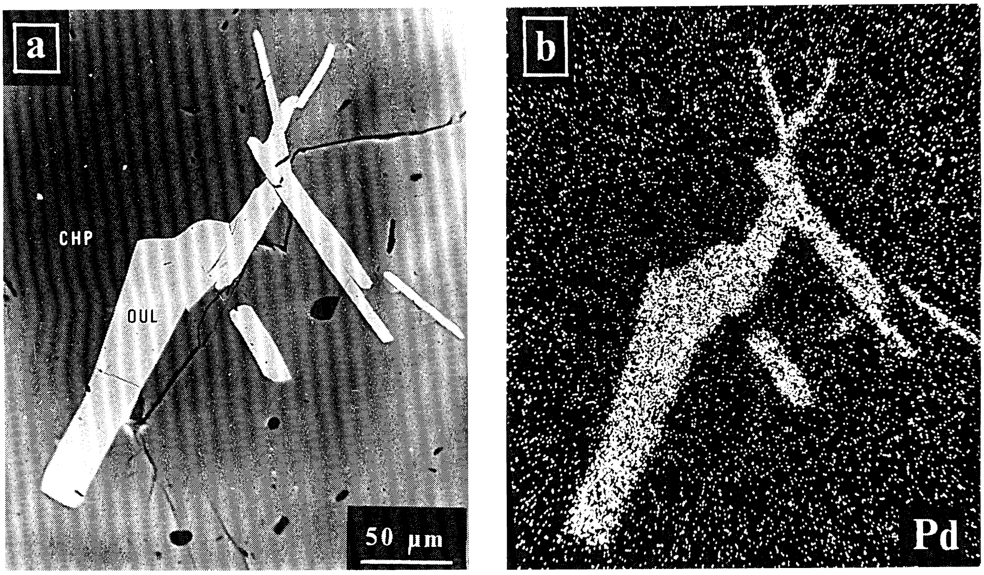

Fig. 1. *(a)* Secondary electron micrograph of the oulankaite platy crystals (OUL) enclosed within chalcopyrite (CHP); *(b)* Palladium X-ray scanning micrograph of the same crystals as in Fig. 1a.

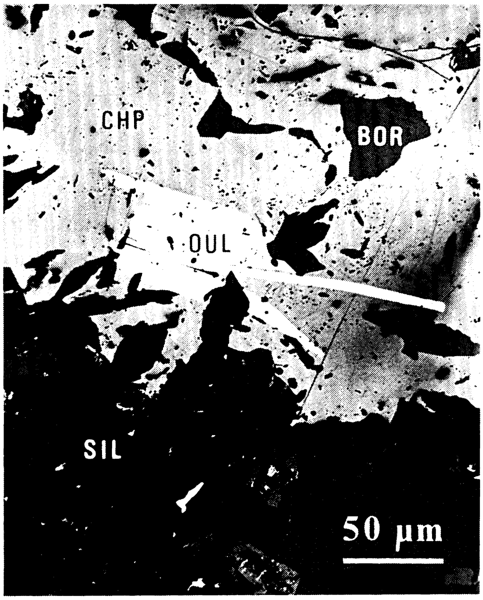

Fig. 2. Photomicrograph of a euhedral oulankaite grain (OUL) located at the boundary between chalcopyrite (CHP) and hydrosilicate (SIL). Note that the hydrosilicate grains cut the oulankaite crystal. BOR = bornite. Partly crossed nicols.

moncheite, kotulskite, tulameenite, sperrylite, taimyrite, atokite-rustenburgite series members, zvyagintsevite, irarsite, telluropalladinite (?) and tarkianite. It is also of interest to note an unnamed rhenium-rich sulphide, $(Cu,Fe)(Re,Mo)_4S_8$, from the segregations (Barkov & Lednev, 1993).

Appearance, physical and optical properties

Oulankaite is typically present as platy subhedral to euhedral inclusions in chalcopyrite (*e.g.*, Fig. 1). It commonly forms intergrowths with other platinum-group minerals (telargpalite, moncheite, sperrylite, tulameenite and kotulskite), but individual grains of oulankaite are not rare in this occurrence. In addition, several minute irarsite grains (up to 10 μm across) were observed as inclusions within oulankaite. It is notable that some oulankaite grains contain abundant hydrosilicate inclusions and may be cut by the hydrosilicate (*e.g.*, Fig. 2). The size of the oulankaite grains is highly variable, with the largest grains reaching approximately 0.2 x 0.1 mm.

Vickers microhardness VHN (31 indentations, either 20 or 40 g load) is 221 kg/mm^2 (range 156-334). Deformed indentations observed in the course of the microhardness measurements reveal microhardness anisotropy.

Oulankaite is distinctly to strongly bireflectant and pleochroic from yellowish-rose to violet-rose. The anisotropy is mainly strong from yellowish-white to bluish-grey. However, some grains exhibit moderate anisotropy. This differ-

Table 1. Reflectance data for oulankaite.

λ nm	R_1	R_2	R_1 *	R_2 *
	in air		in oil	
400	33.0	31.5	24.3	22.0
420	35.6	33.2	26.1	22.5
440	38.4	34.5	27.0	23.2
460	40.4	35.6	27.7	23.1
470	**41.6**	**36.2**	**29.1**	**23.5**
480	42.8	36.8	30.7	23.8
500	44.9	38.2	31.8	25.3
520	46.6	39.4	35.0	28.5
540	48.2	40.7	35.0	28.8
546	**48.7**	**41.0**	**35.2**	**29.5**
560	49.9	41.8	35.9	30.1
580	51.2	42.8	36.7	30.3
589	**51.7**	**43.1**	**37.1**	**30.8**
600	52.3	43.5	39.0	32.7
620	53.1	44.0	40.7	34.3
640	53.8	44.4	40.1	34.0
650	**54.0**	**44.6**	**39.4**	**33.8**
660	54.2	44.7	39.2	33.8
680	54.2	44.8	39.1	33.6
700	54.3	45.0	38.5	33.0

Colour values: C illuminant (in oil) *

	x	y	Y %	P_e %	λ_d
R_1	0.338	0.345	35.9	15.3	577
R_2	0.341	0.343	29.7	15.3	580

* Courtesy Prof. M. Tarkian, University of Hamburg

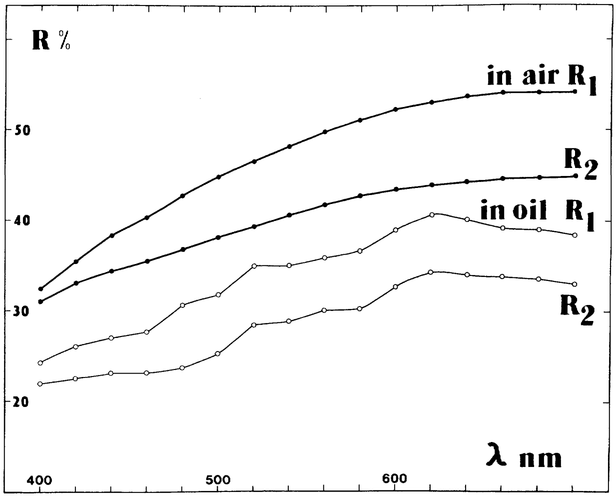

Fig. 3. Spectral reflectance curves of oulankaite measured *in air* (solid circles) and *in oil* (open circles).

ence is ascribed to different optical orientations of the grains in polished sections. In addition, platy oulankaite twins have been observed in some cases.

A MSFP-2 microphotometer and a Si standard (R_{589} *in air* = 35.7 %) were used for reflectance measurements *in air*, and a Zeiss MPM microphotometer with a continuous band interference filter and a WTiC standard (R_{589} *in oil* = 35.5 %) were used for measurements *in oil* (M. Tarkian, written comm.). The measurements in air and in oil were performed on two different grains of oulankaite. The reflectance data are listed in Table 1 and are plotted in Fig. 3.

Table 2. Representative electron microprobe analyses of oulankaite.

	Weight %				Atomic proportions (Σ atoms = 14)		
	1*	2**	3***		1	2	3
Pd	41.3	42.04	41.45	Pd	4.85	4.93	4.80
Pt	2.6	2.37	3.59	Pt	0.17	0.15	0.23
Cu	17.4	17.45	17.75	Σ	5.02	5.08	5.03
Fe	2.7	2.31	2.52	Cu	3.42	3.42	3.44
Sn	9.6	9.65	9.93	Fe	0.60	0.52	0.56
Te	21.6	21.21	21.16	Σ	4.02	3.94	4.00
S	4.7	4.88	4.93	Sn	1.01	1.01	1.03
Total	99.9	99.91	101.33	Te	2.12	2.07	2.04
				S	1.83	1.90	1.90

* MAR-2 electron microprobe; V.D. Begizov, analyst
** Cameca MS-46 electron microprobe; A.I. Lednev, analyst
***JEOL JSM-6400 scanning electron microscope equipped with a LINK eXL energy dispersive spectrometer; R.J. Kaukonen , analyst
For analytical conditions and standards used see text

Chemical composition and formula

Several oulankaite grains were analysed using (1) a MAR-2 electron microprobe; analytical conditions were previously given by Begizov & Batashev (1981); (2) a Cameca MS-46 electron microprobe operated at 25 kV with a beam current of 20 nA. The X-ray lines (and standards used) were Pd*L*α (synthetic Pd_3Pb_2), Cu*K*α, Fe*K*α, S*K*α ($CuFeS_2$), Pt*L*α, Sn*L*α and Te*L*α (pure elements); (3) a JEOL JSM-6400 scanning electron microscope equipped with a LINK eXL energy dispersive spectrometer. The results were processed by the ZAF-4 program.

Representative analyses are presented in Table 2. They demonstrate that oulankaite is characterized by a complex composition, with as many as five elements (Pd, Cu, Sn, Te and S) as major constituents of the mineral. Additionally, minor contents of Fe and Pt are constantly present in all the grains analysed.

Empirical formulae of oulankaite can be calculated on the basis of totals of either 7 or 14 atoms per formula unit. If calculated assuming Σ atoms = 7, two probable formulae can be proposed: $(Pd,Cu,Sn,Fe,Pt)_5(Te,S)_2$ or $(Pd,Cu,Sn,Fe,Pt)_5TeS$. However, from the point of view of crystal chemistry, it is difficult to expect that Sn substitutes either for Pd or Cu. It is also highly unlikely that Sn replaces both Te and S; it seems reasonable however that there is a minor replacement of S by Te in oulankaite. In this respect, constancy of the Sn contents of oulankaite should be particularly taken into consideration.

Following these arguments, we suggest that the above formula variants should be discarded. On the basis of the new compositional data obtained (*e.g.*, analysis No. 3, Table 2) no reliable evidence in favour of significant substitution of Cu by Pd was found, although such substitution was previously proposed to occur in oulankaite (*e.g.*, Barkov *et al.*, 1994). In addition, rather restricted substitutions of Pt for Pd and Fe for Cu are the most probable in the mineral.

Consequently, we suggest calculating the formula of oulankaite on the basis of either a total of 14 atoms or Sn = 1. Electron microprobe data correspond well to the $(Pd,Pt)_5(Cu,Fe)_4Sn Te_2S_2$ formula (Table 2).

X-ray study

A single-crystal X-ray study of oulankaite could not be carried out on the material available. Therefore, after the microprobe analyses, oulankaite powder was extracted from a polished section and studied by X-ray powder diffraction, using a 57.3 mm Debye-Scherrer camera, Fe*K*α radiation. The X-ray pattern obtained is presented in Table 3. The pattern was indexed for a tetragonal cell, with the following unit-cell parameters refined by least-squares from the powder data: a = 9.044(3) Å, c = 4.937(3) Å, $c : a$ = 0.5459, V = 403.8(5) Å^3. Assuming Z = 2, the density calculated for a composition given in Table 2 (analysis No. 1) is 10.27(1) g/cm^3.

Although the unit cell proposed for oulankaite provides satisfactory indexing of the X-ray powder diffraction pattern and gives a reasonable

Table 3. X-ray powder data for oulankaite

I *	d_{meas} (Å)	d_{calc} (Å)	hkl
1	4.940	4.937	001
3	3.330	3.335	201
< 1	3.220	3.197	220
1	3.140	3.129	211
10	2.472	2.475	311
		2.469	002
9	2.260	2.261	400
2	2.101	2.107	212
3	2.056	2.056	401
6	2.022	2.022	420
3	1.870	1.871	421
		1.869	312
2	1.458	1.459	432,502
3	1.430	1.430	620
		1.427	313
4	1.361	1.358	541
3	1.239	1.238	711,551
		1.237	622
5	1.213	1.215	641
		1.212	114
5	1.205	1.206	513
		1.205	721
1	1.182	1.183	632
		1.181	214
1	1.174	1.175	523
5	1.129	1.130	800
		1.129	533
		1.127	651
< 1	1.051	1.054	424
		1.051	750

* Intensities estimated visually

calculated density, a single-crystal study is required to confirm the crystallographic parameters.

Acknowledgements: This study was supported by grant RLY300 to the first author from the International Science Foundation. AYuB gratefully acknowledges a research grant from the Centre for International Mobility, Finland. We would like to thank Prof. T. T. Alapieti and Dr. R. J. Kaukonen for providing some microprobe analyses for us, Prof. M. Tarkian for the reflectance data in oil, and Dr. Yu. N. Neradovskii for the reflectance data in air. We are grateful to S.N. Britvin, S.F. Klyunin and A.A. Zakharov for their help in this research. We thank Prof. E.A.J. Burke and Prof. W.V. Maresch for improvements to the manuscript.

References

Alapieti, T.T., Filén, B.A., Lahtinen, J.J., Lavrov, M.M., Smolkin V.F., Voitsekhovsky, S.N. (1990): Early Proterozoic layered intrusions in the northeastern part of the Fennoscandian shield. *Mineral. Petrol.*, **42**, 1-22.

Barkov, A.Yu. (1992): Aspects of petrology and geochemistry of the Lukkulaisvaara and Kivakka layered intrusions, northern Karelia, Russia. Unpublished Ph.D. Thesis, IGEM, Moscow, 253 p. (in Russian).

Barkov, A.Yu. & Lednev, A.I. (1993): A rhenium-molybdenum-copper sulfide from the Lukkulaisvaara layered intrusion, northern Karelia, Russia. *Eur. J. Mineral.*, **5**, 1227-1233.

Barkov, A.Yu., Lednev, A.I., Men'shikov, Yu.P. (1994): Some patterns of distribution and compositional variation of platinum minerals in the Lukkulaisvaara pluton, northern Karelia. *Transact. (Doklady) Russ. Acad. Sci.*, Earth Sci. Sect., **323A**, 170-176.

Barkov, A.Yu., Pakhomovskii, Ya.A., Men'shikov, Yu.P. (1995a): Zoning in the platinum-group sulfide minerals from the Lukkulaisvaara and Imandrovsky layered intrusions, Russia. *N. Jb. Mineral., Abh.*, **169**, 97-117.

Barkov, A.Yu., Savchenko, Ye.E., Zhangurov, A.A. (1995b): Fluid migration and its role in the formation of platinum-group minerals: evidence from the Imandrovsky and Lukkulaisvaara layered intrusions, Russia. *Mineral. Petrol.*, **54**, 249-260.

Barkov, A.Yu., Pakhomovskii, Ya.A., Men'shikov, Yu.P. (1995c): Baddeleyite: new occurrences from two mafic-ultramafic layered intrusions, Russia. *Mineral. Mag.*, **59**, 349-353.

Begizov, V.D. & Batashev, Ye.V. (1981): Platinum minerals of the Lukkulaisvaara pluton. *Transact. (Doklady) USSR Acad. Sci.*, Earth Sci. Sect., **243**, 163-166.

Grokhovskaya, T.L. & Laputina, I.P. (1989): Minerals of platinum metals in the Lukkulaisvaara layered intrusion, North Karelia. *in:* Proc. 1st All- Union Seminar, Suzdal, 119-122 (in Russian).

Lavrov, M.M. (1979): The Precambrian ultrabasic rocks and layered peridotite-gabbro-norite intrusions of North Karelia. Nauka, 136 p. (in Russian).

Received 17 October 1995
Accepted 16 January 1996