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THE NOMENCLATURE OF THE NATURAL ALLOYS OF OSMIUM, IRIDIUM AND RUTHENIUM BASED ON NEW COMPOSITIONAL DATA OF ALLOYS FROM WORLD-WIDE OCCURRENCES *

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ABSTRACT

A new proposal for the nomenclature of natural Os-Ir-Ru alloys is presented as well as compositional data for 105 new micro-analyses of these natural alloys from Canada, Territory of Papua and New Guinea, and Colombia, South America. The minerals redefined are osmiridium and iridosmine for binary alloys, rutheniridosmine and ruthenosmiridium for ternary alloys, and compositional limits are proposed for the end members, native osmium, native iridium and native ruthenium.

The first occurrence of the minerals rutheniridosmine, iridium, and osmium in Canada is reported, as well as confirmation of the occurrence of osmiridium. The nature of the Os-Ir-Ru alloys from the Territory of Papua and New Guinea is also described.

INTRODUCTION

In the course of a broader investigation of minerals of the platinum-group elements (PGE), currently underway in the Mineral Sciences Division, Mines Branch, it was evident that a more detailed study and an assessment of the nomenclature of the natural alloys of osmium, iridium, and ruthenium was required. Cabri (1972), in a review on the mineralogy of the platinum-group elements, briefly discussed the existing nomenclature of the Os-Ir-Ru system and pointed out its disadvantages and inaccuracies.

This paper reports the results of a study of the Os-Ir-Ru alloys, some of which were mentioned in Cabri's paper, involving 105 new electron microprobe analyses of natural alloys from five localities, widely separated in the world. These compositions, together with additional data from the literature, have enabled us to revise the nomenclature of the Os-Ir-Ru system. The proposed nomenclature has been accepted by the International Mineralogical Association (IMA) Commission on New Minerals and Mineral Names. In addition, the first Canadian occurrence of the minerals rutheniridosmine, iridium and osmium is reported, and the Canadian occurrence of osmiridium is confirmed.

MATERIALS

Samples of natural Os-Ir-Ru alloys were examined from the following localities: Spruce Creek, British Columbia ; Tulameen River, British Columbia ; Atlin, British Columbia ; Cariboo District, British Columbia ; Colombia, South America, and the Territory of Papua and New Guinea.

Nuggets from the Spruce Creek locality (U.B.C. No. MA3) and Colombia, South America (U.B.C. M1161, A1) were obtained from the mineral collection, Geology Department, University of British Columbia. A small nugget from the former Lincoln mine, Tulameen River, B.C. was purchased privately from a collector in the area.

The mineral collections of the Royal Ontario Museum, Toronto, provided the following specimens in vials containing numerous grains and were labelled : 10120 "iridosmine or osmiridium", Atlin, B.C. ; M12340 "iridosmine", Atlin, B.C. ; M11735 "osmiridium", Ruby Creek, Atlin, B.C. ; M14274 "platinum", Bullion, Kariboo District, B.C. (modern spelling "Cariboo") ; M12410 "platinum", above junction of Bear Creek on Tulameen River, Tulameen, B.C. ; M18477 "platinum", Granite Creek, B.C. ; M12339 "platinum", Discovery, Atlin, B.C., 10120 "iridosmine", Atlin, B.C. Only a few grains from each vial were mounted and polished for examination.

The Atlin district is in the northwest corner of British Columbia, adjacent to the Yukon Territory. This district produced about $15 million of gold between 1898 and 1946 and $1 million between 1946 and 1953. The town of Discovery is on the north bank of Pine Creek, which connects Surprise Lake with Atlin Lake. Ruby Creek drains into Surprise Lake and iridosmine from Ruby Creek is the only mineral of the platinum group that had previously been reported from this area (Gledhill 1921). Spruce Creek is a

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tributary of Pine Creek and may be *the* Spruce Creek from which the sample of the U.B.C. collection (No. MA3) originated. Numerous outcrops of ultramafic and mafic intrusions, referred to as the "Atlin intrusions" (Aitken 1959), occur associated with Paleozoic greenstones in the area between the town of Atlin and Surprise Lake as well as to the north of Surprise Lake in the headland of Ruby Creek.

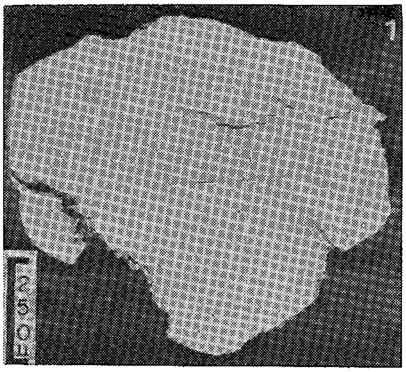
Platinum and "osmiridium" have been reported from the Quesnel River area, Cariboo Mining Division, about 350 km due north of Hope, B.C. This area is noted mainly for its gold production. The history and some details of assays reporting platinum, palladium and "osmiridium" from the Bullion mine are given by O'Neill & Gunning (1934). This may be the locality from which ROM sample M14274 was obtained.

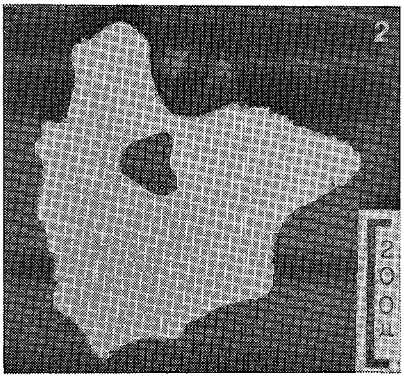
The geology of the Tulameen River area, in south-central British Columbia, has been described by Camsell (1913) ; Rice (1947) has summarized the origin, history, and description of its gold and platinum-bearing placers. The petrology and origin of the ultramafic Tulameen layered complex, discussed by Findlay (1969), is considered to be a "concentric" intrusion (Jackson & Thayer 1972). Early assays for "platinum" nuggets, tabulated by Rice (1947) and O'Neill & Gunning (1934), reported mainly platinum with minor quantities of "osmiridium", palladium, osmium, and rhodium. The Lincoln mine is thought to have been located about half a mile below the mouth of Britton Creek (formerly Eagle Creek).

The grains from British Columbia are between 200 µm (sample M12339, gr. 5) and about 2 mm (sample M12340, gr. 6) in diameter. They are usually rounded to sub-rounded with a metallic lustre. A few grains of iridosmine are hexagonal in cross section (*e.g.* sample M12339, gr. 1). The Os-Ir-Ru minerals were always found in the non-magnetic fractions (hand magnet).

Many inclusions were observed even though several of the grains appeared free of inclusions in polished sections. Most common were iron-bearing platinum, irarsite (IrAsS), and osmian irarsite.

Iridosmine occurs with osmiridium in two grains (samples 10120, gr. 2 and M12339, gr. 1). The first of these is shown in Figure 1 with minor irarsite (IrAsS) ; the second grain occurs as a small (16 × 27-µm) inclusion in an iridosmine matrix which is hexagonal in cross section. Iridosmine was also found as laths in iron-bearing platinum, (*e.g.* sample M18477, gr. 1, 8 × 93-µm lath and, in the Lincoln mine sample, as a 25 × 100-µm lath). Osmium was found as a large homogeneous inclusion-free grain (M12340, gr. 6, 1.5 × 2 mm) and as a lath (10 × 100-µm in a grain of iron-bearing plati-





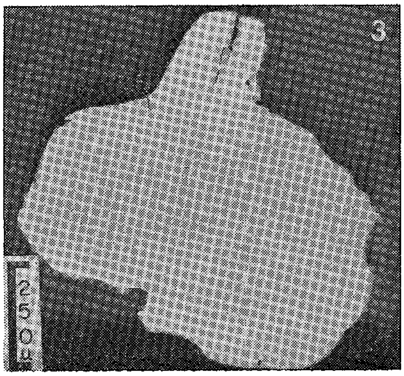


FIG. 1. Photomicrograph of a nugget from Atlin, B.C. (10120, gr. 2) showing iridosmine (light grey) in contact with osmiridium (medium grey). Finely disseminated irarsite rims and partly replaces the iridosmine.

FIG. 2. Photomicrograph showing inclusions of iridium (light grey) in a matrix of iron-bearing platinum. The nugget is from Bear Creek, B.C. (M12410, gr. 4).

FIG. 3. Photomicrograph showing curved veinlets of "osmiridium" (light grey) in a matrix of ruthen-iridosmine (M12340, gr. 2, Atlin, B.C.).

num, M11735, gr. 4). Iridium was observed as numerous inclusions in a matrix of iron-bearing platinum (M12410, gr. 4, shown in Fig. 2). In one case, rutheniridosmine was found to contain curved veins of what was tentatively identified as osmiridium (Fig. 3).

The New Guinea material, originally labelled as "osmiridium", was purchased in the early 1960's from Johnson, Matthey and Mallory Ltd., Montreal. The exact origin of the material is uncertain, but information obtained from the company's associate in Australia states "The material was probably found by the natives when they were gold prospecting and more than likely has been picked out by hand from alluvial gold.... The material was delivered to the Bank at Port Moresby." Correspondence (9/3/72) with Mr. A. Renwick, Chief Government Geologist, Territory of Papua and New Guinea, states that "It is almost certain that the osmiridium referred to comes from the Ioma area of the northern district of Papua.... The area lies within the Papuan Ultramafic Belt." According to Davies (1968), who has studied the area in detail, our material could have come from either the Waria River (Bowutu Mountains) or the Yodda Goldfield, part of the broad Papua Ultramafic Belt.

The concentrate consists of several hundred nuggets ranging from 100 μm up to 2 mm in diameter. The nuggets occur in various shapes from rounded to flattened irregular forms to tabular, short, hexagonal-prismatic crystals. A few of the nuggets occur as thin cleavage flakes derived from larger pieces, though a few have a spongy appearance. Under a binocular microscope, the material has a metallic luster varying from a dull mat finish to smooth, bright {0001} cleavage planes; however, most of the grains are steel grey. Numerous inclusions of iron-bearing platinum, irarsite, laurite, and two unidentified ruthenian and iridian arsenides were observed and these will be described in another note in preparation.

METHOD OF INVESTIGATION

The individual nuggets were mounted in cold setting Araldite (several to a section), polished on water-cooled lead laps with final buffing using MgO. The sections were examined under an ore microscope and analyzed with a Materials Analysis Company microprobe. The normal corrections to the x-ray intensity data were made with a computer program of Rucklidge & Gasparrini (1969), revised and updated. Each grain was analyzed for nine elements using the following standards and x-ray lines: iridium metal $\mathrm{Ir}L_\alpha$, osmium metal $\mathrm{Os}L_\alpha$, ruthenium metal $\mathrm{Ru}L_\alpha$, palladium metal $\mathrm{Pd}L_\alpha$, copper metal $\mathrm{Cu}K_\alpha$, nickel metal $\mathrm{Ni}K_\alpha$, iron metal $\mathrm{Fe}K_\alpha$, a $Pt_{95}Rh_5$ alloy $\mathrm{Pt}L_\alpha$, $\mathrm{Rh}L_\alpha$. Allowances were made for the enhancement of $\mathrm{Cu}K_\alpha$ intensities by iridium and slits were used to improve the peak/background of osmium and iridium. Since the pure ruthenium and osmium could be obtained in powder form only, a chemical vapour transport technique was used to recrystallize the material into coarser fragments.

OPTICAL PROPERTIES AND CRYSTALLOGRAPHY

Osmium, iridosmine, and rutheniridosmine are white, with a bluish grey tinge in reflected light. They are weakly to moderately anisotropic, sometimes exhibiting wavy extinction, but bireflectance is weak to absent. Iridium and osmiridium are white, with a cream-coloured tinge, in reflected light. Both are isotropic. The bluish white colour of the hexagonal anisotropic minerals is enhanced, as is the cream-white colour of the isotropic minerals, when they occur together. The bluish white colour of the anisotropic minerals is also enhanced when they occur with white iron-bearing platinum.

The crystal system of pure osmium and ruthenium has long been known to be hexagonal whereas pure iridium is cubic. The x-ray diffraction data and unit cell dimensions are listed in the PD File as follows:

	Osmium	*Ruthenium*	*Iridium*
File No.	6-0662	6-0663	6-0598
Symmetry	Hexagonal	Hexagonal	Cubic
Space group	$P6_3/mmc$	$P6_3/mmc$	$Fm3m$
*a*Å	2.7341	2.7058	3.8394
*c*Å	4.3197	4.2819	—

The symmetry of natural compositions was confirmed by x-ray powder patterns using a 57.3-mm-diameter Gandolfi camera. X-ray powder patterns were obtained for two compositions (indicated in Table 1) of rutheniridosmine from the Territory of Papua and New Guinea, of iridosmine, gr. 1, Spruce Creek, B.C., and of osmiridium, gr. 5, Spruce Creek, B.C.

Determination of the unit cell dimension of this iridosmine gave a 2.724, c 4.333Å whereas the osmiridium gave a 3.822Å. All the natural alloys of rutheniridosmine are hexagonal and isomorphous with pure osmium and ruthenium in spite of minor substitution of other elements.

COMPOSITIONS OF THE NATURAL Os-Ir-Ru ALLOYS

The results of the electron microprobe analyses of the natural Os-Ir-Ru alloys are listed in Table 1. These analyses, with others taken from

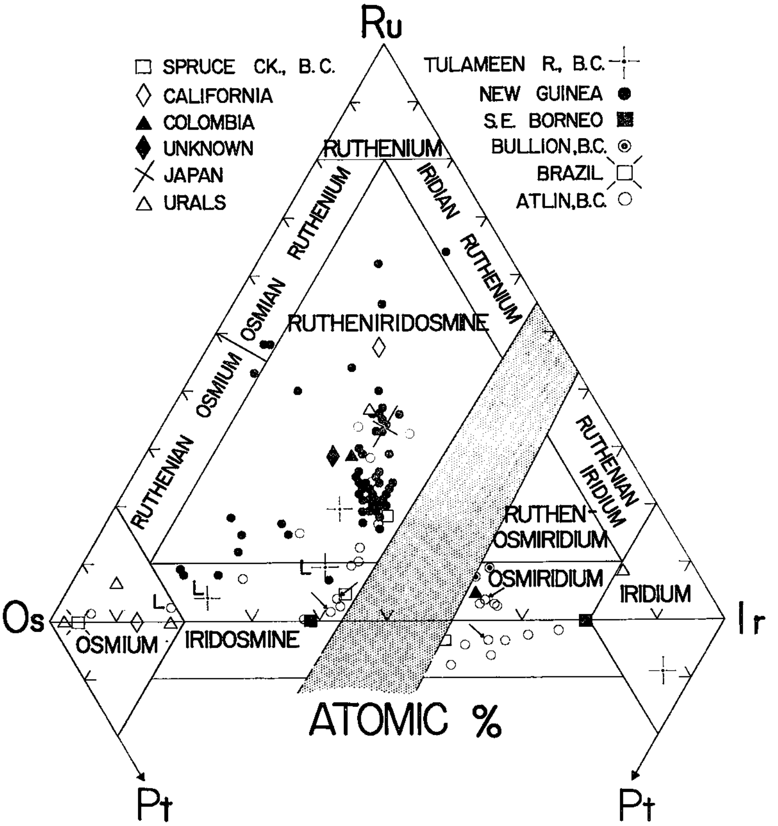


FIG. 4. Natural Os-Ir-Ru and Os-Ir-Pt minerals from this study and from the literature. The two analyses from Granite Creek, B.C. (see Table 1) have been plotted with the symbol for Tulameen River because Granite Creek is one of its tributaries. The four compositions indicated with an arrow represent two sets of co-existing iridosmine and osmiridium. The three compositions labelled "L" signify a lath.

the literature, are plotted in Figure 4. The compositions plotted have been recalculated to atomic per cent, based on the three major elements, and are given in Table 1. The compositions used from the literature are the same as reported by Cabri (1972). The sources of the data are as follows: California (Snetsinger 1971), unknown (Lévy & Picot 1961), Japan (Aoyama 1936), Urals (Lévy & Picot 1961; Westland & Beamish 1958) southeast Borneo (Stumpfl & Clark 1966) and Brazil (Lévy & Picot 1961). These compositions were considered the most reliable of the numerous analyses quoted in the literature, considering the completeness and method of analysis and the size and microscopic descriptions of the nuggets. Even then, one must accept the analyses with caution because many of the nuggets examined in this study were found to consist of more than one phase for which the microprobe must be considered the most reliable method of analysis.

Subsequent to writing this paper, additional microprobe analyses of natural Os-Ir-Ru alloys from Borneo by Stumpfl & Tarkian (1973) were found to be consistent with our data.

THE TERNARY SYSTEM Os-Ir-Ru

Work in the synthetic Os-Ir system by Vacher *et al.* (1954) and by Rudman (1967) has indicated that a miscibility gap exists, though its boundaries have not been precisely defined. Raub (1964) showed that in the Ru-Ir system a miscibility gap exists from 45 to 57 atomic % Ir at 1300°C and widens at lower temperatures. Raub (1959) reported complete hexagonal solid solution for the Os-Ru binary. Our analytical results (Table 1) of natural Os-Ir-Ru alloys with additional data from the literature has enabled us to more precisely define the boundaries (Fig. 4). The cubic alloy extends from 100 atomic % to about 62 atomic % Ir, whereas the hexagonal

TABLE 1. ELECTRON MICROPROBE ANALYSES OF NATURAL Os-Ir-Ru-Pt ALLOYS

Locality		Weight Per Cent										Atomic Proportions				Mineral
		Ir	Os	Ru	Pt	Pd	Rh	Fe	Cu	Ni	Totals	Ir	Os	Ru	Pt	
Atlin, British Columbia																
M12340	Gr. 2	29.4	54.0	7.9	2.9	0.6	3.8	0.1	---	---	98.7	29.7	55.1	15.2	---	rutheniridosmine
"	Gr. 3	42.2	44.2	9.3	1.4	0.3	1.2	0.1	---	---	98.7	40.4	42.7	16.9	---	rutheniridosmine
"	Gr. 4	42.0	55.5	1.3	0.3	---	0.2	0.3	---	---	99.6	41.9	55.6	2.5	---	iridosmine
"	Gr. 5	37.9	61.8	0.2	0.2	---	---	0.1	---	---	100.2	37.7	62.0	0.3	---	iridosmine
"	Gr. 6	5.4	94.1	0.8	0.1	---	---	---	---	---	100.4	5.3	93.2	1.5	---	osmium
Ruby Ck., M11735	Gr. 1	54.9	36.0	1.4	7.5	---	0.5	0.3	---	0.1	100.7	55.6	36.8	---	7.6	osmiridium
" "	Gr. 2	24.5	69.7	4.0	0.2	0.1	0.4	---	---	---	98.9	24.1	68.6	7.3	---	iridosmine
" "	Gr. 3	64.5	29.8	0.6	3.4	---	0.3	0.3	---	---	98.9	65.8	30.7	---	3.5	osmiridium
" "	Gr. 4 (lath)	16.8	80.1	1.2	1.7	---	0.7	0.1	---	---	100.6	16.8	80.9	2.3	---	osmium
" "	Gr. 5	35.9	40.4	15.8	3.7	0.5	2.1	0.1	---	---	98.5	33.6	38.1	28.2	---	rutheniridosmine
" "	Gr. 6	41.4	33.1	19.0	1.6	0.7	2.3	0.1	---	---	98.2	37.2	30.2	32.6	---	rutheniridosmine
" "	Gr. 7	64.3	31.8	1.2	2.0	---	0.4	0.3	---	---	100.0	65.2	32.5	2.3	---	osmiridium
" "	Gr. 8	61.5	30.9	1.0	6.0	0.1	0.5	0.3	0.1	0.4	100.8	62.4	31.6	---	6.0	osmiridium
Discovery, M12339, N.M.*	Gr. 2	41.0	48.7	6.7	0.9	0.2	0.9	0.1	---	---	98.5	39.7	47.8	12.5	---	rutheniridosmine
" " N.M.	Gr. 5	38.3	42.5	13.5	1.3	0.5	1.7	0.1	---	---	97.9	35.8	40.1	24.1	---	rutheniridosmine
" " N.M.	Gr. 7	68.0	27.0	1.3	2.5	---	0.3	0.3	---	0.1	99.5	69.5	27.9	---	2.6	osmiridium
" " N.M.	Gr. 1 (inclusion)	61.6	33.1	1.8	1.8	0.1	1.0	0.5	---	0.1	100.0	62.6	33.9	3.5	---	osmiridium
" " N.M.	Gr. 1 (matrix)	41.3	55.5	2.0	---	0.1	0.3	0.3	---	---	99.5	40.9	55.3	3.8	---	iridosmine
ROM-10120	Gr. 1	30.9	39.2	19.0	4.3	0.8	3.0	0.1	---	0.2	97.5	29.0	37.1	33.9	---	rutheniridosmine
"	Gr. 2 (white)	41.1	57.3	0.8	0.4	---	0.2	0.2	---	---	100.0	41.0	57.5	1.5	---	iridosmine
"	Gr. 2 (creamy)	63.0	33.1	0.6	3.3	---	0.2	0.3	---	0.1	100.5	63.3	33.4	---	3.3	osmiridium
"	Gr. 3	40.4	50.4	5.2	1.8	0.2	0.9	0.2	---	---	99.1	40.0	50.3	9.7	---	iridosmine
"	Gr. 4	62.0	34.4	1.5	1.2	0.1	0.5	0.3	---	0.1	100.1	62.2	34.9	2.9	---	osmiridium
"	Gr. 9	58.6	35.5	1.2	4.1	0.1	0.4	0.3	---	0.1	100.3	59.6	36.3	---	4.1	osmiridium
"	Gr. 11	73.5	23.2	0.8	1.6	---	0.2	0.5	---	0.1	99.9	74.6	23.8	---	1.6	osmiridium
ROM-10120 N.M.	Gr. 3	42.2	50.3	5.6	---	0.2	0.5	0.1	---	---	98.9	40.7	49.1	10.2	---	rutheniridosmine
" N.M.	Gr. 4	63.3	32.3	1.4	0.4	0.2	0.6	0.4	---	---	98.6	64.3	33.0	2.7	---	osmiridium
Bullion, Kariboo District, British Columbia																
M14274 N.M.	Gr. 1	61.6	30.4	4.8	1.9	0.2	0.4	---	---	---	99.3	60.7	30.2	9.1	---	osmiridium
" N.M.	Gr. 4	56.6	32.3	3.7	3.7	0.2	1.0	---	---	---	97.5	58.8	33.8	7.4	---	osmiridium
Spruce Creek, British Columbia																
U.B.C. No. MA3	Gr. 1 (*X*-ray)	42.5	54.6	2.3	0.4	---	0.2	0.3	---	---	100.3	41.7	54.0	4.3	---	iridosmine
" "	Gr. 2	42.9	42.2	9.9	2.2	0.4	1.4	0.1	---	---	99.1	41.1	40.8	18.1	---	rutheniridosmine
" "	Gr. 5 (*X*-ray)	59.3	35.7	1.6	3.4	---	0.5	0.3	0.1	---	100.9	60.2	36.5	---	3.3	osmiridium
Tulameen River, British Columbia																
Lincoln mine nugget -	(lath)	22.2	76.1	2.1	---	---	---	---	---	---	100.4	21.7	74.4	3.9	---	iridosmine
Near Bear Ck., M12410, N.M.	Gr. 4 (inclusion)	81.6	4.4	1.2	8.6	0.2	1.8	1.4	---	0.1	99.3	86.3	4.7	---	9.0	iridium
Granite Ck., M18477, N.M.	Gr. 1 (lath)	36.1		4.9	2.1	0.3	1.3	0.3	---	---	99.1	36.2	54.6	9.2	---	iridosmine
" " " "	Gr. 1 (inclusion)	32.4	45.4	10.0	6.3	0.5	1.1	1.3	---	---	97.0	33.3	47.1	19.6	---	rutheniridosmine
Colombia, South America																
U.B.C. No. M1161, A1, N.M.	Gr. 7	60.1	33.8	2.5	3.7	0.2	1.1	0.2	---	0.1	101.7	60.8	34.4	4.8	---	osmiridium
Territory of Papua and New Guinea		36.6	36.1	20.0	1.7	0.7	2.8	0.8	0.4	0.1	99.2	33.0	32.7	34.3	---	rutheniridosmine
		38.2	43.7	13.6	1.7	0.4	1.7	0.6	0.4	0.1	100.4	35.3	40.7	24.0	---	
	(*X*-ray)	35.0	41.9	16.3	2.8	0.6	2.2	0.1	0.4	---	99.3	32.3	39.1	28.6	---	
		39.0	45.1	10.5	2.3	0.4	1.3	0.2	0.4	---	99.2	37.3	43.6	19.1	---	
		34.4	36.1	20.9	2.9	0.7	2.6	0.4	0.3	0.1	98.4	31.1	32.9	36.0	---	

	35.5	43.8	14.1	2.5	0.5	2.2	0.3	0.3	0.1	99.3	33.3	41.4	25.3	---	
	36.4	44.3	13.4	2.8	0.4	1.7	0.2	0.4	0.1	99.7	34.1	41.9	24.0	---	
	38.5	44.3	11.4	2.8	0.3	1.4	0.2	0.4	---	99.3	36.9	42.5	20.6	---	
	41.1	40.3	13.0	1.9	0.4	1.9	0.4	0.5	0.1	99.6	38.7	38.2	23.1	---	
	41.9	43.3	9.8	1.4	0.3	1.1	1.1	0.5	0.3	99.7	40.2	41.9	17.9	---	
	36.9	36.3	19.4	2.4	0.7	2.3	0.4	0.4	0.1	98.9	33.4	33.4	33.2	---	
	40.6	41.3	13.5	2.4	0.4	1.4	0.3	0.4	---	100.3	37.6	38.7	23.7	---	
	39.5	43.9	12.4	1.4	0.3	1.6	0.4	0.4	---	99.9	36.7	41.2	22.1	---	
	40.0	43.1	12.0	2.6	0.3	1.3	0.2	0.4	---	99.9	37.7	40.9	21.4	---	
	37.5	45.7	12.0	2.4	0.3	1.2	0.2	0.3	---	99.6	35.2	43.3	21.5	---	
	39.7	42.0	13.6	1.7	0.4	1.7	0.3	0.4	---	99.8	36.8	39.3	23.9	---	
	40.1	44.2	11.8	1.9	0.4	1.5	0.4	0.4	0.1	100.8	37.5	41.5	21.0	---	
	40.1	43.9	11.5	2.9	0.4	1.4	0.2	0.4	---	100.8	37.8	41.6	20.6	---	
	40.2	44.0	11.6	2.1	0.4	1.5	0.3	0.4	---	100.5	37.7	41.6	20.7	---	
	40.4	44.6	10.8	2.1	0.4	1.3	0.2	0.4	---	100.2	38.1	42.5	19.4	---	
	35.8	43.6	14.9	2.7	0.4	1.9	0.1	0.3	---	99.7	33.1	40.7	26.2	---	
	37.9	45.2	12.3	2.7	0.4	1.5	0.2	0.4	---	100.6	35.5	42.7	21.8	---	
	30.0	59.7	8.0	1.2	0.2	0.7	0.5	0.3	0.1	100.7	28.5	57.1	14.4	---	
	42.4	42.1	12.2	2.3	0.3	1.4	0.1	0.5	---	101.1	39.1	39.4	21.5	---	
	38.3	44.0	14.0	1.4	0.4	1.8	0.7	0.4	0.2	101.2	35.0	40.7	24.3	---	
	34.9	36.7	22.1	1.5	0.7	2.6	0.3	0.3	0.1	99.2	30.7	32.4	36.9	---	
(X-ray)	18.8	66.3	9.9	2.8	0.3	1.7	---	0.1	---	99.9	18.0	64.0	18.0	---	
	41.3	43.8	11.4	1.1	0.3	1.0	0.7	0.5	0.1	100.2	38.7	41.2	20.1	---	
	43.4	44.6	9.0	1.4	0.3	1.0	0.5	0.5	0.1	100.8	41.2	42.6	16.2	---	
	27.1	59.4	9.6	1.4	0.4	2.1	0.2	0.2	---	100.4	25.7	57.0	17.3	---	
	39.1	41.7	14.2	2.1	0.5	1.4	0.4	0.4	0.1	99.9	36.1	39.0	24.9	---	
	25.5	26.9	33.9	6.5	1.1	5.0	0.2	0.1	---	99.2	21.8	23.2	55.0	---	
	15.2	77.3	4.9	2.1	0.1	0.5	---	0.1	---	100.2	14.8	76.0	9.2	---	iridosmine
	33.6	41.9	17.2	3.5	0.6	2.1	0.3	0.3	---	99.5	31.0	38.9	30.1	---	rutheniridosmine
	39.0	56.4	3.8	1.1	---	0.3	0.3	0.4	0.1	101.4	37.8	55.1	7.1	---	iridosmine
	16.6	76.2	4.2	2.1	0.1	0.8	0.1	0.1	---	100.2	16.4	75.6	8.0	---	iridosmine
	41.4	41.9	12.2	1.5	0.3	0.9	0.5	0.4	0.1	99.2	38.8	39.5	21.7	---	rutheniridosmine
	39.8	47.0	9.6	2.1	0.4	0.7	0.2	0.4	0.1	100.3	37.8	44.9	17.3	---	
	39.3	45.1	11.6	2.1	0.4	1.6	0.3	0.4	---	100.8	36.8	42.7	20.5	---	
	41.3	43.2	11.0	1.5	0.3	1.4	0.7	0.4	0.2	100.0	39.0	41.2	19.8	---	
	33.4	37.2	21.0	3.3	0.7	3.3	0.2	0.3	---	99.4	30.2	33.8	36.0	---	
	35.8	38.4	19.0	2.5	0.5	1.8	0.4	0.4	---	98.8	32.3	32.6	35.1	---	
	36.1	36.0	20.6	2.7	0.6	2.5	0.4	0.4	---	99.3	32.4	32.5	35.1	---	
	26.4	36.6	26.0	4.8	0.8	3.6	0.1	0.3	---	98.6	23.3	32.7	44.0	---	
	37.5	44.8	12.7	2.5	0.4	1.4	0.3	0.4	---	100.0	35.1	42.2	22.7	---	
	32.9	33.5	23.7	3.9	0.7	3.0	0.2	0.3	---	98.2	29.4	30.2	40.4	---	
	37.3	42.9	13.9	1.6	0.5	1.5	0.4	0.4	0.1	98.6	34.8	40.4	24.8	---	
	37.4	44.5	12.8	3.1	0.4	1.6	0.2	0.4	---	100.4	35.1	42.1	22.8	---	
	40.2	38.0	16.8	2.2	0.5	1.8	0.5	0.4	---	100.4	36.4	34.7	28.9	---	
	42.5	40.3	13.7	1.0	0.5	1.6	0.2	0.4	---	100.2	38.9	37.2	23.9	---	
	39.0	45.3	10.7	2.7	0.4	1.4	0.2	0.4	---	100.1	37.1	43.5	19.4	---	
	22.8	66.2	8.6	1.9	0.3	0.8	0.1	0.2	---	100.9	21.4	63.2	15.4	---	
	23.6	68.3	6.4	1.6	0.3	0.6	0.2	0.2	---	101.2	22.6	65.7	11.7	---	
	41.2	42.5	11.7	1.9	0.4	1.6	0.4	0.4	---	100.1	38.7	40.3	21.0	---	
	38.4	41.4	14.7	2.3	0.5	2.0	0.2	0.3	---	99.8	35.5	38.6	25.9	---	
	21.2	72.4	4.6	1.4	0.2	0.6	0.1	0.2	---	100.7	20.6	71.0	8.4	---	iridosmine
	38.3	45.4	12.4	2.2	0.4	1.6	0.4	0.4	---	101.1	35.5	42.5	22.0	---	rutheniridosmine
	42.2	44.0	10.6	2.1	0.4	1.2	0.2	0.4	---	101.1	39.5	41.6	18.9	---	
	40.1	44.0	11.5	2.7	0.4	1.5	0.3	0.4	---	100.9	37.8	41.8	20.4	---	
	38.7	45.4	11.5	2.2	0.4	1.5	0.2	0.4	---	100.3	36.3	43.1	20.6	---	
	21.5	24.5	39.3	6.9	1.1	5.9	0.2	0.1	---	99.5	17.8	20.5	61.7	---	
	37.5	33.7	20.9	3.7	0.7	2.9	0.2	0.3	---	99.9	33.7	30.5	35.8	---	
	42.2	42.5	10.9	2.1	0.4	1.4	0.4	0.4	---	100.3	39.9	40.5	19.6	---	
	41.6	45.1	9.5	2.5	0.4	1.2	---	0.4	---	100.7	39.6	43.2	17.2	---	
	10.8	53.2	25.2	5.8	0.8	3.8	0.1	---	---	99.7	9.6	47.7	42.7	---	ruthenian osmium
	33.0	10.6	41.5	4.8	1.4	7.3	0.5	0.3	---	99.4	26.9	8.8	64.3	---	iridian ruthenium
	10.6	52.2	31.4	0.7	1.0	3.3	---	---	---	99.2	8.6	42.9	48.5	---	osmian ruthenium
	9.6	52.8	30.8	1.5	0.9	3.2	---	---	---	98.8	7.9	43.8	48.3	---	osmian ruthenium

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* N.M. - non-magnetic

alloy extends from 100 atomic % to about 55 atomic % Os. These new boundaries for the miscibility gap are slightly changed from Cabri's (1972) proposal because of the larger number of analyses now available. In particular, two samples from Atlin, B.C., which consist of co-existing hexagonal and cubic ternary alloys, help to define the boundary along the Os-Ir join. These co-existing grains are indicated with arrows pointing to the locality symbol in Figure 4. The two phase field extends into the Pt-Os-Ir system, as shown in Figure 4, and must intercept the Os-Pt binary at a position which has not yet been exactly determined. This is assumed because it is unlikely that a solid solution exists between hexagonal osmium and cubic platinum. On the other hand, it is probable that complete solid solution exists between cubic iridium and cubic platinum.

NOMENCLATURE FOR NATURAL Os-Ir-Ru ALLOYS

An excellent historical review on the nomenclature of natural Os-Ir alloys was made by Hey (1963). From this review, he suggested that the most suitable nomenclature for the natural Os-Ir alloys, now in common usage, be the following:

For the **cubic** alloys: *osmiridium* with Os < 32 at. %

For the **hexagonal** alloys: *iridosmine* with 32 < Os < 80 at. %

Native *osmium* for Os > 80 at. %

The name *ruthenosmiridium* was proposed by Aoyama (1936) for a hexagonal Os-Ir-Ru natural alloy with composition RuOsIr. Strunz (1966) however, introduced the term *ruthen-iridosmium* for Aoyama's mineral. In this study, it has been shown (Fig. 4) that there is a very extensive range of compositions for hexagonal Ru-Os-Ir alloys. The name ruthenosmiridium proposed by Aoyama is unfortunate because it includes the term "osmiridium", which from Hey's proposal, is associated with **cubic** alloys. Based on our analytical results, it is obvious that the names osmiridium and iridosmine should be re-defined to make provision for a miscibility gap in the Os-Ir system and also to provide flexibility for the solid solution of specific maximum quantities of other platinum-group elements. It is also necessary to re-examine the nomenclature for hexagonal ternary alloys and to propose a name for cubic ternary alloys. At the same time, uniform definitions are proposed for the native metal end-members and alloys along the Os-Ru and Ir-Ru binary joins.

Our proposals for alloys in the Os-Ir-Ru system are that:

a) the name *osmium* is for **hexagonal** alloys with ≧ 80 at. % Os;
b) the name *iridium* is for **cubic** alloys with ≧ 80 at. % Ir;
c) the name *ruthenium* is for **hexagonal** alloys with ≧ 80 at. % Ru;
d) the name *ruthenosmiridium* of Aoyama (1936) be applied to **cubic** (Ir, Os, Ru) alloys, where Ir < 80 at. % of (Ir + Ru + Os) and Ru > 10 at. % of (Ir + Ru + Os); also with no single other element > 10 at. % of total;
e) *Iridosmine* of Hey (1963) be redefined as **hexagonal** (Os, Ir) alloys with no single other element > 10 at. % of total, and where Os < 80 at. % of (Os + Ir); the presence of the miscibility gap defines the other boundary at approximately 55 at. % Os;
f) *Osmiridium* of Hey (1963) be redefined as **cubic** (Ir, Os) alloys with no single other element > 10 at. % of total, and where Ir < 80 at. % of (Ir + Os); again the miscibility gap limits the field to approximately 62 at. % Ir;
g) *Rutheniridosmine* or ruthen-iridosmium of Strunz (1966) be re-defined as **hexagonal** (Os, Ir, Ru) alloys where Os < 80 at. % of (Os + Ir + Ru) and Ru is 10 to 80 at. % of (Os + Ir + Ru), also where no single other element > 10 at. % of total; and
h) to be consistent with our proposal on the binary join Os-Ir, similar lines must be drawn parallel to the Ru-Os and Ru-Ir edges; these alloys would not require new names, but using Schaller's (1930) adjectival modifiers these compositions may be simply known as *ruthenian osmium*, *osmian ruthenium*, *iridian ruthenium*, and *ruthenian iridium*; these fields would have similar boundaries (where no single other element > 10 at. % of total) as proposed for iridosmine and osmiridium; for the former two minerals, the boundary between them is arbitrarily taken at 50 at. % Os whereas the boundary between the latter two minerals is as defined by the miscibility gap, *i.e.*, to a minimum 57 at. % Ir for ruthenian iridium and to a minimum of 55 at. % Ru for iridian ruthenium.

DISCUSSION ON THE PROPOSED NOMENCLATURE OF THE Os-Ir-Ru ALLOYS

Several noteworthy comments made by members of the Commission on New Minerals and Mineral Names (IMA) deserve some discussion in order to avoid possible confusion by other workers. The questions raised were: (a) Is it necessary to introduce so many names when perhaps four are sufficient? (b) Why are special names needed for *iridosmine* and *osmiridium* and should not the names nevyanskite (Ir > Os) and sysertskite (Os > Ir) be retained? (c) Is the distinction of *rutheniridosmine* from *iridosmine* easy to make by using their physical properties? (d) Should new names like *ruthenium* be proposed if no occurrence has been found? (e) Should not the proposed *rutheniridosmine* field be further subdivided because, in its present form, a mineral with 79% Os will bear the same name as a mineral with 79% Ru? (f) Should not lines be drawn parallel to the Ru-Os and Ru-Ir edges as drawn for the Ir-Os edge?

In reply to the above questions, we feel that our proposed nomenclature has not introduced new or additional names, but is simply a re-definition of names existing in the literature. Special names such as *iridosmine* and *osmiridium* were suitably discussed by Hey (1963) and are retained as more descriptive than such names as nevyanskite and sysertskite. It is necessary to give a different name or names for the higher Ru-bearing alloys because iridosmine and osmiridium are traditionally known as *binary* alloys. The distinction of *iridosmine* from *rutheniridosmine* is not easy because both minerals are hexagonal and have similar optical and *x*-ray properties. Our proposed nomenclature is based on composition because many of these alloys occur as small composite grains suitable only for electron microprobe analysis. The field proposed for *rutheniridosmine* is large, unfortunately, but we feel that further subdivision of this field would lead to more confusion and would require too many names, not to mention more accurate compositional data. We agree that compositions occurring in the field of *ruthenium* and *ruthenosmiridium* have not yet been found in nature. The latter name is suggested as a *redefinition* because it, likewise, is a good descriptive name, whereas *ruthenium* is the most logical name for the ruthenium end-member. Our original proposal, submitted to the Commission, did not include boundary lines parallel to the Ru-Os and Ru-Ir edges. This noteworthy suggestion by the Commission has been incorporated in our present proposal, and, using Schaller's (1930) adjectival modifiers, these compositions may be simply known as *ruthenian osmium, osmian ruthenium, iridian ruthenium*, and *ruthenian iridium*. These fields would have similar boundaries (< 10 at. % *etc.*) to those proposed for iridosmine and osmiridium.

After sufficient data are available, a similar type of nomenclature can be applied to other ternary systems such as the Pt-Os-Ir system. From our present study, *ternary* cubic and hexagonal alloys with Pt > 10 at. % can be expected to occur; they would require new species names similar to ruthenosmiridium, and rutheniridosmine, for example, platinosmiridium and platiniridosmine, respectively.

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