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RUTHENARSENITE AND IRIDARSENITE, TWO NEW MINERALS FROM THE TERRITORY OF PAPUA AND NEW GUINEA AND ASSOCIATED IRARSITE, LAURITE AND CUBIC IRON-BEARING PLATINUM *

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Abstract

Ruthenarsenite is a new mineral with the idealized formula RuAs. The mineral is orthorhombic with *a* 5.628, *b* 3.239, *c* 6.184Å. The strongest lines on the powder pattern are 2.710(7), 2.124(5), 2.078(10), 1.795(4), 1.750(4), 1.354(4), 1.290(4). The mineral occurs as irregular inclusions up to 100 microns in diameter in a matrix of rutheniridosmine associated with irarsite and iridarsenite. In reflected light under oil immersion, the colour is pale orange-brown to brownish grey. Bireflectance is distinct with strong anisotropism varying from orange-brown to light steel grey. Reflectance measurements in air at 470, 546, 589 and 650 nm gave (max.-min.) 48.6-46.1, 49.5-47.5, 50.9-49.3, 52.4-51.1%, respectively. Micro-indentation hardness gave for two grains 743 and 933 kg/mm² for a 100 g load.

Iridarsenite is a new mineral with the idealized formula $IrAs_2$. The mineral is monoclinic with *a* 6.05, *b* 6.06, *c* 6.18Å, β 113° 17′. The strongest lines on the powder pattern are 3.90(10), 2.84(7), 2.61(5), 2.069(6), 1.910(5). The mineral occurs as irregular inclusions up to 60 microns in diameter in a matrix of rutheniridosmine. In reflected light under oil immersion, the colour is medium grey with a brownish tint. Bireflectance is weak to nil, with weak but distinct anisotropism varying from medium grey to pale orange-brown, similar to that of ruthenarsenite. Reflectance measurements in air at 470, 546, 589 and 650 nm gave (max. -min.) 46.9-47.2, 46.1-45.4, 46.6-44.9, 44.0-41.4%, respectively. Micro-indentation hardness gave for two grains 488 and 606 kg/mm² for 100 g load.

Additional microprobe analyses are presented for associated irarsite, laurite and cubic iron-bearing platinum.

Introduction

During a study of natural Os-Ir-Ru alloys from world-wide occurrences, which led to a revision of the nomenclature (Harris & Cabri 1973), numerous inclusions of arsenides, sulpharsenides, and sulphides of iridium and ruthenium were noted. This paper reports on the inclusions that were identified in the alloys from the Territory of Papua and New Guinea. Two of the inclusions are new mineral species, iridarsenite ($IrAs_2$) and ruthenarsenite (RuAs). The new minerals and mineral names have been accepted by the International Mineralogical Association (IMA) Commission on New Minerals and Mineral Names.

Polished sections of the rutheniridosmine nuggets containing the new minerals are catalogued in the National Mineral Collection, Ottawa.

Material and Method of Investigation

The natural alloys of Os-Ir-Ru from the Territory of Papua and New Guinea were discussed in detail by Harris & Cabri (1973). The alloys were found to have a wide range of composition, with the majority of the microprobe analyses giving compositions that correspond to the mineral rutheniridosmine.

The inclusions identified in the alloys consist of the new minerals ruthenarsenite and iridarsenite as well as laurite, irarsite, and cubic iron-bearing platinum. More than 75 nuggets or fragments were examined. Irarsite was the most common of the inclusions occurring in six of the 75 nuggests ; laurite was found in one nugget and two contained the new minerals. Cubic iron-bearing platinum is more widespread.

The samples were mounted in cold-setting plastic, polished on lead laps and lightly buffed on a cloth lap using minus 0.05-μ alumina. The reflectance values were obtained with reference to a silicon standard calibrated by the National Physical Laboratory, Great Britain. The micro-indentation hardness was measured with a Leitz Durimet tester.

The compositions were determined using a Materials Analysis Company (MAC) microprobe, operated at 25kv. The following *x*-ray lines and standards were used : Ir$L\alpha$, Os$L\alpha$, Ru$L\alpha$, Ni$K\alpha$ (pure metals) ; Pt$L\alpha$, (a $Pt_{95}Rh_5$ alloy) ; As$K\alpha$ (InAs) ; S$K\alpha$, Fe$K\alpha$(FeS_2). The corrections to

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the *x*-ray data were applied with the EMPADR VII computer program (Rucklidge & Gasparrini 1969).

Optical, Physical, and Chemical Properties

Ruthenarsenite

The mineral occurs as irregular inclusions (Fig. 1) up to 100 microns in diameter in a matrix of rutheniridosmine which also contains inclusions of irarsite and iridarsenite. In reflected light under oil immersion, the colour is pale orange-brown to brownish grey. Bireflectance is distinct with strong anisotropism varying from orange-brown to light steel-grey. Reflectance measurements in air on four grains are given in Table 1. Micro-indentation hardness gave for two grains 743 and 933 kg/mm² for a 100 g load.

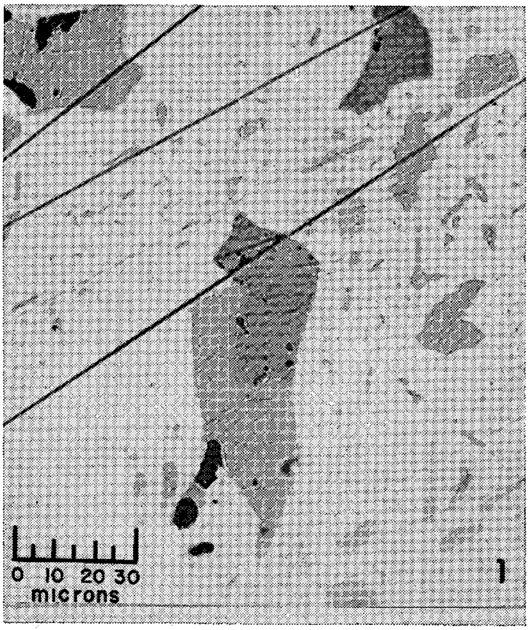

FIG. 1. Photomicrograph of the largest inclusion of ruthenarsenite (light grey) associated with irarsite inclusions (dark grey) in a rutheniridosmine matrix.

Microprobe analyses for three of the largest grains are given in Table 2. The average formula derived from the analyses is $(Ru_{.81}Ni_{.12}Rh_{.06}Ir_{.04}Pd_{.03}Os_{.01})_{\Sigma 1.07}As_{1.00}$ idealized as RuAs.

The *x*-ray powder pattern from a 57.3 mm Debye-Scherrer camera, was spotty, but distinct (Table 3). Heyding & Calvert (1961) reported that two binary compounds are formed in the ruthenium-arsenic system: RuAs and $RuAs_2$. RuAs is orthorhombic, MnP type structure, space group *Pnma* with *a* 5.70, *b* 3.25, *c* 6.27Å. By means of a least-squares refinement program PARAM (Stewart *et al.* 1972) our pattern gave *a* 5.628, *b* 3.239, *c* 6.184Å. With Z=4, for a composition $Ru_{.89}Ni_{.11}As_{1.00}$, the calculated density is 10.0.

TABLE 1. REFLECTANCES OF RUTHENARSENITE, IRIDARSENITE, IRARSITE AND LAURITE

Wavelength		470 nm	546 nm	589 nm	650 nm
Ruthenarsenite 4 grains	Max.	46.8-51.2 48.6	47.5-51.9 49.5	48.0-52.6 50.9	48.4-55.6 52.4
	Min.	44.1-49.5 46.1	45.3-49.7 47.5	46.4-52.1 49.3	46.6-54.7 51.1
Iridarsenite 4 grains	Max.	44.9-48.2 46.9	44.2-46.8 46.1	45.0-47.8 46.6	34.6-47.4 44.0
	Min.	44.6-48.6 47.2	42.5-46.8 45.4	41.4-46.7 44.9	31.9-47.4 41.4
Irarsite		46.2-50.7 48.3	43.3-45.5 44.6	42.6-43.0 42.9	40.3-42.2 41.6
Laurite Anal. 7 & 8		43.7,44.6	41.6,41.8	39.4,41.1	38.3,40.7

TABLE 2. ELECTRON MICROPROBE ANALYSES OF RUTHENARSENITE, IRIDARSENITE, LAURITE, AND CUBIC IRON-BEARING PLATINUM

MINERAL	Elements Weight Per Cent												Atomic Proportions							
	Ir	Ru	Os	Pt	Rh	Pd	Cu	Ni	Fe	As	S	Total								
													Ru	Ni	Ir	Rh	Pd	Os	Σ	As
ruthenarsenite	4.0	44.6	2.1	--	2.3	1.8	--	4.4	--	39.4	-	98.6	.84	.14	.04	.04	.03	.02	*1.12*	1.00
"	5.5	43.4	---	--	2.1	1.6	--	4.1	--	41.2	-	97.9	.78	.12	.05	.04	.03	---	*1.02*	1.00
"	2.1	44.7	---	--	5.4	2.0	--	3.5	--	40.7	-	98.4	.81	.11	.02	.10	.03	---	*1.07*	1.00
													Ir	Ru	Os	Pt	Σ	As		
iridarsenite	40.7	10.3	1.3	0.5	0.9	---	--	---	--	46.2	-	99.9	.69	.33	.02	--	*1.04*	2.00		
"	51.4	1.5	0.4	1.5	0.6	0.5	--	---	--	43.9	0.2	100.0	.90	.05	----	.03	*.98*	2.00		
"	52.1	1.7	0.2	1.3	0.4	---	--	---	--	44.4	0.2	100.3	.90	.06	---	.02	*.98*	2.00		
"	53.1	1.5	0.3	0.7	---	---	--	---	--	44.2	0.3	100.1	.92	.07	---	---	*.99*	2.00		
"	52.2	2.0	0.5	0.8	---	---	--	---	--	43.6	0.3	99.4	.92	.07	---	---	*.99*	2.00		
													Ir	Ru	Pt	Rh	Σ	As	S	
irarsite	60.3	0.4	---	3.0	0.1	---	--	---	--	26.9	9.1	99.8	.98	--	.05	---	*1.13*	1.12	.88	
"	59.8	0.3	0.4	3.2	0.5	---	--	---	--	26.9	9.0	100.1	.97	--	.05	---	*1.12*	1.12	.88	
"	59.3	0.8	0.6	4.7	0.9	---	--	---	--	26.3	9.2	101.6	.96	--	.07	---	*1.13*	1.10	.90	
"	61.7	0.8	0.4	1.6	0.9	---	--	---	--	26.3	9.2	100.9	1.01	.02	.02	.03	*1.08*	1.10	.90	
"	57.4	0.8	0.9	5.1	0.9	---	--	---	--	26.4	9.2	100.7	.93	--	.08	---	*1.11*	1.10	.90	
"	53.4	1.2	0.6	11.4	1.2	---	--	---	--	27.0	8.6	103.4	.88	.04	.18	.04	*1.14*	1.15	.85	
"	43.3	5.3	0.3	14.2	1.5	---	--	---	--	27.4	9.2	101.2	.73	.17	.24	.05	*1.19*	1.06	.94	
"	43.4	3.2	0.5	12.8	1.5	---	--	---	--	27.3	9.2	97.9	.73	.10	.21	.05	*1.09*	1.07	.93	
"	50.7	3.5	0.5	9.2	1.5	---	--	---	--	26.6	11.0	103.0	.76	.10	.13	.06	*1.05*	1.02	.98	
"	52.4	5.5	0.6	7.4	1.2	---	--	---	--	23.9	10.6	101.6	.84	.17	.12	.04	*1.17*	.98	1.02	
"	40.9	7.4	0.5	10.7	3.1	---	--	---	--	25.2	11.8	99.6	.60	.21	.16	.08	*1.05*	.96	1.04	
													Ru	Ir	Os	Σ	As	S		
laurite	11.4	46.7	1.8	----	---	---	--	---	--	1.1	38.3	99.3	.76	.10	.02	*.88*	.02	1.98		
													Pt	Ir	Ru	Rh	Fe	Cu	Ni	Σ
cubic iron-bearing platinum	8.4	----	---	77.1	1.7	---	.04	1.9	9.6	---	---	99.1	2.38	.26	--	.10	1.03	.04	.19	*4.00*
	3.3	----	---	85.4	1.5	---	.04	0.6	8.2	---	---	99.4	2.77	.11	--	.09	.93	.04	.06	*4.00*
"	8.8	0.2	0.2	74.9	1.6	---	.09	2.7	10.1	---	---	99.4	2.24	.27	--	.09	1.05	.08	.27	*4.00*
"	6.8	---	0.2	79.6	1.4	---	.08	1.2	9.5	---	---	99.5	2.49	.21	--	.08	1.03	.07	.12	*4.00*
"	4.6	4.5	0.8	74.2	3.8	0.6	.06	1.9	9.4	---	---	100.4	2.20	.14	.25	.21	.97	.05	.18	*4.00*
"	3.6	0.7	---	83.6	1.3	---	---	---	9.4	---	---	98.6	2.70	.12	.04	.08	1.06	---	---	*4.00*

The name ruthenarsenite is derived from its composition, the analyzed material is a nickelian ruthenarsenite.

Iridarsenite

The mineral occurs as irregular inclusions up to 60 microns in diameter associated with irarsite and ruthenarsenite in a matrix of rutheniridosmine (Fig. 2). In reflected light under oil immersion, the colour is medium grey with a brownish tint. Bireflectance is weak to nil, with weak but distinct anisotropism varying from medium grey to pale orange-brown, similar to that of ruthenarsenite. Reflectance measurements in air on four grains are given in Table 1. Micro-indentation hardness gave for two grains 488 and 606 kg/mm² for a 100 g load.

Microprobe analyses for four grains of similar composition and for another that gave higher ruthenium values are given in Table 2. The average formula of the four analyses is $(Ir_{.88}Ru_{.06}Os_{.01}Rh_{.01}Pt_{.02}Cu_{.03})_{\Sigma 1.01}(As_{1.97}S_{.03})_{\Sigma 2.00}$ whereas the higher ruthenium grain corresponds to $(Ir_{.69}Ru_{.33}Os_{.02}Rh_{.02}Pt_{.01}Cu_{.01})_{\Sigma 1.08}As_{2.00}$ idealized as $IrAs_2$.

The *x*-ray powder pattern (Table 3) of a single fragment obtained from a 57.3 mm Gandolfi camera is identical to synthetic $IrAs_2$ (pre-

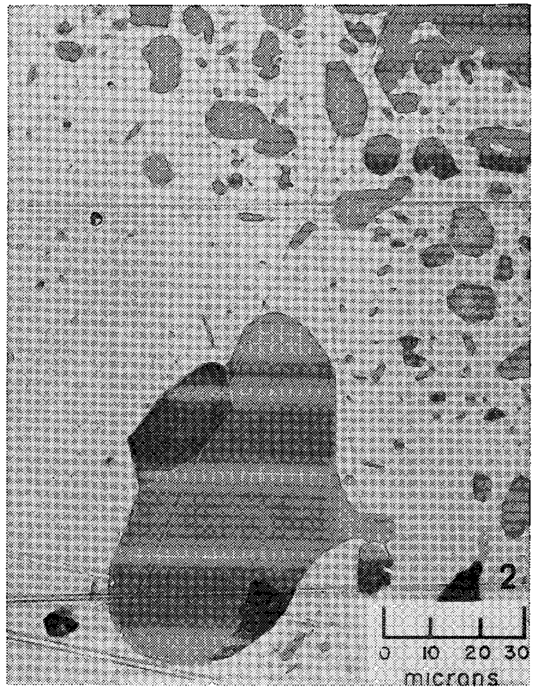

FIG. 2. Iridarsenite inclusions (light grey) associated and in contact with irarsite inclusions (dark grey) in a rutheniridosmine matrix.

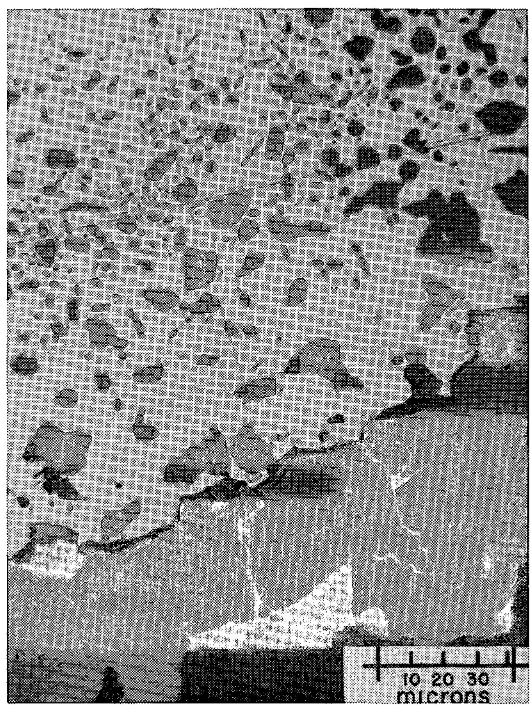

FIG. 3. Irarsite (dark grey) rimming and as inclusions in rutheniridosmine (white) with other inclusions of ruthenarsenite (indistinct).

TABLE 3. *X*-RAY POWDER DIFFRACTION DATA OF RUTHENARSENITE AND IRIDARSENITE

Ruthenarsenite				Iridarsenite			
I_{est}	d_{meas}Å	*hkl*	d_{calc}Å	I_{est}	d_{meas}Å	*hkl*	d_{calc}Å
*2	3.322	---	-----	2	4.16	011	4.14
2	3.075	002	3.092	10	3.90	$11\bar{1}$	3.90
3	2.891	011	2.869	4	3.07	$10\bar{2}$	3.06
2	2.811	200	2.814	7	2.840	002	2.439
7	2.696	102	2.710	5	2.610	$12\bar{1}$	2.606
*1	2.36	---	-----	2	2.549	$20\bar{2}$	2.553
5	2.124	210	2.124	1	2.531	210	2.526
10	2.061	112	2.078	1	2.354	$21\bar{2}$	2.353
3	1.931	103	1.935	1	2.200	102	2.200
4	1.780	301	1.795	1	2.154	$12\bar{2}$	2.155
4	1.750	212	1.750	6	2.069	022	2.071
1	1.662	203	1.663	4	1.943	$30\bar{2}$	1.942
1	1.619	020	1.619	5	1.910	$31\bar{1}$	1.908
1	1.478	213	1.479	4	1.875	$13\bar{1}$	1.878
1/2	1.433	022	1.434	1	1.807	013	1.806
1	1.374	401	1.371	1	1.766	122	1.769
4	1.343	114	1.354	4	1.732	131	1.731
4	1.302	410	1.290	2	1.682	202	1.681
2	1.271	313	1.275	1	1.645	032	1.646
2	1.251	214	1.250	1	1.599	023	1.605
3	1.206	105	1.208	2	1.304	$24\bar{2}$	1.302
1/2	1.189	412	1.191	1	1.262	104	1.261
1	1.138	322	1.139	2	1.185	051	1.185
2	1.124	314	1.119	2	1.165	124	1.164
1	1.090	413	1.093	1	1.144	430	1.144
1/2	1.071	215	1.069	2	1.121	303	1.120
1/2	1.059	502	1.057	1	1.073	412	1.072
2	1.028	006	1.030				
1	1.013	106	1.013				
2	0.992	231	0.994				
2	0.968	125	0.968				
1	0.925	331	0.925				
2	0.916	521	0.914				
1	0.885	522	0.885				
3	0.876	514	0.876				
2	0.853	603	0.853				
2	0.832	505	0.832				

* extra lines are due to impurities of irarsite.

pared in our laboratory by L. J. Cabri) and the data listed in JCPDS 14-411. Quensel & Heyding (1962) reported that the structure of $IrAs_2$ is monoclinic with *a* 6.060, *b* 6.071, *c* 6.158Å, β 113° 16′. By means of a least-squares refinement program PARAM (Stewart *et al.* 1972) the mineral gave *a* 6.05, *b* 6.06, *c* 6.18Å, β 113°17′. With Z = 4 the calculated density for $IrAs_2$ is 10.9.

The name iridarsenite is derived from its composition. The grain with higher ruthenium values is a ruthenian iridarsenite.

Irarsite

Irarsite, a sulpharsenide of iridium, ruthenium and platinum was first described by Genkin *et al.* (1966). The synthetic equivalent or end member is IrAsS, but, as pointed out by Cabri (1972), other elements such as Rh, Pd, Os, Ni and Co have been reported to replace Ir. In this study, irarsite occurs rimming the rutheniridosmine nuggets and as inclusions which generally decrease in size and abundance towards the centre of the individual grains (Figs. 3 and 4). Several of the irarsite inclusions showed variations in composition. Analyses of eleven areas selected for grains of more uniform composition are given in Table 2. The most significant feature of the analyses is the variation in platinum values which range from 3.0 to 14.2 wt% and in the inverse correlation between Ir and (Ru+Pt). Reflectance measurements of irarsite for which compositions 7 and 8 were obtained are given in Table 1.

Laurite

Laurite was identified in only one nugget, as a rim and as inclusions (Fig. 5) in rutheniridosmine. The electron microprobe analysis (Table 2) represents the average of analyses of several spots. Reflectance measurements are listed in Table 1.

Cubic iron-bearing platinum

Cubic iron-bearing platinum was observed in several nuggets. The mineral occurs as rounded to euhedral inclusions between 50 and 200 microns in size. Its colour, in contrast to the white of rutheniridosmine, appears creamy-white. Electron microprobe analyses of six of the larger inclusions are given in Table 2. The formulae are calculated on the basis of 4 formula weights per unit cell.

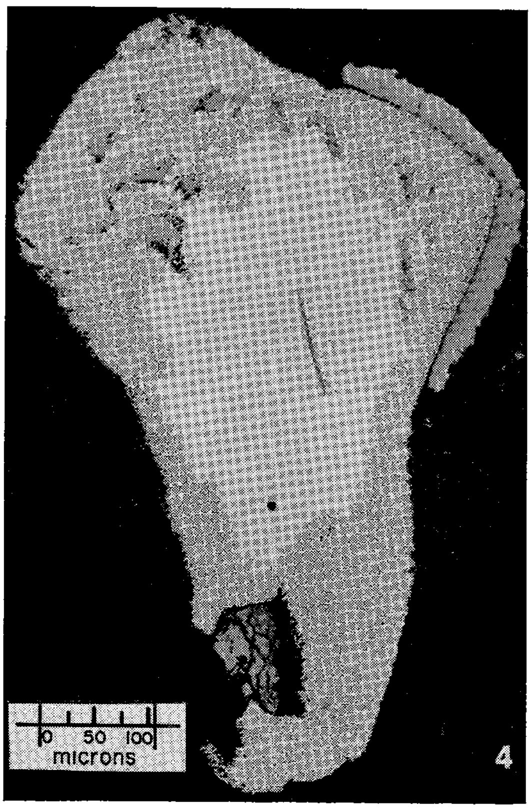

Fig. 4. Irarsite (grey) rimming and partly replacing a rutheniridosmine nugget (white).

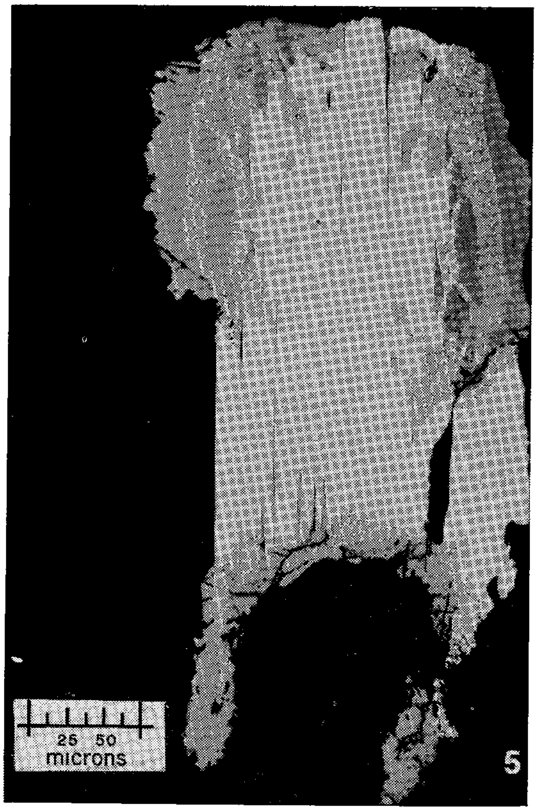

Fig. 5. Laurite (grey) rimming and partly replacing a nugget of rutheniridosmine (white).

The compositions of the cubic iron-bearing platinum, though showing a small spread, correspond to the general formula (Pt,Ir,Ru,Rh)$_3$ (Fe,Ni,Cu) or Pt_3Fe. Cabri *et al.* (1973) reported similar compositions and showed that the *x*-ray powder diffraction data for these alloys are the same as for pure platinum, but different from the cubic diffraction pattern of synthetic Pt_3Fe. Although *x*-ray studies were not made of the inclusions in this study, their compositions suggest that they are the cubic iron-bearing platinum alloy type.

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