LAVRENTIEVITE AND ARKAZITE: NEW NATURAL MERCURY SULFOHALIDES

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Described are the properties, composition, and X-ray data for two previously unknown mercury sulfohalides: Lavrentievite $Hg_3S_2(Cl, Br)_2$ and arzakite $Hg_3S_2(Br, Cl)_2$, which have either monoclinic or triclinic crystal system. It is assumed that the minerals are an isomorphous series of $Hg_3S_2Cl_2$-$Hg_3S_2Br_2$, the first half of which includes natural compounds with a predominant (of the total halide atoms) amount of chlorine in the composition, and the second with a greater content of bromine. The primarily chlorine-bearing mineral is called lavrentievite after M. A. Lavrent'ev, and the mineral with a dominant amount of bromine is called arzakaite after the location of the find: the Arzak mercury ore occurrence in the Tuva ASSR.

Among natural sulfohalide compounds of mercury, until recently we knew of only one mineral: corderoite [2,7], a complete analog of the artificial α-$Hg_3S_2Cl_2$ and a compositional analog of γ-$Hg_3S_2Cl_2$, synthesized by Carlson [6]. The X-ray diffraction pattern of the metastable γ phase was not indexed. In studying cinnabar ores from oxidation zones of the Arzak and Kadyrel mercury ore occurrences (Tuva ASSR), Vasil'ev found two more minerals, similar to each other and to corderoite and γ-$Hg_3S_2Cl_2$ in terms of composition, but differing from them by individual X-ray diffraction data. It was established that the new minerals, which also turned out to be isostructural, have a variable amount of chlorine and bromine.

We call the mineral with a predominance of chlorine over bromine (at.%) lavrentievite in memory of the founder of the Siberian Department of the AS USSR and it's first President, Academician M. A. Lavrent'ev. We propose that the mineral with more bromine than chlorine be called arzakite after the location of the find.

In the Arzak ore occurrence (its geological structure is discussed in [3]) lavrentievite and arzakite are found jointly in rhyolite-dacite poryphyries which have experienced hydrothermal alteration; and in the cavities of fractures filled by hypogenic quartz, milky white kaolinite, and cinnabar. The minerals form groups of small concretions (0.2 mm) of crystals of very complicated form (Fig. 1), attached by the base to the fringe of corderoite and its individual crystals which cover the cinnabar. Occasionally lavrentievite and arzakite grew directly on disturbed cinnabar. Most favorable for the free growth of crystals of these minerals were mocrocavities between spherical aggregates of kaolinite surrounding the cinnabar. Of the accompanying supergene mercury-bearing minerals we found calomel, eglestonite, corderoite, kuznetsovite, and native mercury, which owe their origin to the breakdown of hypogenic cinnabar and arsenopyrite in the oxidation zone. Lavrentievite and arzakite contact only cinnabar, corderoite, quartz, and kaolinite. Both new minerals are later than corderoite.

At the Kadyrel ore occurrence only lavrentievite has yet been found in small cavities remaining in veined calcite after complete or partial breakdown of the sulfides (pyrite, cinnabar, saucovite). There it associates simultaneously with calomel, eglestonite, and native mercury, or with native mercury and a powdery mixture of undetermined mercury-bearing minerals. Individual elongated grains of lavrentievite not larger than 0.1 mm are found. We were unable to establish the sequence of crystallization of the supergene minerals in the cavities.

In view of the similarity of physical properties of both minerals their description

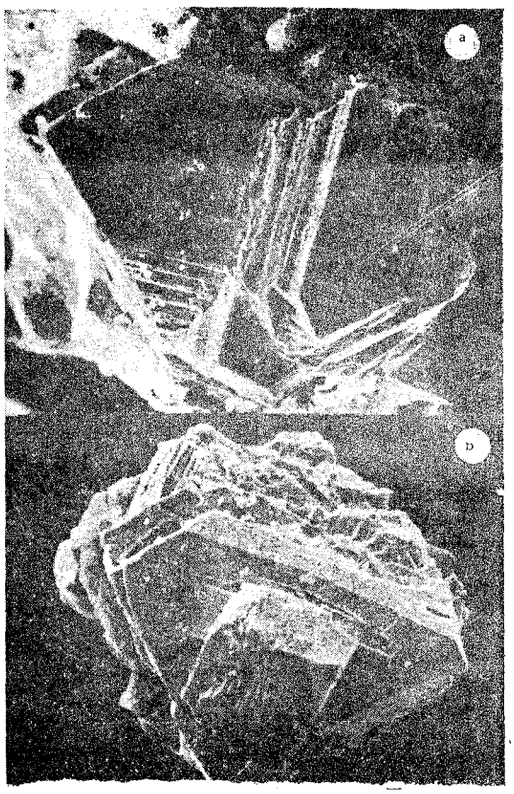

Fig. 1. Concretions of lavrentievite crystals among kaolinite (a) and mutual intergrowth of lavrentievite crystals in their central areas b). Scanning electron microscope. 400×.

is presented together.

The color of lavrentievite obviously depends on the amount of bromine in it and ranges from almost colorless to light olive, light marsh-green, and muddy yellow. The color of arzakite is more saturated and approaches brown. In light both minerals slowly darken (arzakite more rapidly) and become marsh-green with a brownish tint. Powder of the minerals under electric light is first colorless and pale yellow (olive green upon intense pulverization), then becomes gray. In thin chips the minerals are transparent. They have strongly glassy to diamond luster. The minerals are brittle, with perfect cleavage in two directions, and fracture across cleavage is uneven. Hardness is 2.0-2.5. Microindentation hardness (PMT-3, P = 10 g, n = 10) of lavrentievite ranges from H_{max} = 103 to H_{min} = 82 kgf/mm^2 with H_{av} = 94 kgf/mm^2. These data may be slightly overstated due to the small load on the indentation instrument selected with consideration of the grain size and the brittleness of the mineral. Density of lavrentievite, measured conventionally, ranges from 7.40-7.47 to 7.52 g/cm^3 (for crystals with 5.75 to 8.44% bromine). Due to the limited number of arzakite grains its density was not determined, but it should obviously be somewhat higher. Relationship of both minerals to reagents is monotypic: in KOH pieces of the minerals slowly become distinctly olive green, then blacken; HCl and HNO_3 do not affect them; in polished sections they do not react to standard reagents.

Upon heating in a sealed glass tube both minerals volatilize with the formation of white, yellow, and black deposits in the less heated area.

In polished sections lavrentievite is colorless or has a very slight yellow-brown color, which for arzakite is more saturated. Pleochroism is not noted for either mineral, but anisotropy is clearly expressed. Extinction is direct relative to cleavage. Indices of refraction are greater than 2.

In refelcted light lavrentievite and arzakite are sphalerite-gray, and double reflection is not observed visually for them. Magnitudes of the reflection of the minerals are almost identical since the difference is barely captured by the instrument. Determined for lavrentievite (with Br content in the grains from 5.75 to 8.44 mass%) are R_2 = 19.0, 18.3, 17.5, 17.5, 16.2, 15.8, and 15.6%; R_1 = 18.0, 17.5, 16.0, 15.5, 15.0, 14.8, 14.5%; wavelengths are respectively 436, 460, 500, 546, 590, 620, 656 nm (Fig. 2) (POOS-1, standard STF-2). The slight anisotropic effect for the minerals is masked by intense colorless or pale yellow interior reflexes.

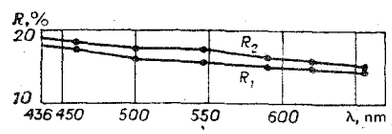

Fig. 2. Spectrum of lavrentievite reflection.

X-ray diffraction patterns of lavrentievite (Table 1) from both ore occurrences practically coincide, but they differ markedly from those of artificial α-$Hg_3S_2Cl_2$, γ-$Hg_3S_2Cl_2$ and corderoite [6, 7]. The X-ray diffraction pattern of arzakite (Table 2) fully preserves the motif of the lavrentievite patterns, but has higher values of d. Attempts to carry out monocrystal photography to determine the crystal system and cell dimensions of the minerals were unsuccessful due to the low quality of the samples. Due to the instability of lavrentievite and arzakite under electron beam, their electron microscope study to obtain electronograms was also unsuccessful. Therefore the powdergrams obtained were indexed and cell parameters were determined by computer with the Powder-1 program [4], and the two versions of the calculation, which showed that the minerals may have either monoclinic or triclinic crystal system, turned out to be applicable.

According to the first version of the calculation, proposed for the monoclinic crystal system, from the indexing data we can assume that the cell of the minerals is primitive, since there are reflexes hkl with (h + k) = 2n + 1. The presence of reflexes hol with l = 2n + 1 also lets us assume the absence of gliding planes c. Therefore the possible spatial group of symmetry for lavrentievite and arzakite should be one of P2/m, P2, Pm, and the diffraction class should be Cl_{2h} = 2/m. In this version the unit cell dimensions of lavrentievite are: $a = 8{,}94(2)$ Å; $b = 5{,}194(7)$ Å; $c = 18{,}33(4)$ Å; $\beta = 92{,}44(8)°$; $V = 850{,}3$ Å^3; $Z = 5$. Calculated X-ray density ρ ranges from 7.51 g/cm^3 (with 8.44 mass% Br in the mineral) to 7.26 g/cm^3 (with determined minimal Br content of 1.29 mass%). Unit cell dimensions of arzakite are: $a = 8{,}99(4)$ Å; $b = 5{,}24(1)$ Å; $c = 18{,}45(8)$ Å; $\beta = 92{,}28(15)°$; $V = 868{,}1$ A^3; $Z = 5$. Calculated X-rays density ρ is 7.64 g/cm^3.

According to the second version of the calculation, which considers the possibility of crystallization of the minerals in triclinic crystal system, we established for lavrentievite and arzakite the spatial groups $P1$ or $\bar{P}1$, diffraction class C_1 = 1. Obtained for lavrentievite are unit cell dimensions: $a = 8{,}90(1)$ Å; $b = 5{,}207(6)$ Å; $c = 18{,}34(3)$ Å; $\alpha = 89{,}67(7)°$; $\beta = 88{,}88(7)°$; $\gamma = 92{,}28(9)°$; $V = 849{,}2$ Å^3; $Z = 5$. The calculated X-ray density ρ varies as a function of the amount of bromine from 7.52 to 7.27 g/cm^3. According to calculation, the cell dimensions differ slightly: $a = 8{,}95(4)$ Å; $b = 5{,}25(2)$ Å; $c = 18{,}49(9)$ Å; $\alpha = 89{,}57(24)°$; $\beta = 88{,}74(24)°$; $\gamma = 92{,}16(32)°$; $V = 868{,}6$ Å^3; $Z = 5$. The calculated X-ray density is 7.63 g/km^3. For comparison Tables 1 and 2 give both versions of the indices of X-ray diffraction patterns and calculated d. The final selection of symmetry, spatial group, and unit cell dimensions can be made only after monocrystal photography.

The composition of lavrentievite and arzakite was studied by X-ray spectral microanalysis on the Camebax microprobe by Lavrent'ev. A total of 19 concretions of lavrentievite crystals and 1 of arzakite from the ores of the Arzak ore occurrence were analyzed. Lavrentievite of ore occurrence was not analyzed due to the small size and limited number of the grains. With accelerating stress of 20 kV and current of absorbed electrons of 8-10 nA we recorded analytical Hg_{M_α}-, Cl_{K_α}-, Br_{L_α} and S_{K_α} lines. X-radiation was recorded with continuous movement of the preparation. Recalculation of the measured intensities in concentration was done according to the Karat program [1] with consideration of a modern method of introducing corrections [5]. Used as standards were kalomel Hg_2Cl_2 (for Hg and Cl), artificial HgS (for Hg and S), and $Pb_7S_2Br_{10}$ (for S and Br). Reproduci-

Table 1

Results of X-Ray Investigations of Lavrentievite

Lavrentievite								Artificial			
1		2		3		4		α-$Hg_3S_2Cl_2$		ν-$Hg_3S_2Cl_2$	
I	*d*Å	*I*	*d*Å	*d*Å	*hkl*	*d*Å	*hkl*	*I*	*d*Å	*I*	*d*Å
0,5	9,13	0,5	9,20	9,16	002	9,17	002			2	9,35
0,5	8,00	0,5—1	8,00	7,90	101	8,06 7,94	101 $10\bar{1}$			1	7,99
										3	6,27
								3	6,23	3	6,25
										0,5	6,12
3d	5,00	2	5,00	5,00	011	5,01 5,00	011 $01\bar{1}$			3	4,77
										1	4,68
0,5	4,59	0,5	4,57	4,58	004	4,58	004			3	4,55
						4,41 4,34	110 201	1	4,43		
0,5—1	4,38	0,5—1	4,37	4,38	$20\bar{1}$; $11\bar{1}$					0,5	4,27
										3	4,21
2	4,11	1	4,12	4,14	$10\bar{4}$	4,11	104			5	4,09
4	3,96	4—5	3,97	3,96	013	3,97	$20\bar{2}$, 013			0,5	4,02
										5	3,85
										5	3,84
+	+	0,25	3,58	3,58	113	3,60	113	10	3,62	10	3,69
										1	3,36
5	3,38	5	3,37	3,39	210	3,38 3,37	$2\bar{1}1$ $10\bar{5}$			0,5	3,25
										5	3,12
+**	+**	+**	+**			3,06	006			1	3,04
						3,02	$2\bar{1}3$			1	3,03
5—6w*	3,01	6w*	3,00	3,006 2,993	$21\bar{3}$ 015	3,01	015			3	2,99
										7	2,94
										7	2,93
3	2,90	3	2,89	2,893	$20\bar{5}$	2,89	$21\bar{3}$	5	2,81	2	2,84
										6	2,70
2**	2,63	2**	2,63	2,63	016; 303	2,627	$01\bar{6}$			6	2,68
										0,5	2,67
10	2,61	10	2,60	2,616 2,60	007 020	2,601 2,599	020 $3\bar{1}1$			7	2,59
								7	2,57	9	2,57
										0,5	2,51
0,25	2,52	0,25	2,52	2,527 2,51	$21\bar{5}$ $31\bar{2}$	2,524 2,515	$1\bar{2}0$ 311			1	2,46
										1	2,45
										0,5	2,42
										0,5	2,40
								4	2,38	3	2,34
4	2,292	4	2,290	2,300 2,290	$20\bar{7}$; 123 008	2,292 2,289	008 $3\bar{1}4$	3	2,23	10	2,27
										0,5	2,25
										0,5	2,21
4	2,199	4—3	2,198	2,201 2,195	$12\bar{4}$ 108	2,200 2,198 2,196	$40\bar{1}$ $31\bar{4}$ 221			0,5	2,20
										0,5	2,15
										0,5	2,14
								4	2,10	7	2,11
										0,5	2,08
						1,982	$\bar{3}21$			0,5	2,02
0,25	1,981	0,25	1,979	1,978	026	1,981	307			1	2,00
						1,977	$10\bar{9}$; 412	3	1,993	1	1,957
2w	1,946	2w	1,945	1,943		1,946	$\bar{3}22$; $1\bar{2}6$	2	1,901	3	1,909
					$40\bar{5}$; $12\bar{6}$	1,944	$30\bar{7}$; $2\bar{2}5$			1	1,884
											57
										0,5	1,874
										0,5	1,866
										0,5	1,853
										0,5	1,844
0,5—1	1,831	1	1,831	1,831	0.0.10	1,831	308; $41\bar{4}$			2	1,834
								0,5	1,817	0,25	1,803
2w	1,788	2	1,787	1,786	500	1,788 1,786	1.0.$\bar{1}\bar{0}$ $12\bar{7}$	6	1,749	0,5	1,752
										2	1,738
0,25	1,733	0,25	1,732	1,734 1,732	$41\bar{6}$ 030	1,732 1,728	0.1.10 031			2	1,734
										1	1,701
1	1,662	1	1,663	1,663	407	1,662	$30\bar{9}$; 510			0,5	1,635
		0,25	1,612	1,611	$23\bar{1}$; 513	1,612	$\bar{2}32$; $\bar{2}$.1.10	3	1,629	1	1,629

Table 1 (continued)

Lavrentievite								Artificial			
1		2		3		4		α-$Hg_3S_2Cl_2$		ν-$Hg_3S_2Cl_2$	
I	dÅ	I	dÅ	dÅ	hkl	dÅ	hkl	I	dÅ	I	dÅ
										0,5	1,603
4—5	1,587	4	1,588	1,586	228; 232; $12\bar{9}$	1,588	$50\bar{5}$; $\bar{5}14$			0,5	1,596
								2	1,577	0,5	1,590
										1	1,559
										1	1,553
								3	1,529	2	1,543
1wd	1,484	1wd	1,485	1,489 1,485 1,482	600 $23\bar{5}$; $1.2.\overline{10}$ $33\bar{2}$	1,484	$\bar{1}.2.10$; 328	1 3	1,487 1,448	1	1,472
		1wd	1,398	1,398 1,396	604 $33\bar{5}$	1,398	612; $\bar{3}.1.11$; 2.1.12	0,5	1,412		
1wd	1,373	1wd	1,373	1,375 1,372	2.1.12 $50\bar{9}$	1,373	335			1	1,377
0,5	1,334	0,25	1,332	1,334 1,333	518 336	1,334	336; $2\bar{3}8$			0,5	1,346
2d	1,302	1	1,299	1,302 1,299	434; $1.0.\bar{1}\,\bar{4}$ 139	1,301 1,300	519 $\bar{4}35$				

There are ten more diffuse lines lower than 1.302—1.299 with intensity to 1.

Note. Experimental data (mean for three independent films): 1) Arzak, 2) Kadyrel ore occurrences; photographic conditions: filtered Cu_{K_α} radiation, D_{fr} = 57.3 and D_{sam} = 0.2 mm (calculation of Vasil'ev indexed by computer; 3 and 4) calculation data for monoclinic and triclinic crystal system, respectively; w) wide and d) diffuse lines; +) very weak line (present); *two close lines are possible; **line is not present on all films. Additional indices are possible for some reflexes. Powdergram of the mineral of the Arzak ore occurrence is obtained for a mixture of crystals with Br from 5.75 to 8.44 mass %.

Table 2

Results of X-Ray Investigations of Arzakite

Arzakite						Artificial			
1		2		3		α-$Hg_3S_2Cl_2$		ν-$Hg_3S_2Cl_2$	
I	dÅ	dÅ	hkl	dÅ	hkl	I	dÅ	I	dÅ
0,25	9,30	9,22	002	9,24	002			2	9,35
0,5	8,00	7,95	101	8,12 7,98	101 $10\bar{1}$			1 3	7,99 6,27
						3	6,23	3	6,25
3	5,05	5,04	011	5,06 5,04	011 $01\bar{1}$			0,5 3	6,12 4,77
0,25	4,62	4,61	004	4,62	004			1	4,68
0,5	4,44	4,42 4,40	$11\bar{1}$ $20\bar{1}$	4,45 4,37	110 201	1	4,43	3 0,5	4,55 4,27
>1	4,15	4,17	$10\bar{4}$	4,14	104			3	4,21
4	3,99	3,99	013	4,01 3,99	013 $20\bar{2}$			5 0,5	4,09 4,02
								5	3,85
								5	3,84
<0,25	3,63	3,61	113	3,64	113	10	3,62	10	3,69
5	3,41	3,41	210	3,417 3,40 3,39	$21\bar{1}$ $\bar{2}11$ $10\bar{5}$			1 0,5	3,36 3,25
<1d	3,06	3,07	006	3,08	006			1	3,04
6	3,02	3,021 3,015	$21\bar{3}$ 015	3,04 3,03	$2\bar{1}3$ 015			1	3,03
>2	2,91	2,907	$20\bar{5}$	2,911	$21\bar{3}$			3 7 7	2,99 2,94 2,93
						5	2,81	2	2,84
								6	2,70
								6	2,68
10	2,63	2,636 2,620	007 020	2,635 2,624	$3\bar{1}0$ 020			0,5 7	2,67 2,59

Table 2 (continued)

Arzakite						Artificial			
1		2		3		α-$Hg_3S_2Cl_2$		ν-$Hg_3S_2Cl_2$	
I	dÅ	dÅ	hkl	dÅ	hkl	I	dÅ	I	dÅ
<0,25	2,54	2,542 2,530	$21\bar{5}$ $31\bar{2}$	2,543 2,534	$1\bar{2}0$ 311	7	2,57	9	2,57
								0,5	2,51
								1	2,46
								1	2,45
								0,5	2,42
4	2,313	2,318 2,312 2,304	123 $20\bar{7}$ 008	2,311 2,304	008 $3\bar{1}4$	4 3	2,38 2,23	0,5 3 10	2,40 2,34 2,27
>3	2,212	2,218 2,211	$12\bar{4}$ 108	2,214 2,213 2,212	221 $40\bar{1}$ $31\bar{4}$			0,5	2,25
								0,5	2,21
								0,5	2,20
								0,5	2,15
								0,5	2,14
						4	2,10	7	2,11
<0,25	2,053	2,054 2,051	217 $40\bar{4}$	2,054 2,053	009 $12\bar{5}$			0,5	2,08
								0,5	2,02
<0,5	1,993	1,993	026	1,994 1,992	321 $10\bar{9}$; 412	3	1,993	1	2,00
2d	1,955	1,957 1,955 1,953	$12\bar{6}$ 321 $40\bar{5}$	1,959 1,957 1,955	$1\bar{2}6$; $\bar{3}22$ $2\bar{2}5$ $30\bar{7}$	2	1,901	1 3 1	1,957 1,909 1,884
								0,5	1,874
								0,5	1,866
2	1,843	1,843	0.0.10	1,846 1,842	308 $41\bar{4}$			0,5 0,5	1,853 1,844
								2	1,834
2	1,799	1,797	500	1,802 1,799	$1.0.\bar{1}0$ $12\bar{7}$	0,5	1,817	0,25	1,803
0,5	1,743	1,747 1,743	030 $41\bar{6}$	1,748 1,743	0.1.10 031	6	1,749	0,5 2	1,752 1,738
								2	1,734
<0,25	1,706	1,706	131; 503	1,706	128; $50\bar{3}$			1	1,701
<1	1,674	1,676	407; 0.0.11	1,673	510; $30\bar{9}$				
0,5	1,635	1,636	1.0.11; $31\bar{9}$	1,634	$2\bar{2}8$			0,5	1 635
						3	1,629	1	1,629
								0,5	1,603
4	1,595	1,599 1,597	228; 232 $12\bar{9}$	1,596	$\bar{5}14$; $50\bar{5}$			0,5	1,596
						2	1,577	0,5	1,590
								1	1,559
								1	1,553
						3	1,529	2	1,543
>1wd	1,495	1,497 1,493	$23\bar{5}$; 600 $33\bar{2}$; $1.2.\bar{1}0$	1,498 1,497	328 $\bar{1}.2.10$	1 3	1,487 1,448	1	1,472
<0,25	1,413	1,413 1,408	$61\bar{3}$ 604	1,413	$61\bar{1}$	0,5	1,412		
>1wd	1,386	1,386 1,385	335 2.1.12	1,386	335; $\bar{4}32$			1	1,377
<0,25	1,338	1,339 1,338	$23\bar{8}$ 433	1,339	$3.\bar{1}.12$;$\bar{6}15$			0,5	1,346
1	1,309	1,312 1,310	434 $1.0\bar{1}\bar{4}$.; 139	1,312 1,309	519 $\bar{4}35$				

There are about 10 more diffuse lines lower than 1.309 with intensity to 1.

Note. Photographic conditions: filtered Cu_{K_α} radiation; D_{fr} = 57.3 and D_{sam} = 0.2 mm (calculation of Vasil'ev), indexed by computer. 1) experimental, 2 and 3) calculation data for monoclinic and triclinic crystal system, respectively; w) wide and d) diffuse lines. Additional indices are possible for some reflexes.

bility of the measurements, which characterizes the spread of data in the different grains of minerals, was about 1.2 rel% for Hg, 2.8 for S, 6.3 for Cl, and 11.9 for Br. Established in the first series of randomly selected and studied samples was 1.29 to 10.3 m mass% bromine and the range of variation of the contents of all elements in lavrentievite from the second series of samples (10 grains), selected with consideration of the identity of color, was as follows (mass%): 77.1-79.8 Hg, 5.75-8.44 Br, 5.46-6.75 Cl, 8.16-8.63 S (Table 3). At the same time it was established that in some preparations of lavrentievite the halides are zonally distributed, and the external parts of the crystals are bromine-poor. As a rule, these are weakly colored and almost colorless areas of the mineral.

Table 3

Chemical Composition of Lavrentievite and Arzakite (mass%) from the Arzak Ore Occurrence

Element	Lavrentievite						Arzakite		Theoretical composition for formulas			
	1		2		3				$Hg_3S_2Cl_2$		$Hg_3S_2Br_2$	
	A	B	A	B	A	B	A	B	A	B	A	B
Hg	81,4	0,406	77,1	0,384	78,48	0,391	75,3	0,375	81,68	0,407	72,88	0,363
Cl	9,13	0,258	5,46	0,154	6,04	0,170	3,13	0,088	9,62	0,271	—	—
Br	1,29	0,016	8,44	0,106	6,94	0,087	11,6	0,145	—	—	19,35	0,242
S	8,51	0,265	8,32	0,259	8,35	0,260	7,98	0,249	8,70	0,271	7,77	0,242
Total	100,33		99,32		99,81		98,01		100,00		100,00	

Note. Analyses: 1) with minimal Br content from first series of randomly selected samples; 2) with maximal Br content from 10 color-selected samples (5.75 to 8.44 mass % Br); 3) average composition for 10 analyzed crystals, A) content, B) atomic ratio.

As evident from the analyses, as a whole the bromine content in our lavrentievite samples is very inconstant, ranging from 6 to 48% of the total halide atoms. This circumstance along with the X-ray data may testify to the isomorphous entrance of bromine into the lattice of the compound, where it replaces part of the chlorine atoms. Obviously we can expect to discover varieties of lavrentievite in which the bromine content is even smaller than established by analysis, or even absent in general. Also quite realistic is a larger bromine content in the compounds, exceeding 50% of the total halide atoms. Then the isomorphous admixture will be chlorine. This assumption is confirmed both by the presence of lavrentievite with 48 at.% bromine and arzakite with 65 at.% bromine. Evidently the established quantity of bromine in arzakite is not limiting, and a mineral exists in which the halides are represented by one bromine. This mineral should have the formula $Hg_3S_2Br_2$ and consequently a different mercury and sulfur content from lavrentievite.

According to the established content of elements, X-ray data, and considering filling the cell with 7 atoms we calculated the formulas of lavrentievite for grains with minimal and maximal quantities of bromine and for the average (of 10 analyses) composition of the mineral, and also for arzakite:

$$Hg_{3,007}S_{1,963}(Cl_{1,911}Br_{0,112})_{2,023}, \quad (1)$$

$$Hg_{2,977}S_{2,003}(Cl_{1,194}Br_{0,822})_{2,016}, \quad (2)$$

$$Hg_{3,014}S_{2,004}(Cl_{1,310}Br_{0,671})_{1,981}, \quad (3)$$

$$Hg_{3,06}S_{2,03}(Br_{1,18}Cl_{0,72})_{1,90}. \quad (4)$$

In the idealized version the formulas take the form $Hg_3S_2(Cl, Br)_2$ for lavrentievite and $Hg_3S_2(Br, Cl)_2$ for arzakite.

As mentioned above, the formulas for our samples of lavrentievite and arzakite are similar to those of corderoite and artificial α-$Hg_3S_2Cl_2$, γ-$Hg_3S_2Cl_2$, but differ from them for lavrentievite by additional bromine and for arzakite by the predominance of bromine. According to this indication we could formally identify the bromine-bearing variety as either α-$Hg_3S_2Cl_2$, or γ-$Hg_3S_2Cl_2$ compounds. However, the similarity of the formulas in this

case are not a major fact since the X-ray patterns of lavrentievite and arzakite are individual and the minerals have monoclinic or triclinic crystal system unlike corderoite and synthetic α-$Hg_3S_2Cl_2$ (cubic) and γ-$Hg_3S_2Cl_2$ (metastable, synogony unknown).

Considering the isostructural nature of lavrentievite and arzakite, the similarity of their physical properties, and the variability of composition (in terms of Cl:Br), we can consider that they are members of a isomorphous series of monoclinic or triclinic $Hg_3S_2Cl_2$-$Hg_3S_2Br_2$, which probably exist in nature. The first half of this series contains primarily chlorine-bearing minerals with an isomorphous admixture of bromine to 50 at.% (Cl ≥ Br) of the total halides, and the second has minerals with predominant bromine (Br > Cl from 50 at.% and up). Unfortunately, we have not yet encountered the end members of this series in "pure" form.

Samples of lavrentievite and arzakite have been sent for storage to the Central Siberian Geological Museum of the Institute of Geology and Geophysics of the Siberian Department of the AS USSR.

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