PECULIARITIES OF COMPOSITION OF Te–BEARING FAHLORES

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The possibility of new mineral species close in optical and chemical features to fahlores is shown in the article. Their idealized formulae, calculated with 32 and 33 atoms in a unit cell, are as follows: $Cu^{+}_{11}Me^{2+}_{1.00}Me^{3+}_{1.00}\Pi Me_{4.00}S_{15}$ and $Cu^{+}_{10}Me^{2+}_{3.00}\Pi Me_{4.00}S_{16}$. It is assumed that they are germanium-free analogues of complex sulfides of germanium (germanite, renierite, briartite). Moreover, the character of tellurium in Te-bearing fahlores from volcanogenic and hydrothermal quartz-sulfide vein deposits of gold – sulfide formation is considered. It is shown that tellurium may enter both cation (Te^{4+}) and anion positions (Te^{2-}) in goldfieldite and Te-bearing tetrahedrite. Goldfieldites containing more than 24 wt.% tellurium are heterogenous as a rule, and contain native tellurium as a very fine admixture. Te-bearing fahlores with a high content of silver (7 – 13 wt.%) may contain admixtures of fine-grained kervelleite Ag_4TeS.
7 tables, 12 references.

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Te-bearing fahlores are characteristic of many volcanogenic and hydrothermal quartz-sulfide vein deposits of gold – sulfide formation. Samples from such deposits were investigated by many researchers: Ransome *et al.* (1909), Frenzel *et al.* (1975), Novgorodova *et al.* (1978), Mozgova and Tsepin (1983), Spiridonov (1987), Spiridonov and Badalov (1983), Sakharova *et al.* (1984), Kovalenker *et al.* (1980, 1986) and Borisova *et al.* (1986). The samples are from the following deposits: Goldfield (Nevada, USA), Calabona (Sardinia island, Italy), Butte (USA), Koch-Bulak (Kuraminsky ridge, Uzbekistan), Kunashir (Kuril Islands, Russia), deposits of the Kamchatka peninsula (Russia), Bulgarian deposits (Chelopech, Radka, Elshitsa). The similarity of geological position and structure of ore bodies of several of the above-mentioned deposits is shown in Table 1.

As was shown during investigation of ore samples from the copper pyrite deposit of Chelopech (see the article of S.N. Nenasheva in this issue), microprobe analyses of optically identified fahlores gave non-electroneutral formulae for recalculation on 29 atoms per unit cell. It is assumed that the average formula of fahlore is $Cu_{12}\Pi Me_4S_{13}$, and that the conventional formula is $Cu^{+}_{10}Me^{2+}_{2}\Pi Me_4S_{13}$ (Mozgova and Tsepin, 1983). Formulae with a balance of valences (Δ – is the absolute value of deviation from zero) not exceeding 3% were considered to be electroneutral. Electroneutrality was obtained only for recalculation on a larger number of atoms in the unit cell, namely 32, 33, 34 (see Table 8 in the article of S.N. Nenasheva in this issue): $Cu^{+}_{8}Cu^{2+}_{2}Fe^{2+}_{3}As_4S_{15}$, $Cu^{+}_{8}Cu^{2+}_{3}Fe^{2+}_{2}As_4S_{15}$, $Cu^{+}_{11}Me^{2+}_{2}Me^{3+}\Pi Me^{3+}_{4}S_{15}$, $Cu^{+}_{11}Me^{2+}_{3}(\Pi Me^{3+}, Te^{4+})_4S_{16}$. Perhaps they are new mineral species. In this connection, literature analyses of Te-bearing fahlores from other deposits (102 analyses altogether) were recalculated. Some of these analyses recalculated to non-electroneutral formulae. Unfortunately, the authors did not give the valence balance. There are two possible explanations of this fact: (1) the authors did not pay attention to valence balance, and so it was not calculated; (2) the authors neglected this data. In my opinion, one can publish only analyses with electroneutral formulae. If a formula is non-electroneutral, it is necessary to explain this phenomenon. Due to the fact that almost all recalculated analyses were given without X-ray characterization, it is possible that these analyses did not belong to fahlores, or the analyzed material was heterogeneous. In some cases during recalculation of formulae and calculation of valence balance, tellurium was assigned not only as Te^{4+} in the position of ΠMe but also as Te^{2-} occupying the position of sulfur. The result of this action is that the amount of atoms at the position ΠMe in these analyses significantly exceeds 4 and the amount of S is very low.

In fahlores (goldfieldite and high-tellurium tetrahedrite) containing more than 20 wt.% tellurium, the distribution of tellurium into different positions does not contradict the crystallochemical features of tellurium. We know the following minerals containing Te^{2-} in the position of sulfur: kervelleite $Ag^{+}_{4}Te^{2-}S$, aleksite $PbBi_2(Te_2S_2)_{\Sigma 4}$, sedlebakite $Pb_2Bi_2Te_2S_3$, and poubaite $Pb_3Bi_6(Te_4Se_6S_2)_{\Sigma 12}$. We also know minerals where tellurium enters both cation and anion positions, for example, nagyagite-(Te^{4+}) $Au_{2.5+x}Pb_{22+y}Te^{4+}_{6}\square_2(S,Te^{2-})_{35.25+0.5x+y}$.

Table 1. **Brief characteristics of the deposits where Te-bearing fahlores occur**

Deposit	Geological setting of deposit	Characteristics of ore bodies
Goldfield, Nevada, USA	Ores are deposited within the Early Tertiary volcanogenic construction of the central type among the silificated dacites	Abundance of sulfides, native gold, tellurides. Fahlores of the tetrahedrite-goldfieldite series are characteristic to the later mineral association
Calabona, Island Sardinia, Italy	Copper porphyric deposit, connected with Post-Triassic Pre-Oligocene dioritic stock within the silificated Triassic limestones	Subvertical intensively weathered lenses of copper ores
Butte, Montana, USA	Hydrothermal quartz-sulfide vein deposit	Sulfide ores contain pyrite, chalcopyrite, chalcocite, fahlores, bornite, enafgite
Kayragach, Kuraminsky ridge, Eastern Uzbekistan	Deposit is located in the caldera of Carboniferous age filled by volcanites connected with secondary quartzites (Spiridonov *et al.*, 1983)	Ore bodies are represented by intersecting calcite-quartz with barite moderate sulfide veins among secondary quartzites
Koch-Bulak, Kuraminsky ridge, Uzbekistan	Ore field is located within one of the satellites of multi-channel central type paleovolcans composed of volcanogenic rocks of andesite and felsite composition	Gold-sulfide-quartz mineralization is connected with the final stage of Lower Triassic acid volcanism procedded after formation of large batholith-like intusions of Middle and Upper Carboniferous age
Deposits of the volcanic belt of Central Kamchatka	Veins and mineralized zones of crushing connected with volcanic structure of Neogene age (Sakharova *et al.*, 1984)	Gold-bearing quartz veins with sulfides and tellurides. Goldfieldite occurs in association with chalcopyrite, pyrite, and native tellurium
Chelopech, Radka, Elshitse, Bulgaria	Copper pyrite deposites are located in the central part of structure-metallogenic zone Sredna Hora. They are formed in the Late Cretaceous in tight connection with andesite-dacititic volcanism. It is attributed to the volcano-hydrothermal type (Bogdanov, 1984)	Ore bodies of band-like and stock-like form are steeply dipping and are connected with dacitic and andesitic agglomerate tuffs. They contain about 50 hypogene ore minerals: besides ordinary sulfides there are fahlores, rare minerals of germanium, tellurides
Oziornoye, Kamchatka	Volcanogenic deposit (Spiridonov, Okrugin, 1985)	Selenium and tellurium bearing fahlore forms metasomatic ingrowths up to 0.1 mm in size in quartz in association with telluroselenides and selenides of Bi and Ag
Gold ore deposit of the East of the USSR	Oligocene and Miocene tuffs of andesites and andesito-basalts with intersecting Early Miocene gabbro-diorites of subvolcanic massif contain ore mineralization (Borisova *et al.*, 1986)	Hydrothermal quartz and quartz-sulfide veins and veinlets with sulfides: sphalerite, galenite, fahlores, and chalcopyrite

Results of recalculation

Recalculated analyses and valence balance of fahlores from the Koch-Bulak deposit are shown in Table 2. These analyses were given by Novgorodova *et al.* (1978). Fifteen of the 32 analyses given in Table 2 (analyses 1, 2, 3, 4, 5, 6, 7, 8, 12, 14, 15, 20, 22, 23 and 27) may be recalculated as electroneutral conventional formula $Cu^{+}_{10}Me^{2+}_{2}\Pi Me_4S_{13}$. Formulae for 5 analyses (analyses 11, 18, 19, 21 and 32) are non-electroneutral. Formulae of analyses from the former list (11, 21 and 32) have valence balance 3.5, 3.1 and 3.2%, and analyses (18 and 19) have 17 and 16.5% valence balance, respectively. They lack S (less than 12 atoms per formula unit) and have much Ag. Attempts to represent Ag as kervelleite, Ag_4TeS, and to recalculate the analyses were unsuccessful. Balance of valences became better, but was 11.4 and 11.7%, respectively, exceeding the norm (3%). The rest of the analyses were recalculated to electroneutral formulae under different conditions: (1) taking some tellurium as Te^{2-} at the S position (analyses 9, 10, 13, 16, 17 and 25). Analysis 17 was recalculated in two ways: (a) tellurium exceeding 4 atoms in the formula at the ΠMe position was assumed to be Te^{2-}, and

Table 2. **Recalculation of analyses of fahlores from the Koch-Bulak deposit given by M.I. Novgorodova *et al.* (1978) to formulae and calculation of their valence balance**

№	Cu	Fe	Zn	Sn	Ag	Sb	As	Te	S	Σ
1	42.99	4.01	0.23	1.58	0.20	19.95	7.24	0.07	26.12	102.40
2	38.93	1.13	6.39	0.00	0.28	25.03	3.50	0.11	25.21	100.59
3	43.08	2.95	0.19.	2.42	0.23	20.77	6.68	0.19	25.70	102.21
4	41.13	5.76	0.70	0.43	0.08	19.70	7.66	0.19	26.29	101.94
5	42.79	2.56	0.15	2.81	0.26	21.13	6.52	0.21	25.46	101.88
6	41.13	0.38	6.99	0.00	0.16	16.83	9.19	0.22	26.85	101.86
7	40.17	2.29	4.41	0.00	0.37	25.02	3.50	0.42	25.43	101.61
8	43.65	2.39	0.13	2.95	0.18	19.25	7.43	0.69	25.72	102.38
9	40.46	0.60	5.71	0.00	0.14	25.57	2.69	1.45	24.33	100.95
10	40.84	0.55	5.56	0.00	0.15	24.84	2.75	1.87	24.17	100.73
11	43.48	0.32	4.23	0.00	0.25	15.85	5.30	6.83	25.44	101.70
12	42.59	1.35	1.64	0.00	0.09	17.86	2.76	7.49	24.56	98.34
13	43.02	1.47	1.50	0.00	0.21	17.55	3.56	7.61	24.32	99.24
14	43.91	0.65	3.37	0.00	0.25	12.58	6.44	8.41	26.72	102.23
15	44.46	1.25	1.05	0.00	0.26	16.35	3.15	9.41	25.44	101.37
16	45.41	0.37	1.62	0.00	0.15	15.29	2.64	11.48	25.39	102.35
17	41.80	0.25	1.12	0.00	0.26	14.26	2.53	12.49	23.79	96.50
18	36.53	5.44	1.28	0.00	7.81	10.66	3.23	12.55	22.19	99.69
	36.53	5.44	1.28	0.00	0.00	10.66	3.23	10.24	21.61 +$Te_{nat.}$	88.99
19	37.49	5.40	1.05	0.00	6.34	10.40	3.01	12.81	22.15	98.65
	37.49	5.40	1.05	0.00	0.00	10.40	3.01	10.94	21.68 +$Te_{nat.}$	89.97
20	44.94	0.33	0.29	0.00	0.18	12.88	2.80	14.04	25.57	101.03
21	47.04	0.65	0.00	0.00	0.21	10.99	3.96	14.51	24.52	101.88
22	45.96	0.05	0.11	0.00	0.00	11.63	1.63	14.98	26.03	100.42
23	44.63	2.22	0.15	0.00	0.52	9.06	2.93	15.50	25.70	100.71
24	46.68	0.10	0.16	0.00	0.09	11.00	2.90	15.57	24.98	101.48
25	47.68	0.04	0.00	0.00	0.06	7.76	4.90	16.32	24.54	101.29
26	45.98	0.06	0.05	0.01	0.86	7.93	4.65	16.79	25.36	101.69
27	44.82	0.82	0.00	0.00	0.20	7.97	2.54	19.11	25.63	101.09
28	44.93	0.17	0.00	0.04	0.60	6.87	2.88	21.76	25.32	102.57
29	42.98	0.39	0.06	0.00	1.03	7.15	1.28	22.21	24.52	99.62
30	44.49	0.31	0.00	0.00	0.71	5.23	2.60	23.06	24.34	100.74
31	44.36	0.29	0.00	0.03	0.94	6.32	2.31	23.69	25.25	103.20
32	44.51	0.45	0.00	0.00	1.49	5.40	2.21	24.09	24.41	102.55

№	Formula	$Te_{nat.}$ apfu	Δ, %
1	$(Cu^{+}_{10.65}Ag_{0.03})_{10.68}(Fe_{1.13}Zn_{0.05}Sn_{0.21})_{1.39}(Sb_{2.58}As_{1.52}Te^{4+}_{0.01})_{4.11}S_{12.82}$	0.00	0.6
2	$(Cu^{+}_{10.02}Ag_{0.04})_{10.06}(Fe_{0.33}Zn_{1.60})_{1.93}(Sb_{3.36}As_{0.76}Te^{4+}_{0.01})_{4.13}S_{12.86}$	0.00	2.3
3	$(Cu^{+}_{10.81}Ag_{0.03})_{10.84}(Fe_{0.84}Zn_{0.05}Sn_{0.32})_{1.21}(Sb_{2.72}As_{1.42}Te^{4+}_{0.02})_{4.16}S_{12.78}$	0.00	0.5
4	$(Cu^{+}_{10.14}Ag_{0.01})_{10.15}(Fe_{1.62}Zn_{0.17}Sn_{0.06})_{1.85}(Sb_{2.54}As_{1.60}Te^{4+}_{0.02})_{4.16}S_{12.85}$	0.00	2.4
5	$(Cu^{+}_{10.83}Ag_{0.04})_{10.87}(Fe_{0.74}Zn_{0.04}Sn_{0.38})_{1.16}(Sb_{2.79}As_{1.40}Te^{4+}_{0.03})_{4.22}S_{12.77}$	0.00	1.3
6	$(Cu^{+}_{10.07}Ag_{0.02})_{10.09}(Fe_{0.11}Zn_{1.66})_{1.77}(Sb_{2.15}As_{1.91}Te^{4+}_{0.04})_{4.10}S_{13.03}$	0.00	0.3
7	$(Cu^{+}_{10.23}Ag_{0.06})_{10.29}(Fe_{0.66}Zn_{1.09})_{1.75}(Sb_{3.32}As_{0.76}Te^{4+}_{0.05})_{4.13}S_{12.83}$	0.00	2.2
8	$(Cu^{+}_{10.93}Ag_{0.03})_{10.96}(Fe_{0.68}Zn_{0.03}Sn_{0.40})_{1.11}(Sb_{2.52}As_{1.58}Te^{4+}_{0.09})_{4.19}S_{12.76}$	0.00	1.2
9	$(Cu^{+}_{10.54}Ag_{0.02})_{10.56}(Fe_{0.18}Zn_{1.45})_{1.63}(Sb_{3.48}As_{0.59})_{4.07}(S_{12.56}Te^{2-}_{0.19})_{12.75}$	0.00	2.0
10	$(Cu^{+}_{10.66}Ag_{0.02})_{10.68}(Fe_{0.16}Zn_{1.41})_{1.57}(Sb_{3.38}As_{0.61}Te^{4+}_{0.01})_{4.00}(S_{12.51}Te^{2-}_{0.23})_{12.74}$	0.00	1.4
11	$(Cu^{+}_{10.99}Ag_{0.04})_{11.03}(Fe_{0.09}Zn_{1.04})_{1.13}(Sb_{2.09}As_{1.14}Te^{4+}_{0.86})_{4.09}S_{12.75}$	0.00	3.5
	$(Cu^{+}_{10.99}Ag_{0.04})_{11.03}(Fe_{0.09}Zn_{1.04})_{1.13}(Sb_{2.09}As_{1.14}Te^{4+}_{0.77})_{4.00}(S_{12.75}Te^{2-}_{0.09})_{12.84}$	0.00	1.5
12	$(Cu^{+}_{11.25}Ag_{0.01})_{11.26}(Fe_{0.42}Zn_{0.41})_{0.83}(Sb_{2.46}As_{0.62}Te^{4+}_{0.99})_{4.07}S_{12.85}$	0.00	1.6
13	$(Cu^{+}_{11.30}Ag_{0.03})_{11.33}(Fe_{0.44}Zn_{0.38})_{0.82}(Sb_{2.41}As_{0.79}Te^{4+}_{0.80})_{4.07}(S_{12.66}Te^{2-}_{0.2})_{12.86}$	0.00	0.2

14	$(Cu^{+}_{10.86}Ag_{0.04})_{10.90}(Fe_{0.81}Zn_{0.18})_{0.99}(Sb_{1.62}As_{1.35}Te^{4+}_{1.04})_{4.01}S_{13.10}$	0.00	0.9
15	$(Cu^{+}_{11.37}Ag_{0.04})_{11.41}(Fe_{0.36}Zn_{0.26})_{0.62}(Sb_{2.18}As_{0.68}Te^{4+}_{1.20})_{4.06}S_{12.90}$	0.00	0.9
16	$(Cu^{+}_{11.58}Ag_{0.02})_{11.60}(Fe_{0.11}Zn_{0.40})_{0.51}(Sb_{2.03}As_{0.57}Te^{4+}_{1.40})_{4.00}(S_{12.83}Te^{2-}_{0.06})_{12.89}$	0.00	2.3
17	$(Cu^{+}_{11.41}Ag_{0.04})_{11.45}(Fe_{0.08}Zn_{0.30})_{0.38}(Sb_{2.03}As_{0.59}Te^{4+}_{1.38})_{4.00}(S_{12.87}Te^{2-}_{0.32})_{13.19}$	0.00	3.0
	$(Cu^{+}_{11.41}Ag_{0.04})_{11.45}(Fe_{0.08}Zn_{0.30})_{0.38}(Sb_{2.03}As_{0.59}Te^{4+}_{1.57})_{4.17}(S_{12.87}Te^{2-}_{0.13})_{13.00}$	0.00	1.1
18	$(Cu^{+}_{9.89}Ag_{1.25})_{11.14}(Fe_{1.68}Zn_{0.34})_{2.02}(Sb_{1.51}As_{0.74}Te^{4+}_{1.69})_{3.94}S_{11.91}$	0.00	17.0
	$Cu^{+}_{10.57}(Fe_{1.79}Zn_{0.36})_{2.15}(Sb_{1.61}As_{0.79}Te^{4+}_{1.48})_{3.88}S_{12.40}$ + 10.7 мас.% Ag_4TeS	0.00	11.4
19	$(Cu^{+}_{10.20}Ag_{1.02})_{11.22}(Fe_{1.67}Zn_{0.28})_{1.95}(Sb_{1.48}As_{0.69}Te^{4+}_{1.74})_{3.91}S_{11.94}$	0.00	16.5
	$Cu^{+}_{10.76}(Fe_{1.76}Zn_{0.29})_{2.05}(Sb_{1.55}As_{0.73}Te^{4+}_{1.56})_{3.84}S_{12.33}$ + 8.68 мас.% Ag_4TeS	0.00	11.7
20	$(Cu^{+}_{11.59}Ag_{0.03})_{11.62}(Fe_{0.10}Zn_{0.07})_{0.17}(Sb_{1.73}As_{0.61}Te^{4+}_{1.80})_{4.14}S_{13.07}$	0.00	0.08
21	$(Cu^{+}_{12.09}Ag_{0.03})_{12.12}Fe_{0.19}(Sb_{1.47}As_{0.86}Te^{4+}_{1.67})_{4.00}(S_{12.49}Te^{2-}_{0.19})_{12.68}$	0.00	3.1
22	$Cu^{+}_{11.83}(Fe_{0.01}Zn_{0.03})_{0.04}(Sb_{1.56}As_{0.36}Te^{4+}_{1.92})_{3.84}S_{13.28}$	0.00	4.6
	$Cu^{+}_{10.00}(Cu^{2+}_{1.83}Fe_{0.01}Zn_{0.03})_{1.87}(Sb_{1.56}As_{0.36}Te^{4+}_{1.92})_{3.84}S_{13.28}$	0.00	2.3
23	$(Cu^{+}_{11.47}Ag_{0.08})_{11.55}(Fe_{0.65}Zn_{0.04})_{0.69}(Sb_{1.21}As_{0.64}Te^{4+}_{1.97})_{3.82}S_{13.02}$	0.00	0.9
24	$(Cu^{+}_{12.04}Ag_{0.01})_{12.05}(Fe_{0.03}Zn_{0.04})_{0.07}(Sb_{1.48}As_{0.63}Te^{4+}_{1.89})_{4.00}(S_{12.77}Te^{2-}_{0.11})_{12.88}$	0.00	1.2
	$(Cu^{+}_{12.08}Ag_{0.01})_{12.09}(Fe_{0.03}Zn_{0.04})_{0.07}(Sb_{1.49}As_{0.64}Te^{4+}_{1.89})_{4.02}S_{12.81} + Te_{nat.}$	0.11	2.1
25	$(Cu^{+}_{12.27}Ag_{0.01})_{12.28}Fe_{0.01}(Sb_{1.04}As_{1.07}Te^{4+}_{1.89})_{4.00}(S_{12.51}Te^{2-}_{0.20})_{12.71}$	0.00	2.9
26	$(Cu^{+}_{11.77}Ag_{0.13})_{11.90}(Fe_{0.02}Zn_{0.01})_{0.03}(Sb_{1.06}As_{1.01}Te^{4+}_{1.93})_{4.00}(Te^{2-}_{0.21}S_{12.86})_{13.07}$	0.00	1.0
	$(Cu^{+}_{11.85}Ag_{0.13})_{11.98}(Fe_{0.02}Zn_{0.01})_{0.03}(Sb_{1.07}As_{1.02}Te^{4+}_{1.94})_{4.03}S_{12.96} + Te_{nat.}$	0.21	0.6
27	$(Cu^{+}_{11.55}Ag_{0.03})_{11.58}Fe_{0.24}(Sb_{1.07}As_{0.56}Te^{4+}_{2.45})_{4.08}S_{13.10}$	0.00	2.0
28	$(Cu^{+}_{11.58}Ag_{0.09})_{11.67}(Fe_{0.05}Sn_{0.01})_{0.06}(Sb_{0.92}As_{0.63}Te^{4+}_{2.45})_{4.00}(S_{12.93}Te^{2-}_{0.34})_{13.27}$	0.00	1.1
	$(Cu^{+}_{11.72}Ag_{0.09})_{11.81}(Fe_{0.05}Sn_{0.01})_{0.06}(Sb_{0.94}As_{0.64}Te^{4+}_{2.48})_{4.06}S_{13.08} + Te_{nat.}$	0.34	1.6
29	$(Cu^{+}_{11.48}Ag_{0.16})_{11.64}(Fe_{0.12}Zn_{0.02})_{0.14}(Sb_{1.00}As_{0.29}Te^{4+}_{2.71})_{4.00}(S_{12.98}Te^{2-}_{0.24})_{13.22}$	0.00	0.7
	$(Cu^{+}_{11.58}Ag_{0.16})_{11.74}(Fe_{0.12}Zn_{0.02})_{0.14}(Sb_{1.00}As_{0.29}Te^{4+}_{2.74})_{4.03}S_{13.09} + Te_{nat.}$	0.24	2.5
30	$(Cu^{+}_{11.87}Ag_{0.11})_{11.98}Fe_{0.09}(Sb_{0.73}As_{0.59}Te^{4+}_{2.60})_{3.92}(S_{12.87}Te^{2-}_{0.13})_{13.00} + Te_{nat.}$	0.33	2.0
31	$(Cu^{+}_{11.45}Ag_{0.14})_{11.59}Fe_{0.08}(Sb_{0.85}As_{0.51}Te^{4+}_{2.64})_{4.00}(S_{12.92}Te^{2-}_{0.40})_{13.32}$	0.00	0.9
	$(Cu^{+}_{11.61}Ag_{0.14})_{11.75}Fe_{0.09}(Sb_{0.86}As_{0.51}Te^{4+}_{2.69})_{4.06}S_{13.09} + Te_{nat.}$	0.40	2.3
32	$(Cu^{+}_{11.63}Ag_{0.23})_{11.86}Fe_{0.13}(Sb_{0.74}As_{0.49}Te^{4+}_{2.77})_{4.00}(S_{12.64}Te^{2-}_{0.37})_{13.01}$	0.00	3.2

Note. Here and further in the tables Te_{nat} apfu corresponds with amount of Te atoms per formula unit excluded from the analysis, after this operation analysis is recalculated. Result of recalculation is presented in the column "Formula". Δ, % — corresponds with balance of valences.

(b) the amount of Te^{2-} was equal to the number of atoms lacking for 13 in the anion position; (2) deduction of tellurium exceeding 4 atoms per formula in the ΠMe position, assuming it to be an admixture of native tellurium (analysis 30). Formulae for analyses 24, 26, 28, 29 and 31 are electroneutral under both conditions.

Analyses of Te-bearing fahlores from different deposits are presented in Table 3. Besides the usual elements in fahlores, there are some analyses containing Au, Bi and Pb. According to the data of Mozgova and Tsepin (1983), Pb may enter the position of the semimetals. Analyses 1, 3, 6, 7, 9 and 14 calculate to the fahlore formula. Formulae for analyses 5, 8, 10 and 11 are electroneutral assuming some tellurium enters the sulfur position. Two analyses became electroneutral where native tellurium in amounts exceeding 4 atoms per formula was excluded. Analyses 12, 13 and 15 contain much Ag that is not characteristic for goldfieldite. The formulae became electroneutral if all Ag is assumed to be present as kervelleite, Ag_4TeS. This mineral is poorly diagnosed in thin section and resembles fahlore in reflected light (bluish-white with greenish shade, isotropic). This mineral was discovered in 1990 as very thin (about 30 micron) rims around acanthite in hessite, and it is difficult to distinguish from these minerals in polished section. Of course, one cannot say unambiguously that all Ag in Te-bearing fahlores occurs as admixed kervelleite, but there are some grounds for this possibility: (1) analyses 12, 13 and 15 containing more than 10 wt.% of tellurium also contain much copper and silver, much Me^{2+} and less sulfur; (2) the difficulty in identifying kervelleite because of its optical similarity with fahlore. These facts suggest that analyses 12, 13 and 15 were obtained from material with inclusions of some additional mineral, possibly kervelleite.

Analyses of Te-bearing fahlores (Table 4) from the Kayragach deposit (analyses 1—7, Spiridonov and Badalov, 1983) and Oziornoye (analyses 8—11, Spiridonov and Okrugin, 1985) contain Bi, Sn and Se in addition to the regularly occurring elements. If they are recalculated, as proposed by Spiridonov (1987), to

Table 3. **Recalculation of analyses of fahlores given by N.N. Mozgova and A.I. Tsepin (1983) and V.A. Kovalenker *et al.* (1980) to formulae and calculation of their valence balance**

№	Cu	Fe	Zn	Sn	Ag	Sb	As	Te	S	∑	Author, Deposit
1	47.60	–	–	–	–	1.30	8.10	17.00	26.00	100.00	Springer, Butte
2	46.54	0.04	0.76	–	0.30	5.08	7.09	15.59	25.13	100.53	Mozgova *et al.*, 1983 Kunashir
3^{*}	45.39	0.20	0.20		0.02	9.44	3.25	15.48	25.52	100.30	Kovalenker, Kochbulak, 1980
4^{2*}	43.15	1.06	0.24	–	0.03	11.66	2.27	15.47	24.39	100.32	Kovalenker, Kochbulak, 1980
5	46.41	0.13	0.58	–	0.56	6.71	5.38	15.45	24.62	99.84	Mozgova *et al.*, 1983 Kunashir
6	47.1	0.3	–	–	–	9.90	3.0	15.2	25.9	101.4	Frenzel *et al.*, 1975
7^{3*}	44.85	1.18	0.22	0.04	0.52	13.46	1.67	14.77	25.57	102.14	Kovalenker, Kochbulak, 1980
8^{4*}	42.55	1.08	0.64	0.04	–	11.98	3.10	14.71	24.91	100.70	Kovalenker, Kochbulak, 1980
9^{5*}	43.94	0.45	0.37	0.04	–	11.35	2.43	14.71	24.90	98.91	Kovalenker, Kochbulak, 1980
10^{6*}	42.53	2.60	0.78	0.03	0.05	10.22	3.59	14.62	24.90	101.57	Kovalenker, Kochbulak, 1980
11	46.06	0.04	1.02	–	0.09	7.80	5.41	14.04	24.86	99.32	Mozgova *et al.*, 1983 Kunashir
12^{7*}	36.59	4.68	1.14	–	7.76	11.40	2.71	13.48	23.32	101.26	Kovalenker, Kochbulak, 1980
13^{8*}	34.91	6.63	1.09	0.27	8.14	9.73	3.35	13.03	22.90	100.63	Kovalenker, Kochbulak, 1980
14	44.17	0.98	1.00	–	0.48	17.00	–	12.10	25.06	100.86	Kovalenker, Kochbulak, 1980
15^{9*}	30.05	7.24	1.64	0.11	12.92	11.70	2.46	11.17	20.08	98.96	Kovalenker, Kochbulak, 1980

№	Formula	$Te_{nat.}$apfu	Δ,%
1	$Cu^{+}_{11.99}(Sb_{0.17}As_{1.73}Te^{4+}_{2.13})_{4.03}S_{12.98}$	0.00	0.9
2	$(Cu^{+}_{11.87}Ag_{0.04})_{11.93}(Fe_{0.01}Zn_{0.19})_{0.20}(Sb_{0.68}As_{1.53}Te^{4+}_{1.98})_{4.19}S_{12.70}$	0.00	4.4
	$(Cu^{+}_{11.95}Ag_{0.04})_{11.99}(Fe_{0.01}Zn_{0.19})_{0.20}(Sb_{0.68}As_{1.54}Te^{4+}_{1.79})_{4.01}S_{12.79} + Te_{nat.}$	0.20	2.4
3	$Cu^{+}_{11.75}(Fe_{0.06}Zn_{0.05})_{0.11}(Sb_{1.28}As_{0.71}Bi_{0.06}Te^{4+}_{2.00})_{4.05}S_{13.09}$	0.00	0.2
4	$(Cu^{+}_{11.45}Au_{0.09})_{11.54}(Fe_{0.32}Zn_{0.06})_{0.38}(Pb_{0.02}Sb_{1.61}As_{0.51}Bi_{0.06}Te^{4+}_{2.04})_{4.22}S_{12.82}$	0.00	5.2
	$(Cu^{+}_{11.54}Au_{0.09})_{11.63}(Fe_{0.32}Zn_{0.06})_{0.38}(Pb_{0.02}Sb_{1.63}As_{0.51}Bi_{0.06}Te^{4+}_{1.84})_{4.06}S_{12.92} + Te_{nat.}$	0.22	2.2
5	$(Cu^{+}_{12.02}Ag_{0.08})_{12.10}(Fe_{0.04}Zn_{0.14})_{0.18}(Sb_{0.91}As_{1.18}Te^{4+}_{1.99})_{4.08}S_{12.63}$	0.00	5.4
	$(Cu^{+}_{12.02}Ag_{0.08})_{12.10}(Fe_{0.04}Zn_{0.14})_{0.18}(Sb_{0.91}As_{1.18}Te^{4+}_{1.81})_{3.90}(S_{12.63}Te^{2-}_{0.18})_{12.81}$	0.00	1.3
6	$Cu^{+}_{11.98}Fe_{0.09}(Sb_{1.31}As_{0.65}Te^{4+}_{1.92})_{3.88}S_{13.05}$	0.00	1.4
7	$(Cu^{+}_{11.48}Ag_{0.08}Au_{0.01})_{11.57}(Fe_{0.34}Zn_{0.05}Sn_{0.01})_{0.40}(Sb_{1.80}As_{0.36}Te^{4+}_{1.88})_{4.04}S_{12.98}$	0.00	1.6
8	$(Cu^{+}_{11.16}Au_{0.14})_{11.30}(Fe_{0.32}Zn_{0.16}Sn_{0.01})_{0.49}(Sb_{1.64}As_{0.69}Te^{4+}_{1.92})_{4.25}S_{12.95}$	0.00	3.9
	$(Cu^{+}_{11.16}Au_{0.14})_{11.30}(Fe_{0.32}Zn_{0.16}Sn_{0.01})_{0.49}(Sb_{1.64}As_{0.69}Te^{4+}_{1.87})_{4.20}(S_{12.95}Te^{2-}_{0.05})_{13.00}$	0.00	2.2
9	$(Cu^{+}_{11.67}Au_{0.06})_{11.73}(Fe_{0.14}Zn_{0.10}Sn_{0.01})_{0.25}(Sb_{1.56}As_{0.54}Te^{4+}_{1.94})_{4.04}S_{13.04}$	0.00	0.8
10	$(Cu^{+}_{11.01}Ag_{0.01}Au_{0.19})_{11.21}(Fe_{0.76}Zn_{0.20})_{0.96}(Sb_{1.38}As_{0.79}Te^{4+}_{1.88})_{4.05}S_{12.77}$	0.00	6.0
	$(Cu^{+}_{11.01}Ag_{0.01}Au_{0.19})_{11.21}(Fe_{0.76}Zn_{0.20})_{0.96}(Sb_{1.38}As_{0.79}Te^{4+}_{1.65})_{3.82}(S_{12.77}Te^{2-}_{0.23})_{13.0}$	0.00	0.9
11	$(Cu^{+}_{11.92}Ag_{0.01})_{11.93}(Fe_{0.01}Zn_{0.26})_{0.27}(Sb_{1.05}As_{1.19}Te^{4+}_{1.81})_{4.05}S_{12.75}$	0.00	3.5
	$(Cu^{+}_{11.92}Ag_{0.01})_{11.93}(Fe_{0.01}Zn_{0.26})_{0.27}(Sb_{1.05}As_{1.19}Te^{4+}_{1.76})_{4.00}(S_{12.75}Te^{2-}_{0.05})_{12.80}$	0.00	2.4
12	$(Cu^{+}_{9.75}Ag_{1.22}Au_{0.01})_{10.98}(Fe_{1.42}Zn_{0.30})_{1.72}(Sb_{1.58}As_{061}Te^{4+}_{1.79})_{3.98}S_{12.32}$	0.00	12.5
	$(Cu^{+}_{10.40}Au_{0.01})_{10.41}(Fe_{1.51}Zn_{0.32})_{1.83}(Sb_{1.69}As_{0.66}Te^{4+}_{1.49})_{3.74}(S_{12.81}Te^{2-}_{0.19})_{13.00}$ + 10.57 mas.% Ag_4TeS	0.00	2.9
13	$(Cu^{+}_{9.34}Ag_{1.28}Au_{0.05})_{10.67}(Fe_{2.02}Zn_{0.28}Sn_{0.04})_{2.34}(Sb_{1.36}As_{0.76}Te^{4+}_{1.74})_{3.86}S_{12.14}$	0.00	15.3
	$Cu^{+}_{10.00}(Fe_{2.16}Zn_{0.30})_{2.46}(Sb_{1.45}As_{0.81}Te^{4+}_{1.17})_{3.43}(S_{12.66}Te^{2-}_{0.34})_{13.00}$ + 11.15 mas.% Ag_4TeS	0.00	1.4
14	$(Cu^{+}_{11.53}Ag_{0.07})_{11.60}(Fe_{0.29}Zn_{0.25})_{0.54}(Sb_{2.32}Te^{4+}_{1.57})_{3.89}S_{12.96}$	0.00	0.0
15	$(Cu^{+}_{8.58}Ag_{2.17}Au_{0.07})_{10.82}(Fe_{2.35}Zn_{0.45}Sn_{0.02})_{2.82}(Sb_{1.74}As_{0.60}Bi_{0.08}Te^{4+}_{1.59})_{4.01}S_{11.35}$	0.00	24.5
	$(Cu^{+}_{9.68}Au_{0.07})_{9.75}(Fe_{2.65}Zn_{0.51}Sn_{0.02})_{3.18}(Sb_{1.97}As_{0.67}Bi_{0.08}Te^{4+}_{0.34})_{3.06}(S_{12.16}Te^{2-}_{0.84})_{13.0}$ + 17.32 mas.% Ag_4TeS	0.00	1.4

Note. Including in: *) Bi 0.80; ^{2*}) Bi 0.81, Au 1.03, Pb 0.21; ^{3*}) Au 0.12; ^{4*}) Au 1.69; ^{5*}) Au 0.72; ^{6*}) Au 2.26; ^{7*}) Au 0.15; ^{8*}) Au 0.58; ^{9*}) Au 0.72, Bi 0.87 the formula $(Cu,Ag)_{10.00}(Cu^{2+},Fe,Zn)_{2.00}(Sb,As,Te^{4+},Bi,Sn)_{4.00}S_{13.00}$, only two analyses (analyses 1 and 7) have electroneutral formulae. Valence balance of the analyses exceeds 3%. Eight analyses (analyses 3 – 6, 8 – 11) have electroneutral formulae if all copper is assumed to be monovalent. The formula for analysis 2 is non-electroneutral; it is deficient in sulfur. According to Spiridonov and Badalov (1983), high arsenious and high bismuth tellurium ores of the Kayragach deposit formed at "specific conditions from hydrothermal solutions rich in tellurium and bismuth with very high activity of sulfur and simultaneously with elevated oxidizing potential".

Recalculation of fahlore analyses from deposits of the volcanic belt of Central Kamchatka (Sakharova *et al*., 1983) and calculation of valence balance shows that only four analyses (analyses 1, 4, 5, 6) have electroneutral formulae. The formula for analysis 2 became electroneutral by exclusion of 0.14 atoms per formula of native tellurium (i.e., 1.06 wt.%). The formula for analysis 3 is non-electroneutral because of an excess of cations. It becomes electroneutral after the deduction of 0.05 atoms per formula of native tellurium and recalculation of the analysis assigning Te^{2-} to the sulfur position. Goldfieldite in this deposit occurs in quartz veins as small xenomorphic aggregates in association with chalcopyrite, pyrite and native tellurium. Native tellurium forms xenomorphic tear-shaped and veinlet aggregates in chalcopyrite and goldfieldite. The presence of goldfieldite

Table 4. **Recalculation of analyses of fahlores from the Kayragach deposit (analyses 1—7, Spiridonov *et al.*, 1983) and Oziornoye deposit (analyses 8—11, Spiridonov *et al.*, 1985) to formulae and calculation of their valence balance**

№	Cu	Fe	Zn	Sn	Ag	Sb	As	Te	Bi	Ge	S	∑
1	43.86	4.77	0.62	0.04	0.16	14.14	6.91	2.58	1.58	0.13	27.00	101.79
2	40.73	5.01	0.57	0.07	0.17	14.76	6.85	2.73	1.61	0.06	24.95	97.51
3	42.84	3.73	0.71	0.11	1.12	14.63	4.89	5.02	1.74	0.14	25.21	100.24
4	42.13	3.77	0.72	0.15	1.32	13.94	5.33	5.39	3.96	0.14	25.64	102.69
5	41.25	3.82	0.67	0.12	1.27	14.47	5.74	5.59	3.18	0.15	25.76	102.02
6	41.94	3.86	0.50	0.15	2.11	12.88	4.50	6.38	5.78	0.17	25.24	102.50
7	42.18	2.04	0.49	0.16	1.90	12.39	4.12	7.27	5.24	0.18	25.51	101.48
8	44.6	–	–	–	0.1	2.7	6.2	16.2	0.2		20.7	101.0
9	43.6	0.1	0.8	–	0.2	2.9	6.1	16.0	1.2	12.2	20.0	103.1
10	44.4	–	–	–	0.1	3.5	6.0	15.9	0.1	11.5	19.5	101.1
11	44.1	0.1	–	–	–	2.7	7.5	14.7	0.3	9.9	20.1	99.4

№	Formula	Δ, %
1	$(Cu^{+}_{9.98}Ag_{0.02})_{10.00}(Cu^{2+}_{0.74}Fe_{1.33}Zn_{0.15})_{2.22}(Sb_{1.80}As_{1.43}Bi_{0.12}Te^{4+}_{0.31}Ge_{0.03}Sn_{0.01})_{3.70}S_{13.08}$	1.0
2	$(Cu^{+}_{9.97}Ag_{0.03})_{10.00}(Cu^{2+}_{0.66}Fe_{1.49}Zn_{0.14})_{2.22}(Sb_{2.01}As_{1.52}Bi_{0.13}Te^{4+}_{0.35}Ge_{0.01}Sn_{0.01})_{4.03}S_{12.68}$	6.2
	$(Cu^{+}_{10.63}Ag_{0.03})_{10.66}(Fe_{1.49}Zn_{0.14})_{1.63}(Sb_{2.01}As_{1.52}Bi_{0.13}Te^{4+}_{0.35}Ge_{0.01}Sn_{0.01})_{4.03}S_{12.68}$	3.9
3	$(Cu^{+}_{9.83}Ag_{0.17})_{10.00}(Cu^{2+}_{1.13}Fe_{1.08}Zn_{0.18})_{2.39}(Sb_{1.95}As_{1.06}Bi_{0.14}Te^{4+}_{0.64}Ge_{0.03}Sn_{0.01})_{3.83}S_{12.78}$	5.2
	$(Cu^{+}_{10.96}Ag_{0.17})_{11.13}(Fe_{1.08}Zn_{0.18})_{1.26}(Sb_{1.95}As_{1.06}Bi_{0.14}Te^{4+}_{0.64}Ge_{0.03}Sn_{0.01})_{3.83}S_{12.78}$	1.0
4	$(Cu^{+}_{9.80}Ag_{0.20})_{10.00}(Cu^{2+}_{0.84}Fe_{1.08}Zn_{0.18})_{2.10}(Sb_{1.84}As_{1.18}Bi_{0.30}Te^{4+}_{0.68}Ge_{0.03}Sn_{0.02})_{4.05}S_{12.84}$	5.2
	$(Cu^{+}_{10.64}Ag_{0.20})_{10.84}(Fe_{1.08}Zn_{0.18})_{1.26}(Sb_{1.84}As_{1.18}Bi_{0.30}Te^{4+}_{0.68}Ge_{0.03}Sn_{0.02})_{4.05}S_{12.84}$	2.1
5	$(Cu^{+}_{9.81}Ag_{0.19})_{10.00}(Cu^{2+}_{0.65}Fe_{1.10}Zn_{0.16})_{1.91}(Sb_{1.91}As_{1.23}Bi_{0.24}Te^{4+}_{0.70}Ge_{0.03}Sn_{0.02})_{4.13}S_{12.94}$	4.0
	$(Cu^{+}_{10.46}Ag_{0.19})_{10.65}(Fe_{1.10}Zn_{0.16})_{1.26}(Sb_{1.91}As_{1.23}Bi_{0.24}Te^{4+}_{0.70}Ge_{0.03}Sn_{0.02})_{4.13}S_{12.94}$	1.6
6	$(Cu^{+}_{9.68}Ag_{0.32})_{10.00}(Cu^{2+}_{1.12}Fe_{0.84}Zn_{0.12})_{2.08}(Sb_{1.73}As_{0.98}Bi_{0.45}Te^{4+}_{0.82}Ge_{0.04}Sn_{0.02})_{4.04}S_{12.88}$	5.2
	$(Cu^{+}_{10.80}Ag_{0.32})_{11.12}(Fe_{0.84}Zn_{0.12})_{0.96}(Sb_{1.73}As_{0.98}Bi_{0.45}Te^{4+}_{0.82}Ge_{0.04}Sn_{0.02})_{4.04}S_{12.88}$	1.1
7	$(Cu^{+}_{9.71}Ag_{0.29})_{10.00}(Cu^{2+}_{1.20}Fe_{0.60}Zn_{0.12})_{1.82}(Sb_{1.67}As_{0.90}Bi_{0.41}Te^{4+}_{0.94}Ge_{0.04}Sn_{0.02})_{3.98}S_{13.08}$	2.2
8	$(Cu^{+}_{11.89}Ag_{0.02})_{11.91}(Sb_{0.38}As_{1.40}Bi_{0.02}Te^{4+}_{2.15})_{3.95}(S_{10.94}Se_{2.20})_{13.14}$	1.4
9	$(Cu^{+}_{11.59}Ag_{0.03})_{11.62}(Fe_{0.03}Zn_{0.21})_{1.26}(Sb_{0.40}As_{1.38}Bi_{0.10}Te^{4+}_{2.12})_{4.00}(S_{10.53}Se_{2.61})_{13.14}$	0.7
10	$(Cu^{+}_{12.00}Ag_{0.02}Au_{0.01})_{12.03}(Sb_{0.50}As_{1.38}Bi_{0.01}Te^{4+}_{2.13})_{4.02}(S_{10.45}Se_{2.50})_{12.95}$	1.2
11	$Cu^{+}_{11.93}Fe_{0.03}(Sb_{0.38}As_{1.72}Bi_{0.02}Te^{4+}_{1.98})_{4.02}(S_{10.79}Se_{2.15})_{12.94}$	1.6

Note. Analyses 1, 2 from the central part of the grain, analyses 3—5 from the outer part of the grain, analyses 6,7 from the most outer part of the grain. Including in analysis 3: Mn 0.02, Cd 0.03, Co 0.03, V 0.02 wt.%, in analysis 8 – 10.3 wt.% Se, in analysis 9 – 12.2 wt.% Se, in analysis 10 – 11.5 wt.% Se, in analysis 11 – 9.9 wt.% Se, in analysis 10 Au 0.1 wt.%, in analyses 8–11 Hg, Cd, Pb, Sn, Ge are not discovered in the gold-bearing quartz-sulfide-telluride veins of the volcanogenic belt of Central Kamchatka and the similarity of mineral associations with those from the deposits of Eastern Uzbekistan and Goldfield (Nevada, USA) is evidence that goldfieldite is a typomorphic mineral of gold-telluride deposits in volcanogenic regions. Results of investigation of fahlores from one of the deposits of the eastern part of Russia (Borisova *et al.*, 1986) also proves this conclusion. These authors discovered Te-bearing fahlores that proved to be goldfieldite – tennantites and goldfieldite – tetrahedrites. Their analyses (Table 5, analyses 7 – 10) are recalculated to a formula with 29 atoms.

Results of investigations of Kovalenker *et al.* (1986) of Te-bearing fahlores from the deposits of the Central Bulgarian Middle Mountains (Table 6, deposits Chelopech and Elshitsa) are interesting. These deposits belong to the same type as described above. Analyses 1 and 2 from the Chelopech deposit and analyses 21 and 22 from the Elshitsa deposit (assumed to be fahlores by V.A. Kovelenker) recalculate to electroneutral formula containing 33 atoms in the unit cell. Only analyses 3 – 5 and 19, 20 recalculate to electroneutral formula with 29 atoms in the unit cell. Analyses of fahlores from the Elshitsa deposit containing high concentrations of tellurium (analyses 6 – 18) are special. Seven analyses (analyses 6 – 11, 14) recalculate to 29 atoms in the formula only if we exclude native tellurium in amounts exceeding 4 atoms in the formula. Supposition that the samples contain very fine-grained inclusions of native tellurium is based on the note of Kovalenker *et al.* (1986) that tennantite in this deposit replaces goldfieldite, with the occurrence of native tellurium. Spiridonov (1987) comes to the same conclusion based on investigation of fahlores from several volcanogenic deposits of Kazakhstan. He noted that goldfieldite was replaced by tetrahedrite, native tellurium and chalcopyrite. Formulae for six analyses (analyses 12, 13, 15 – 18) become electroneutral after exclusion of native tellurium, and under the condition that all copper is monovalent. As seen from

Table 5. **Recalculation of analyses of fahlores from the volcanic belt of Central Kamchatka (analyses 1—6, Sakharova *et al.*, 1983) and one deposit of the Russian Far East (analyses 7—10, Borisova *et al.*, 1986) to formulae and calculation of their valence balance**

№	Cu	Ag	Fe	Au	Sb	As	Bi	Te	S	Se	Σ
1	43.0	0.1	0.7	0.3	6.5	0.2	7.0	15.2	23.3	1.9	98.2
2	45.3	–	0.1	0.2	6.6	4.4	1.5	16.1	24.5	–	98.7
3	42.9	0.9	2.0	0.9	7.7	2.9	0.8	17.4	24.5	–	100.00
4	45.0	2.3	0.3	0.2	6.8	0.9	0.8	17.6	25.0	–	98.9
5	46.5	–	0.1	0.4	5.4	4.1	0.9	18.2	26.1	–	101.7
6	44.4	0.4	0.1	0.4	5.3	2.3	0.5	20.2	25.3	–	98.9
7	45.8	–	–	Zn	3.8	6.7	1.2	18.0	26.2		101.2
8	44.0	3.0	0.5	0.2	5.6	1.3	0.5	16.6	26.2	0.3	97.3
9	46.4	1.0	0.2	0.5	6.0	3.5	0.3	15.6	25.7	0.3	99.5
10	45.6	1.4	0.1	0.2	6.3	1.3	0.1	17.6	25.5	0.1	98.3

№	Formula	$Te_{nat.}$ apfu	Δ, %
1	$(Cu^{+}_{11.91}Ag_{0.01})_{11.92}(Fe_{0.20}Au_{0.03})_{0.23}(Sb_{0.94}As_{0.05}Te^{4+}_{2.10}Bi_{0.59})_{3.68}(S_{12.73}Se_{0.42})_{13.15}$	0.00	2.8
2	$Cu^{+}_{11.98}(Fe_{0.03}Au_{0.02})_{0.05}(Sb_{0.91}As_{0.99}Te^{4+}_{2.12}Bi_{0.12})_{4.14}S_{12.83}$	0.00	3.6
	$Cu^{+}_{12.03}(Fe_{0.03}Au_{0.02})_{0.05}(Sb_{0.92}As_{0.99}Te^{4+}_{1.99}Bi_{0.12})_{4.02}S_{12.90} + Te_{nat.}$	0.14	1.4
3	$(Cu^{+}_{11.32}Ag_{0.14})_{11.46}(Fe_{0.60}Au_{0.08})_{0.68}(Sb_{1.06}As_{0.65}Te^{4+}_{2.28}Bi_{0.06})_{4.05}S_{12.81}$	0.00	6.0
	$(Cu^{+}_{11.34}Ag_{0.14})_{11.48}(Fe_{0.60}Au_{0.08})_{0.68}(Sb_{1.06}As_{0.65}Te^{4+}_{2.23}Bi_{0.06})_{4.00}S_{12.81} + Te_{nat.}$	0.05	5.3
	$(Cu^{+}_{11.34}Ag_{0.14})_{11.48}(Fe_{0.60}Au_{0.08})_{0.68}(Sb_{1.06}As_{0.65}Te^{4+}_{2.06}Bi_{0.06})_{3.83}(S_{12.83}Te^{2-}_{0.17})_{13.0} + Te_{nat.}$	0.05	1.5
4	$(Cu^{+}_{11.64}Ag_{0.14})_{12.00}(Cu^{2+}_{0.26}Fe_{0.09}Au_{0.02})_{0.37}(Sb_{0.94}As_{0.20}Te^{4+}_{2.32}Bi_{0.06})_{3.52}S_{13.11}$	0.00	1.3
5	$(Cu^{+}_{11.82}Ag_{0.03})_{11.85}(Fe_{0.03}Au_{0.03})_{0.06}(Sb_{0.72}As_{0.88}Te^{4+}_{2.30}Bi_{0.07})_{3.97}S_{13.15}$	0.00	0.4
6	$(Cu^{+}_{11.69}Ag_{0.06})_{11.75}(Fe_{0.09}Au_{0.03})_{0.12}(Sb_{0.73}As_{0.51}Te^{4+}_{2.65}Bi_{0.04})_{3.93}S_{13.20}$	0.00	0.1
7	$Cu^{+}_{11.57}(Sb_{0.50}As_{1.44}Te^{4+}_{2.27}Bi_{0.09})_{4.30}S_{13.13}$	0.00	1.8
8	$(Cu^{+}_{9.54}Ag_{0.46})_{10.00}(Cu^{2+}_{2.15}Fe_{0.17}Zn_{0.06})_{2.38}(Sb_{0.78}As_{0.29}Te^{4+}_{2.20}Bi_{0.03})_{3.30}(S_{13.25}Se_{0.06})_{13.31}$	0.00	0.8
9	$(Cu^{+}_{10.10}Ag_{0.15})_{10.25}(Cu^{2+}_{1.82}Fe_{0.06}Zn_{0.12})_{2.00}(Sb_{0.81}As_{0.76}Te^{4+}_{2.00}Bi_{0.03})_{3.60}(S_{13.08}Se_{0.06})_{13.14}$	0.00	2.8
10	$(Cu^{+}_{10.10}Ag_{0.20})_{10.30}(Cu^{2+}_{1.85}Zn_{0.07}Fe_{0.03}Cd_{0.03})_{2.00}(Sb_{0.87}As_{0.29}Te^{4+}_{2.29}Bi_{0.03})_{3.45}(S_{13.25}Se_{0.03})_{13.28}$	0.00	1.4

Note. In analysis 10 – Au 0.1 wt. %, Cd 0.1 wt. %

Table 6, formulae for four analyses (analyses 12, 13, 15 and 16) recalculated after deduction of native tellurium have better balance of valences. Supposition that all copper in the analyses (analyses 12, 13, 15–18) is monovalent is based on the note of Novgorodova *et al.* (1978) that in Te-bearing fahlores, compensation of surplus charge during replacement (As, Sb)$^{3+} \rightarrow$ Te^{4+} occurs by means of vacancy formation. Mozgova and Tsepin (1983) consider that surplus charge compensation is most likely due to "depolarization at the expense of reduction of copper to Cu$^+$ that limits entering of two-valent metals in it". Due to the fact that formulae for the quoted analyses are electroneutral under both conditions, we can conclude that under high content of tellurium (about 10–24 wt.%), all copper in fahlore will be monovalent. Fahlores containing more than 24 wt.% of tellurium may be recalculated to the same formula provided native tellurium is excluded from the analyses. So, not more than 24 wt.% of tellurium can isomorphically enter fahlores. Formulae for the other two analyses (analyses 21 and 22) become electroneutral only if they are recalculated to 33 atoms in the unit cell. Thus, from 22 analyses of Te-bearing fahlores from the Chelopech and Elshitse deposits, 18 analyses (Table 6, analyses 3–20) recalculate to a formula with 29 atoms in the unit cell, and 4 analyses (Table 6, analyses 1,2,21, and 22) recalculate to a formula with 32 and 33 atoms in the unit cell. The idealized formulae are as follows: $\mathrm{Cu^{+}_{11}Me^{2+}_{1.00}Me^{3+}_{1.00}\Pi Me_{4.00}S_{15}}$ and $\mathrm{Cu^{+}_{10}Me^{2+}_{3.00}\Pi Me_{4.00}S_{16}}$.

In Te-bearing fahlores, zoned crystals occur, indicating changing physicochemical conditions (concentrations of solved components, temperature, pressure, redox potential) during growth. Zones are easily visible in reflected light. As a rule, cores of tetrahedrite composition are greenish and the outer rose-colored zone of goldfieldite composition sometimes has fine zonal structure. Pale-rosy fine zones give way to rose-colored zones and vice versa. It is likely that the intensity of the rosy shade in fahlores is caused by an increase in tellurium. Such zoned crystals were investigated by Spiridonov (1987). Recalculation of 13 analyses from this work (Table 7) show that the formulae for nine analyses (analyses 1–7, 11, 13) from different zones of a fahlore crystal from volcanogenic gold-quartz deposit of the Russian Far East are electroneutral. Formulae for two analyses (analyses 6 and 10) are electroneutral if part of the Te^{2-} is placed into the sulfur position. The formula for one analysis (analysis 8) is non-electroneutral. The sum of analysis 12 greatly exceeds 100% (104.36%), and its formula is non-electroneutral (balance of valences is equal to 3.3%). If all Ag is assumed to be kervelleite, the sum of the analysis and balance of valences becomes much better (98.34% and 0.4%, respectively). According to Spiridonov (1987), fahlores with high contents of Te and Ag represent later generations. Kervelleite also occurs at the later stage of ore mineralization.

Comparison of non-electroneutral formulae obtained during recalculation to the conventional formula for fahlores, $\mathrm{Cu^{+}_{10}Me^{2+}_{2}\,\Pi Me_{4}S_{13}}$, and also recalculated to electroneutral formulae (Table 2, analyses 11, 18, 19, 21, and 32; Table 4, analysis 2; Table 5, analysis 3; Table 6, analyses 1, 2, 21, and 22; Table 7, analysis 8) shows that five formulae (of twelve) become electroneutral during recalculation with probable Te^{2-} at the sulfur position (Table 2, analysis 11) and recalculation to 33 atoms in the unit cell (Table 6, analyses 1,2, 21, and 22). One formula for an analysis from the deposit of the volcanic belt of Central Kamchatka (Table 5, analysis 3) becomes electroneutral after excluding 0.05 of atoms per formula of native tellurium and recalculation with Te^{2-} at the sulfur position added to give 13 atoms. Three formulae of analyses (Table 2, analyses 21, 32 and Table 4, analysis 2) have balance of valences 3.1, 3.2 and 3.2 accordingly. They are almost electroneutral. Three formulae, corresponding to two analyses from Koch-Bulak (Table 2, analyses 18 and 19) and one analysis from the volcanogenic gold–quartz deposit of the Russian Far East (Table 7, analysis 8), remain non-electroneutral.

The reader may be surprised by this recalculation of analyses, but all recalculations accord with the isomorphism in fahlores and the complicated, often changing, conditions of crystallization that lead to the formation of zoned crystals.

Conclusions

1. Te-bearing fahlores are very similar to fahlores of different chemical composition and physical features. They have a rosy shade in reflected light, and resemble complex sulfide of germanium (germanite). In volcanogenic and hydrothermal quartz-sulfide vein deposits of gold-sulfide formations (Koch-Bulak, Chelopech, and Elshitsa), isotropic minerals were discovered similar in color to germanite, but their analyses did not contain of germanium. They have non-electroneutral formulae by recalculation to 29 atoms in the unit cell (i.e.,

Table 6. **Recalculation of analyses of fahlores from the deposit Chelopech (analyses 1—5) and Elshitsa (analyses 6—22) given by V.A. Kovalenker *et al.* (1986) to formulae and calculation of their valence balance**

№	Cu	Fe	Zn	Sb	As	Te	Bi	Se	S	∑
1	39.64	4.06	n.d.	2.01	2.48	26.16	0.34	n.d.	24.79	99.48
2	40.30	3.87	n.d.	1.45	4.29	24.38	0.21	n.d.	24.90	99.40
3	43.19	0.41	n.d.	7.50	2.73	17.64	n.d.	1.89	24.91	99.27
4	45.34	0.51	0.45	2.26	6.42	17.64	0.69	0.19	25.82	99.32
5	43.67	1.35	5.59	1.95	17.38	1.81	n.d.	n.d.	27.49	99.24
6	42.48	0.27	n.d.	0.23	4.05	26.44	2.62	n.d.	25.68	101.77
7	44.95	0.16	n.d.	0.27	4.32	25.85	0.47	n.d.	25.43	101.45
8	43.38	0.39	n.d.	0.23	5.30	25.74	0.10	n.d.	25.55	100.69
9	43.62	0.42	n.d.	0.31	5.33	25.64	0.31	n.d.	25.69	100.32
10	42.71	0.64	n.d.	0.15	4.75	24.52	3.38	n.d.	25.25	101.40
11	42.49	0.55	n.d.	0.38	5.66	24.38	1.38	n.d.	25.51	100.35
12	44.72	0.15	n.d.	0.20	5.23	23.97	0.17	n.d.	26.43	100.87
13	43.35	0.20	n.d.	0.39	5.04	23.75	0.23	n.d.	26.13	99.09
14	43.07	1.03	n.d.	0.16	5.26	23.01	1.30	n.d.	25.71	99.74
15	45.15	0.63	0.04	0.20	6.39	22.31	0.14	n.d.	26.72	101.58
16	43.83	0.74	n.d.	0.16	6.44	22.07	n.d.	n.d.	26.14	99.38
17	44.83	0.13	n.d.	0.36	6.84	21.26	1.49	n.d.	26.51	101.42
18	44.47	0.26	n.d.	0.18	5.47	21.24	2.96	n.d.	26.52	101.40
19	46.56	0.20	n.d.	0.14	6.84	19.83	0.27	n.d.	26.35	100.19
20	46.33	4.76	0.25	n.d.	20.11	1.39	n.d.	n.d.	29.00	101.84
21	46.07	4.56	0.26	n.d.	20.04	0.13	n.d.	n.d.	29.26	100.32
22	46.17	4.61	0.23	n.d.	20.35	0.23	0.34	n.d.	30.34	102.27

№	Formula	$Te_{nat.}$ apfu	Δ, %
1	$Cu^{+}_{10.48}Fe^{2+}_{1.22}(Sb_{0.28}As_{0.56}Bi_{0.03}Te^{4+}_{3.44})_{4.31}S_{12.99}$	0.00	11.3
1	$Cu^{+}_{10.48}Fe^{2+}_{1.22}(Sb_{0.28}As_{0.56}Bi_{0.03}Te^{4+}_{3.13})_{4.00}(S_{12.99}Te^{2-}_{0.31})_{13.30}$	0.00	5.2
1*	$Cu^{+}_{10}(Cu^{2+}_{1.93}Fe_{1.07})_{3.00}Fe^{3+}_{0.32}(Sb_{0.32}As_{0.63}Bi_{0.03}Te^{4+}_{3.02})_{4.00}(S_{14.78}Te^{2-}_{0.9})_{15.68}$	0.00	1.9
2	$Cu^{+}_{10.56}Fe^{2+}_{1.15}(Sb_{0.20}As_{0.95}Bi_{0.02}Te^{4+}_{2.83})_{4.00}(S_{12.93}Te^{2-}_{0.35})_{13.28}$	0.00	4.1
2*	$Cu^{+}_{10}(Cu^{2+}_{2.02}Fe_{0.98})_{3.00}Fe^{3+}_{0.33}(Sb_{0.22}As_{1.08}Bi_{0.02}Te^{4+}_{2.68})_{4.00}(S_{14.72}Te^{2-}_{0.94})_{15.66}$	0.00	1.1
3	$Cu^{+}_{10}(Cu^{2+}_{1.43}Fe_{0.12})_{1.55}(Sb_{1.04}As_{0.61}Te^{4+}_{2.32})_{3.97}(S_{13.07}Se_{0.40})_{13.47}$	0.00	1.4
4	$Cu^{+}_{11.60}(Fe_{0.15}Zn_{0.11})_{0.26}(Sb_{0.30}As_{1.39}Bi_{0.05}Te^{4+}_{2.25})_{3.99}(S_{13.10}Se_{0.04})_{13.14}$	0.00	0.2
5	$Cu^{+}_{10}(Cu^{2+}_{0.40}Fe_{0.35}Zn_{1.29})_{2.05}(Sb_{0.24}As_{3.51}Te^{4+}_{0.21})_{3.96}S_{12.97}$	0.00	1.0
6	$Cu^{+}_{11.30}Fe_{0.08}(Sb_{0.03}As_{0.91}Bi_{0.21}Te^{4+}_{2.92})_{4.05}S_{13.54} + Te_{nat.}$	0.57	2.0
7	$Cu^{+}_{11.74}Fe_{0.05}(Sb_{0.04}As_{0.96}Bi_{0.04}Te^{4+}_{3.01})_{4.05}S_{13.17} + Te_{nat.}$	0.35	2.4
8	$Cu^{+}_{11.44}Fe_{0.12}(Sb_{0.03}As_{1.19}Bi_{0.01}Te^{4+}_{2.85})_{4.08}S_{13.36} + Te_{nat.}$	0.52	0.2
9	$Cu^{+}_{11.44}Fe_{0.12}(Sb_{0.06}As_{1.19}Bi_{0.02}Te^{4+}_{2.81})_{4.08}S_{13.35} + Te_{nat.}$	0.53	0.1
10	$Cu^{+}_{11.39}Fe_{0.19}(Sb_{0.02}As_{1.07}Bi_{0.27}Te^{4+}_{2.71})_{4.07}S_{13.34} + Te_{nat.}$	0.54	0.3
11	$Cu^{+}_{11.30}Fe_{0.17}(Sb_{0.05}As_{1.28}Bi_{0.11}Te^{4+}_{2.65})_{4.09}S_{13.44} + Te_{nat.}$	0.57	1.2
12	$Cu^{+}_{11.40}Fe_{0.04}(Sb_{0.03}As_{1.13}Bi_{0.01}Te^{4+}_{3.04})_{4.21}S_{13.35}$	0.00	1.6
	$Cu^{+}_{11.48}Fe_{0.04}(Sb_{0.03}As_{1.14}Bi_{0.01}Te^{4+}_{2.85})_{4.03}S_{13.44} + Te_{nat.}$	0.21	1.4
13	$Cu^{+}_{11.35}Fe_{0.06}(Sb_{0.05}As_{1.12}Bi_{0.02}Te^{4+}_{2.84})_{4.03}S_{13.56}$	0.25	2.6
	$Cu^{+}_{11.25}Fe_{0.06}(Sb_{0.05}As_{1.11}Bi_{0.02}Te^{4+}_{3.07})_{4.25}S_{13.44} + Te_{nat.}$	0.00	1.1
14	$Cu^{+}_{11.29}Fe_{0.31}(Sb_{0.02}As_{1.17}Bi_{0.10}Te^{4+}_{2.75})_{4.04}S_{13.36} + Te_{nat.}$	0.26	0.9
15	$Cu^{+}_{11.33}Fe_{0.18}Zn_{0.01}(Sb_{0.03}As_{1.36}Bi_{0.01}Te^{4+}_{2.79})_{4.19}S_{13.29}$	0.00	1.8
	$Cu^{+}_{11.41}Fe_{0.18}Zn_{0.01}(Sb_{0.03}As_{1.37}Bi_{0.01}Te^{4+}_{2.62})_{4.03}S_{13.38} + Te_{nat.}$	0.19	0.9
16	$Cu^{+}_{11.24}Fe_{0.22}(Sb_{0.02}As_{1.40}Te^{4+}_{2.82})_{4.24}S_{13.29}$	0.00	2.4
	$Cu^{+}_{11.34}Fe_{0.22}(Sb_{0.02}As_{1.41}Te^{4+}_{2.60})_{4.03}S_{13.40} + Te_{nat.}$	0.24	1.2
17	$Cu^{+}_{11.35}Fe_{0.04}(Sb_{0.05}As_{1.47}Bi_{0.11}Te^{4+}_{2.68})_{4.31}S_{13.30}$	0.00	1.6
	$Cu^{+}_{11.47}Fe_{0.04}(Sb_{0.05}As_{1.48}Bi_{0.12}Te^{4+}_{2.40})_{4.05}S_{13.44} + Te_{nat.}$	0.31	2.9
18	$Cu^{+}_{11.36}Fe_{0.08}(Sb_{0.02}As_{1.18}Bi_{0.23}Te^{4+}_{2.70})_{4.13}S_{13.42}$	0.00	0.8
	$Cu^{+}_{11.41}Fe_{0.08}(Sb_{0.02}As_{1.19}Bi_{0.23}Te^{4+}_{2.58})_{4.02}S_{13.48} + Te_{nat.}$	0.13	2.0
19	$Cu^{+}_{11.76}Fe_{0.06}(Sb_{0.02}As_{1.46}Bi_{0.02}Te^{4+}_{2.49})_{3.99}S_{13.19}$	0.00	0.15
20	$Cu^{+}_{10}(Cu^{2+}_{0.56}Fe_{1.23}Zn_{0.06})_{1.85}(As_{3.89}Te^{4+}_{0.16})_{4.05}S_{13.10}$	0.00	0.7
21	$Cu^{+}_{10}(Cu^{2+}_{0.56}Fe_{1.19}Zn_{0.06})_{1.81}(As_{3.89}Te^{4+}_{0.01})_{3.90}S_{13.29}$	0.00	4.7
21*	$Cu^{+}_{11}(Cu^{2+}_{1.01}Fe_{0.35}Zn_{0.07})_{1.43}Fe^{3+}_{1.00}(As_{4.43}Te^{4+}_{0.02})_{4.45}S_{15.12}$	0.00	0.0
22	$Cu^{+}_{10}(Cu^{2+}_{0.36}Fe_{1.18}Zn_{0.05})_{1.59}(As_{3.87}Bi_{0.02}Te^{4+}_{0.01})_{3.90}S_{13.49}$	0.00	7.4
22*	$Cu^{+}_{11}(Cu^{2+}_{0.79}Fe_{0.34}Zn_{0.05})_{1.18}Fe^{3+}_{1.00}(As_{4.41}Bi_{0.03}Te^{4+}_{0.03})_{4.47}S_{15.35}$	0.00	2.9

Note. Analyses 1 and 2*, 21*, 22* are recalculated to formula with 33 atoms in the unit cell, the remaining analyses are recalculated to 29 atoms in the unit cell.*

the formula of the fahlore). The formulae become electroneutral only during recalculation to 32 or 33 atoms in the unit cell. The formulae of complex sulfides of germanium contain the same number of atoms, suggesting that a new mineral species exists that is optically and chemically similar to fahlore with the idealized formulae $Cu^{+}_{11}Me^{2+}_{1.00}Me^{3+}_{1.00}\Pi Me_{4.00}S_{15}$ and $Cu^{+}_{10}Me^{2+}_{3.00}\Pi Me_{4.00}S_{16}$. It is possible that they are germanium-free analogues of complex sulfides of germanium (germanite and renierite).

2. Tellurium may enter the Te^{4+} position as well as the sulfur position as Te^{2-} in Te-bearing fahlore goldfieldite and high-tellurium tetrahedrite.

3. Goldfieldites containing more than 24 wt.% of tellurium are, as a rule, heterogenous and contain admixed native tellurium as

Table 7. **Recalculation of analyses of a zoned crystal of fahlore from the gold-quartz volcanogenic deposit of the Russian Far East (Spiridonov, 1987) to formulae and calculation of their valence balance**

№	Cu	Ag	Zn	Fe	Cd	As	Sb	Te	S	Se	∑
1	38.17	0.99	6.32	1.66	0.07	4.20	23.13	Traces	25.33	0.04	99.91
2	39.22	0.90	6.58	0.08	0.33	3.96	23.48	Traces	25.52	0.32	100.39
3	39.46	0.66	6.55	0.07	0.46	3.70	24.09	0.01	25.08	0.35	100.45
4	43.27	1.39	0.84	0.05	0.35	3.28	9.98	14.52	22.89	4.90	101.48
5	42.70	0.94	2.27	0.02	Traces	3.87	15.99	6.77	24.17	2.04	98.78
6	43.46	0.66	0.62	0.07	0.03	1.73	6.39	20.88	22.82	4.14	100.81
7	43.07	1.50	0.99	0.01	0.08	2.97	9.92	14.15	23.49	2.44	98.63
8	43.23	1.85	0.21	0.05	0.36	1.14	4.87	23.08	22.60	3.92	101.36
9	42.94	0.96	2.25	Traces	0.30	3.92	13.32	9.77	23.73	2.44	99.67
10	45.19	0.73	0.65	0.05	0.09	1.28	6.20	21.23	22.70	4.70	102.22
11	42.57	0.92	2.18	0.02	0.05	2.43	12.18	13.35	22.64	4.54	100.90
12	43.32	4.37	0.18	0.15	Traces	2.59	3.15	22.63	23.27	4.66	104.36
12*	43.32	0.00	0.18	0.15	Traces	2.59	3.15	21.34	22.95	4.66	98.34
13	40.79	2.72	2.60	0.39	Traces	2.61	11.63	13.37	23.52	2.54	100.17

№	Formula	Δ, %
1	$(Cu^{+}_{9.82}Ag_{0.15})_{9.97}(Zn_{1.58}Fe_{0.49}Cd_{0.01})_{2.08}(Sb_{3.11}As_{0.92})_{4.03}(S_{12.92}Se_{0.01})_{12.93}$	1.4
2	$(Cu^{+}_{9.79}Ag_{0.14})_{9.93}(Cu^{2+}_{0.29}Fe_{0.02}Zn_{1.64}Cd_{0.05})_{2.00}(Sb_{3.15}As_{0.86})_{4.01}(S_{12.99}Se_{0.07})_{13.06}$	1.7
3	$(Cu^{+}_{9.90}Ag_{0.10})_{10.00}(Cu^{2+}_{0.29}Fe_{0.02}Zn_{1.64}Cd_{0.07})_{2.02}(Sb_{3.25}As_{0.81})_{4.06}(S_{12.84}Se_{0.07})_{12.91}$	1.4
4	$(Cu^{+}_{10.43}Ag_{0.22})_{10.65}(Fe_{0.02}Zn_{0.22}Cd_{0.05})_{0.29}(Sb_{1.38}As_{0.74}Te^{4+}_{1.91})_{4.03}(S_{11.99}Se_{1.04})_{13.03}$	0.6
5	$(Cu^{+}_{11.26}Ag_{0.14})_{11.40}(Fe_{0.01}Zn_{0.58})_{0.59}(Sb_{2.20}As_{0.86}Te^{4+}_{0.89})_{3.95}(S_{12.62}Se_{0.43})_{13.05}$	3.0
	$(Cu^{+}_{9.86}Ag_{0.14})_{10.00}(Cu^{2+}_{1.40}Fe_{0.01}Zn_{0.58})_{1.99}(Sb_{2.20}As_{0.86}Te^{4+}_{0.89})_{3.95}(S_{12.62}Se_{0.43})_{13.05}$	2.3
6	$(Cu^{+}_{11.64}Ag_{0.10})_{11.74}(Fe_{0.02}Zn_{0.16})_{0.18}(Sb_{0.89}As_{0.39}Te^{4+}_{2.78})_{4.06}(S_{12.10}Se_{0.89})_{12.99}$	4.0
	$(Cu^{+}_{11.64}Ag_{0.10})_{11.74}(Fe_{0.02}Zn_{0.16})_{0.18}(Sb_{0.89}As_{0.39}Te^{4+}_{2.72})_{4.0}(S_{12.10}Se_{0.89}Te^{2-}_{0.06})_{13.05}$	2.7
7	$(Cu^{+}_{11.54}Ag_{0.24})_{11.78}(Zn_{0.26}Cd_{0.01})_{0.27}(Sb_{1.39}As_{0.67}Te^{4+}_{1.89})_{3.95}(S_{12.47}Se_{0.53})_{13.00}$	0.2
8	$(Cu^{+}_{11.64}Ag_{0.29})_{11.93}(Fe_{0.02}Zn_{0.05}Cd^{2+}_{0.05})_{0.12}(Sb_{0.68}As_{0.26}Te^{4+}_{3.00})_{3.94}(S_{12.06}Se_{0.85}Te^{2-}_{0.09})_{13.00}$	3.7
9	$(Cu^{+}_{11.32}Ag_{0.15})_{11.47}(Zn_{0.58}Cd_{0.04})_{0.62}(Sb_{1.83}As_{0.88}Te^{4+}_{1.28})_{3.99}(S_{12.40}Se_{0.52})_{12.92}$	0.8
10	$(Cu^{+}_{11.91}Ag_{0.11})_{12.02}(Fe_{0.01}Zn_{0.17}Cd^{2+}_{0.01})_{0.19}(Sb_{0.85}As_{0.29}Te^{4+}_{2.79})_{3.93}(S_{11.86}Se_{1.00})_{12.86}$	4.7
	$(Cu^{+}_{11.91}Ag_{0.11})_{12.02}(Fe_{0.01}Zn_{0.17}Cd^{2+}_{0.01})_{0.19}(Sb_{0.85}As_{0.29}Te^{4+}_{2.65})_{3.79}(S_{11.86}Se_{1.00}Te^{2-}_{0.14})_{13.00}$	1.6
11	$(Cu^{+}_{11.34}Ag_{0.14})_{11.48}(Cd_{0.01}Zn_{0.56}Fe_{0.01})_{0.58}(Sb_{1.69}As_{0.55}Te^{4+}_{1.77})_{4.01}(S_{11.95}Se_{0.97})_{12.92}$	2.3
12	$(Cu^{+}_{11.30}Ag_{0.67})_{11.97}(Zn_{0.04}Fe_{0.04})_{0.08}(Sb_{0.43}As_{0.57}Te^{4+}_{2.94})_{3.94}(S_{12.02}Se_{0.99})_{13.00}$	3.3
12*	$Cu^{+}_{11.70}(Zn_{0.05}Fe_{0.05})_{0.10}(Sb_{0.44}As_{0.59}Te^{4+}_{2.87})_{3.90}(S_{12.28}Se_{1.01})_{13.29}$ + 5.99% Ag_4TeS	0.4
13	$(Cu^{+}_{10.86}Ag_{0.43})_{11.29}(Zn_{0.67}Fe_{0.12})_{0.79}(Sb_{1.62}As_{0.59}Te^{4+}_{1.77})_{3.98}(S_{12.40}Se_{0.54})_{12.94}$	2.6

*Note. Including Mn: in analyses 1, 2, 10, 12 – traces, in analyses 3 and 11 – 0.02, in analyses 4, 5, 6, 7 – 0.01, in analysis 8 – 0.05, in analysis 9 – 0.04 wt.%. *Analysis is calculated under condition that all Ag is attributed at the expense of kervelleite Ag_4TeS. Correspondingly amount of Te is decreased by 1.29% and amount of S by 0.32%*

shown by the following: analyses become electroneutral only if native tellurium is excluded exceeding 4 atoms occupied by atoms of semimetal in the formula.

4. Te-bearing fahlores with a large amount of silver (7 – 13 wt.%) may contain an admixture of fine-grained kervelleit, Ag_4TeS.

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