Genplesite, $Ca_3Sn(SO_4)_2(OH)_6 \cdot 3H_2O$, a new mineral of the fleischerite group: first occurrence of a tin sulfate in nature

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Abstract: The new mineral genplesite, $Ca_3Sn(SO_4)_2(OH)_6 \cdot 3H_2O$, the first natural tin sulfate, is found in cavities in massive chalcopyrite ore at the Oktyabr'skoe Cu-Ni-Pd-Pt deposit (Oktyabr'sky mine), Talnakh, Norilsk district, Siberia, Russia. It is a late-stage hydrothermal mineral associated with greenalite, chamosite, pectolite, ferroactinolite, calcite and fluorapatite. Genplesite occurs as equant, short prismatic or thick tabular hexagonal crystals up to 0.5 mm and crystal clusters up to 0.6×1.2 mm. The major crystal forms are $\{1\,0\,0\}$ and $\{0\,0\,1\}$ whereas $\{1\,0\,2\}$ and $\{1\,0\,1\}$ are minor. Genplesite is transparent, colourless, with vitreous lustre. It is brittle, the Mohs hardness is *ca.* 3. Cleavage is not observed, the fracture is conchoidal. $D_{meas} = 2.78(1)$, $D_{calc} = 2.773$ g·cm^{-3}. Genplesite is optically uniaxial (–), $\omega = 1.597(2)$, $\varepsilon = 1.572(2)$. The IR spectrum is reported. The chemical composition (wt%, electron microprobe data, H_2O calculated for 3 molecules per formula unit, *pfu*) is: CaO 28.67, Al_2O_3 0.11, GeO_2 0.50, SnO_2 24.20, SO_3 27.25, H_2O_{calc} 18.34, total 99.07. The empirical formula calculated on the basis of 17 O *apfu* is: $Ca_{3.01}(Sn_{0.95}Ge_{0.03}Al_{0.01})_{\Sigma0.99}S_{2.01}O_8(OH)_6 \cdot 3H_2O$. Genplesite is hexagonal, $P6_3/mmc$, $a = 8.5139(2)$, $c = 11.1408(3)$ Å, $V = 699.37(1)$ Å^3 and $Z = 2$. The strongest reflections of the powder X-ray diffraction pattern $[d, Å (I)(hkl)]$ are: 7.38(68)(1 0 0), 4.259(46)(1 1 0), 3.503(15)(2 0 1), 3.383(100)(1 1 2), 2.616(13)(2 0 3), 2.493(14)(2 1 2), 2.249(14)(3 0 2) and 2.130(17)(1 0 5, 2 2 0). Genplesite is a member of the fleischerite group. Its crystal structure was solved from single-crystal X-ray diffraction data ($R = 0.016$). The major building unit of the structure is a column consisting of isolated $Sn^{4+}(OH)_6$ octahedra and trimers of edge-sharing $CaO_2(OH)_4(H_2O)_2$ polyhedra. Adjacent columns are interconnected *via* H_2O molecules and SO_4 tetrahedra. Genplesite is named in honour of Gennadiy N. Plesin (b. 1963), a mine surveyor at the Oktyabr'sky mine and an amateur mineralogist who found the mineral.

Key-words: genplesite; new mineral; tin sulfate; fleischerite group; ettringite group; crystal structure; Oktyabr'skoe deposit; Norilsk.

1. Introduction

This paper is devoted to the first natural sulfate with species-defining tin. It was found in a late-stage hydrothermal assemblage related to sulfide ores of the huge Oktyabr'skoe Cu–Ni–Pd–Pt deposit, operated by the Oktyabr'sky mine, in the Norilsk district, Krasnoyarsk Krai, Siberia, Russia. This new member of the fleischerite group was named genplesite (Cyrillic: генплесит) in honor of Gennadiy Nikolaevich Plesin (born 1963), a mine surveyor at the Oktyabr'sky mine and an amateur mineralogist who has made a significant contribution to the mineralogy of ore deposits of the Norilsk district. In particular, he collected and provided samples that became the holotypes of three mineral species, ferrotochilinite

(Pekov *et al.*, 2013a), ferrovalleriite (Pekov *et al.*, 2013b) and genplesite described herein.

Both the new mineral and its name have been approved by the IMA Commission on New Minerals, Nomenclature and Classification (IMA2014-034). The type specimen of genplesite is deposited in the systematic collection of the Fersman Mineralogical Museum of the Russian Academy of Sciences, Moscow, with the catalogue number 94618.

2. Occurrence and general appearance

Many publications are devoted to the famous Oktyabr'-skoe deposit. The general description of the deposit, its ores and mineralogy can be found in Genkin *et al.* (1981) and Gorbachev (2006).
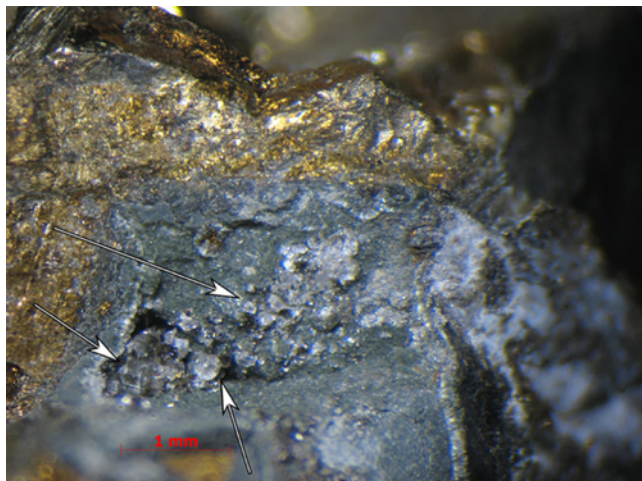
Fig. 1. Numerous transparent, colourless crystals of genplesite (marked with arrows) on greenalite crust in a cavity in massive chalcopyrite. Field of view 5.8 mm. Photo: I.V. Pekov & A.V. Kasatkin.

Specimens bearing the new mineral were collected by G. N. Plesin in March 2013 at the No. 1 shaft (level −750 m) of the Oktyabr'sky mine, Talnakh city, Norilsk district.

Genplesite was found in the cavernous part (about 0.3 m across) of a massive chalcopyrite body located at the contact between a rich mooihoekite–chalcopyrite ore and gabbro-dolerite with embedded chalcopyrite. The new mineral occurs on greenish-grey greenalite crystalline crusts lining walls of roundish caverns (up to 1 cm in diameter) in a massive chalcopyrite (with subordinate pentlandite) ore (Fig. 1). Some genplesite crystals were observed on brown chamosite spherulites overgrowing greenalite crusts. Other minerals found in these cavities are pectolite, ferroactinolite, calcite and fluorapatite.

Genplesite occurs as hexagonal, equant, short prismatic or thick tabular crystals. Their major forms are the hexagonal prism {1 0 0} and the pinacoid {0 0 1}; the hexagonal dipyramidal faces {1 0 2} and {1 0 1} were observed on some crystals (Figs. 2 and 3). Crystal forms were determined after observations under scanning electron microscope. Gear-like parallel intergrowths of crystals are typical (Figs. 2a and 3c). Genplesite crystals are up to 0.5 mm across, gear-like parallel intergrowths are up to 0.6×1 mm and crystal clusters are up to 0.6×1.2 mm in size.

3. Physical properties

Genplesite is transparent, colourless, with a white streak and a vitreous lustre, brittle, with a Mohs hardness of *ca*. 3. No distinct cleavage or parting were observed and the fracture is conchoidal. Density measured by flotation in heavy liquids (bromoform + dimethylformamide) is 2.78 (1) and the density calculated using the empirical formula is 2.773 g·cm^{-3}.

Genplesite is optically uniaxial (−), $\omega = 1.597(2)$, $\varepsilon = 1.572(2)$ (589 nm). Under the microscope it is colourless and non-pleochroic.
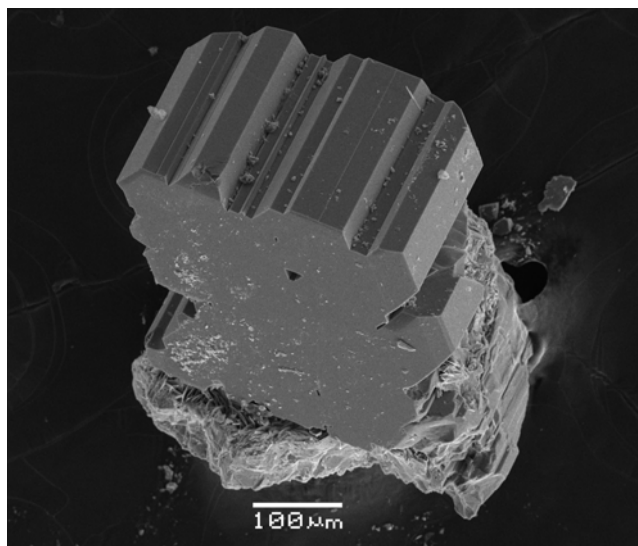
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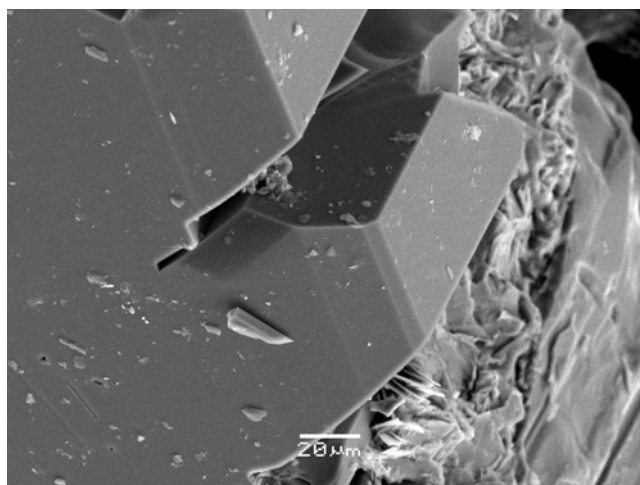
b

Fig. 2. Parallel intergrowth of genplesite crystals (a) and its magnified fragment (b). Genplesite overgrows greenalite crust. Scanning electron microscope (secondary electrons) image.
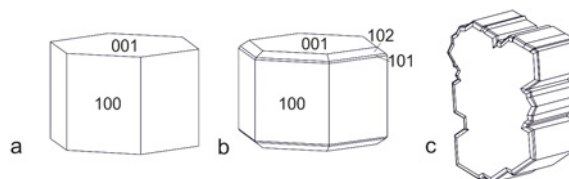
Fig. 3. Genplesite crystals (a–b) and their parallel intergrowth (c).

4. Infrared spectroscopy

Absorption bands in the IR spectrum of genplesite (Fig. 4) and their assignments are (cm^{-1}, s − strong band, w − weak band, sh − shoulder): 3520 sh, 3451 s, 3365 s (O–H stretching vibrations of H_2O molecules and OH groups), 1663, 1550 sh (H–O–H bending vibrations of H_2O molecules; splitting of the band is due to the bifurcation
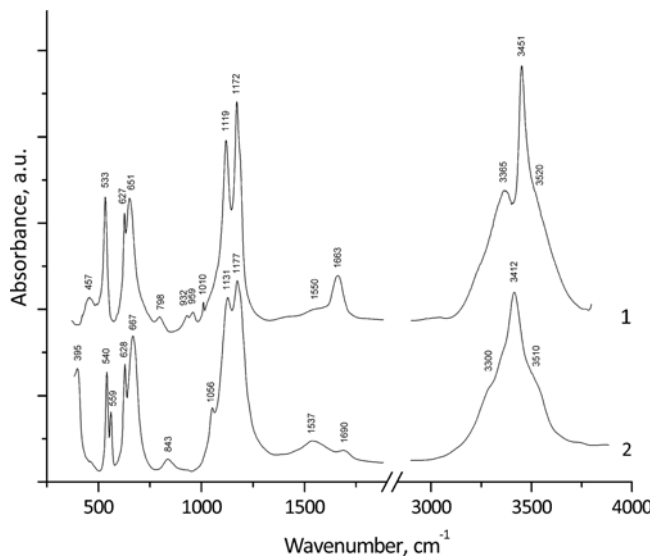
Fig. 4. IR spectra of genplesite (1) and schaurteite from Tsumeb, Namibia (2, after Chukanov, 2014).

of the H-bond formed by the H_2O molecule; see footnote to Table 5), 1172 s, 1119 s [$\nu_3(F_2)$ − asymmetric stretching vibrations of SO_4^{2-} anions], 1010 w ($\nu_1(A_1)$ − symmetric stretching vibrations of SO_4^{2-} anions), 959 w, 932 w, 798 w (Sn···O–H bending vibrations), 651, 627 ($\nu_4(F_2)$ − bending vibrations of SO_4^{2-} anions), 533 (Sn–O stretching vibrations), 457 (possible librational vibrations of H_2O molecules). The presence of $\nu_1(A_1)$ at 1010 cm^{-1} corresponding to the nondegenerate S–O stretching mode, as well as the splitting of the band $\nu_3(F_2)$ of the SO_4 group (the doublet 1119 + 1172 cm^{-1}) reflect some distortion of SO_4 tetrahedra.

Three bands of O–H stretching vibrations in the range 3300–3600 cm^{-1} correspond to three normal modes (O–H stretching mode of the OH group and in-phase and out-of-phase stretching modes of the H_2O molecule).

Characteristic bands of BO_3^{3-}, CO_3^{2-} and NO_3^- groups are absent in the IR spectrum of genplesite.

The IR spectrum of the new mineral is similar to that of its Ge-analogue schaurteite $Ca_3Ge(SO_4)_2(OH)_6 \cdot 3H_2O$ (Fig. 4). The main differences between IR spectra of these sulfates are observed in the ranges of O–H stretching (3300–3600 cm^{-1}) and M–O stretching (530–560 cm^{-1}) vibrations of the $M^{4+}(OH)_6$ octahedra (M = Sn, Ge).

5. Chemical composition

The chemical composition of genplesite was determined using a Jeol JSM-6480LV scanning electron microscope equipped with an INCA-Wave 500 wavelength-dispersive spectrometer (Laboratory of Analytical Techniques of High Spatial Resolution, Dept. of Petrology, Moscow State University), with an acceleration voltage of 20 kV and a beam current of 15 nA; the electron beam was rastered over an area of 10×10 μm to minimize damage to the unstable, highly hydrated mineral. The following standards were used: $CaWO_4$ (Ca), Al_2O_3 (Al), Ge (Ge), SnS (Sn), and FeS_2 (S). Contents of other elements with

Table 1. Powder X-ray diffraction data for genplesite.

I_{obs}	d_{obs}, Å	I_{calc} *	d_{calc}, Å **	hkl
68	7.38	56	7.373	1 0 0
12	6.15	9	6.148	1 0 1
11	5.587	5	5.570	0 0 2
11	4.446	8	4.445	1 0 2
46	4.259	44	4.257	1 1 0
15	3.503	12	3.500	2 0 1
100	3.383	100	3.382	1 1 2
4	3.319	1	3.317	1 0 3
6	3.076	5	3.074	2 0 2
8	2.787	3, 6	2.787, 2.785	2 1 0, 0 0 4
3	2.705	1	2.704	2 1 1
13	2.616	15	2.616	2 0 3
6	2.604	4	2.606	1 0 4
14	2.493	20	2.492	2 1 2
2	2.459	1	2.458	3 0 0
3	2.402	3	2.400	3 0 1
2	2.330	3	2.331	1 1 4
14	2.249	22	2.249	3 0 2
8	2.227	8, 6	2.229, 2.222	2 1 3, 2 0 4
17	2.130	6, 24	2.133, 2.128	1 0 5, 2 2 0
6	2.050	9	2.050	3 0 3
1	2.013	0.5	2.011	3 1 1
5	1.971	9	1.970	2 1 4
2	1.920	1	1.920	3 1 2
2	1.908	2	1.907	2 0 5
1	1.858	1	1.857	0 0 6
4	1.844	5	1.843	3 0 4
3	1.819	4	1.819	4 0 1
2	1.800	3	1.801	1 0 6
3	1.751	5	1.750	4 0 2
3	1.742	6	1.740	2 1 5
3	1.702	6	1.702	1 1 6
11	1.692	6, 19	1.692, 1.691	3 2 0, 2 2 4
2	1.659	5	1.658	2 0 6
4	1.650	1, 8	1.651, 1.648	4 0 3, 3 1 4
1	1.620	1	1.619	3 2 2
2	1.610	4	1.609	4 1 0
1	1.593	0.5	1.592	4 1 1
10	1.547	15, 4	1.546, 1.545	4 1 2, 2 1 6
3	1.483	7	1.482	3 0 6
2	1.462	3	1.461	2 0 7
2	1.447	4	1.446	3 2 4
2	1.427	2	1.426	5 0 2
3	1.420	5	1.419	3 3 0
3	1.394	0.5, 3, 2	1.393, 1.393, 1.393	4 2 0, 4 1 4, 0 0 8
2	1.384	2, 0.5	1.383, 1.382	4 2 1, 2 1 7
5	1.376	7, 4	1.375, 1.375	3 3 2, 3 1 6
1	1.352	2	1.352	4 2 2
1	1.325	1	1.324	1 1 8
1	1.317	0.5	1.315	5 1 1
2	1.305	3, 0.5	1.305, 1.304	4 2 3, 4 1 5
2	1.289	2	1.288	5 1 2
2	1.230	1, 3	1.230, 1.229	5 0 5, 6 0 0
2	1.217	7	1.216	4 1 6
2	1.206	1, 4	1.205, 1.205	4 3 1, 4 0 7
1	1.197	2	1.196	5 1 4
2	1.184	2	1.184	4 3 2

* For the calculated pattern, only reflections with intensities ≥0.5 are given;
** for the unit-cell parameters calculated from single-crystal data.

Table 2. Crystal data, data collection information and structure refinement details for genplesite.

Formula	$Ca_3Sn(SO_4)_2(OH)_6 \cdot 3H_2O$
Formula weight	587.15
Temperature, K	293(2)
Radiation and wavelength, Å	$MoK\alpha$; 0.71073
Crystal system, space group, Z	Hexagonal, $P6_3/mmc$, 2
Unit cell dimensions, Å	$a = 8.5139(2)$ $c = 11.1408(3)$
V, Å^3	699.37(3)
Absorption coefficient μ, mm^{-1}	3.318
ρ_{calc} for the ideal formula, g·cm^{-3}	2.788
F_{000}	580
Crystal size, mm	$0.14 \times 0.14 \times 0.22$
Diffractometer	Xcalibur S CCD
θ range for data collection, °	2.76–34.77
Index ranges	$-13 \le h \le 13$, $-13 \le k \le 13$, $-17 \le l \le 17$
Reflections collected	17960
Independent reflections	613 ($R_{int} = 0.0367$)
Independent reflections with $I > 2\sigma(I)$	590
Structure solution	direct methods
Refinement method	full-matrix least-squares on F^2
Number of refined parameters	35
Final R indices [$I > 2\sigma(I)$]	$R1 = 0.0162$, $wR2 = 0.0414$
R indices (all data)	$R1 = 0.0178$, $wR2 = 0.0420$
Weighting parameters a, b	0.0183, 0.4311
GoF	1.255
Largest diff. peak and hole, e/Å^3	0.325 and -0.783

atomic numbers higher than carbon are below detection limit. H_2O was not determined because of the scarcity of material and its content was calculated on the basis of the structural data (see below), for 3 H_2O molecules per formula unit (*pfu*).

The chemical composition of genplesite (average of 4 spot analyses; wt%, with ranges/standard deviations in parantheses) is: CaO 28.67 (28.49–28.84 / 0.15), Al_2O_3 0.11 (0.04–0.16/0.06), GeO_2 0.50 (0.35–0.63/0.13), SnO_2 24.20 (24.02–24.45/0.19), SO_3 27.25 (27.06–27.53/0.20), H_2O_{calc} 18.34, total 99.07 wt%.

The empirical formula calculated on the basis of 17 O *apfu* is $Ca_{3.01}(Sn_{0.95}Ge_{0.03}Al_{0.01})_{\Sigma 0.99}S_{2.01}O_8(OH)_6 \cdot 3H_2O$. The idealized formula is $Ca_3Sn(SO_4)_2(OH)_6 \cdot 3H_2O$, which requires CaO 28.65, SnO_2 25.66, SO_3 27.28, H_2O 18.41, total 100.00 wt%.

The Gladstone-Dale compatibility index $1-(K_p/K_c)$ is -0.016 (superior) if D_{meas} is used or -0.019 (superior) if D_{calc} is used.

6. X-ray crystallography and crystal structure

Powder X-ray diffraction data of genplesite (Table 1) were collected with a Rigaku R-AXIS Rapid II single-crystal diffractometer equipped with cylindrical image plate detector (radius 127.4 mm) using Debye-Scherrer geometry, $CoK\alpha$ radiation (rotating anode with Vari-MAX microfocus optics), 40 kV, 15 mA, 15 min exposure. The angular resolution of the detector was

0.045 2θ (pixel size 0.1 mm). The data were integrated using the software package Osc2Tab (Britvin *et al.*, 2017).

The hexagonal unit-cell parameters refined from the powder data are: $a = 8.518(1)$, $c = 11.149(2)$ Å and $V = 700.6(3)$ Å^3.

Single-crystal X-ray diffraction study of genplesite was carried out using an Xcalibur S diffractometer equipped with a CCD detector. A full sphere of three-dimensional data was collected. The measured intensities were corrected for Lorentz, background, polarization and absorption effects. Data reduction was performed using CrysAlisPro Version 1.171.35.21 (Agilent Technologies, 2012). The structure was solved by direct methods and refined using the SHELX-97 software package (Sheldrick, 2008) to $R = 0.016$ for 590 independent reflections with $I > 2\sigma(I)$. Hydrogen atoms were located from the difference Fourier electron-density maps and refined freely. Both H atoms form O–H···O hydrogen bonds; moreover, the H bond formed by the H_2O molecule could be considered as bifurcated due to the presence of an O(4) (in the H_2O molecule) − O(2) distance of 3.0051(15) Å, confirmed by the IR spectroscopy data. The crystal data and the experimental details are presented in Table 2, atom coordinates and displacement parameters in Table 3, selected interatomic distances in Table 4, hydrogen-bond geometry in Table 5 and bond-valence calculations in Table 6.

The crystal structure of genplesite (Fig. 5a) is typical for fleischerite-group minerals (Table 7). Its major building unit is a column parallel to [0 0 1], which consists of isolated $Sn^{4+}(OH)_6$ octahedra and trimers of edge-sharing $CaO_2(OH)_4(H_2O)_2$ polyhedra (Fig. 5b). Neighbouring columns are interconnected by Ca-centred polyhedra sharing oxygen atoms of H_2O molecules O(4) and through SO_4 tetrahedra, sharing three O vertices O(2) with Ca-centred polyhedra (Fig. 5a). The O(1) apical vertices of the SO_4 tetrahedra are H-bonded to the O atoms of the H_2O molecules (Table 6). According to Pushcharovsky *et al.* (1998), the structural formula of genplesite could be given as $^3_\infty[Ca_3^{[8]}Sn^0S^tO_8(OH)_6(H_2O)_3]$.

7. Discussion

Genplesite $Ca_3Sn^{4+}(SO_4)_2(OH)_6 \cdot 3H_2O$ is a new member of the fleischerite group (Table 7), and is a tin analogue of schaurteite, $Ca_3Ge^{4+}(SO_4)_2(OH)_6 \cdot 3H_2O$, and despujol-site, $Ca_3Mn^{4+}(SO_4)_2(OH)_6 \cdot 3H_2O$. All these minerals are hexagonal with the unit-cell parameters in the range 8.51–8.94 Å for a and 10.76–11.14 Å for c. Genplesite and schaurteite are isotypic (both crystallize in space group $P6_3/mmc$), whereas other fleischerite-group members possess different space groups: despujolsite and fleischer-ite crystallize in the space group $P\bar{6}2c$, and mallestigite crystallizes in the space group $P6_3$. Origlieri & Downs (2013) noted that, although schaurteite and fleischerite are minerals from the same deposit, no siginificant Pb ↔ Ca

Table 3. Atom coordinates, displacement parameters (U_{eq}, in Å^2) and site multiplicities (Q) for genplesite.

Site	x	y	z	U_{eq}	Q
Sn	0	0	0	0.00817(7)	2
Ca	0.30866(6)	0.15433(3)	1/4	0.01008(9)	6
S	1/3	2/3	0.52868(6)	0.00881(11)	4
O(1)	1/3	2/3	0.10438(18)	0.0166(4)	4
O(2)	0.47792(18)	0.23896(9)	0.07082(12)	0.0195(2)	12
O(3)	0.10624(8)	0.21249(16)	0.11835(10)	0.01105(19)	12
O(4)	0.50906(13)	0.49094(13)	3/4	0.0165(3)	6
H(1)	0.152(2)	0.304(5)	0.084(3)	0.031(8)*	12
H(2)	0.537(2)	0.463(2)	0.695(3)	0.050(11)*	12

* U_{iso}.

Table 4. Selected interatomic distances (Å) in the structure of genplesite.

Sn − O(3)	2.0477(11) × 6
Ca − O(2)	2.3542(13) × 2
− O(3)	2.4939(7) × 4
− O(4)	2.6159(10) × 2
S − O(2)	1.4687(13) × 3
− O(1)	1.482(2)
O(3) − H(1)	0.78(3)
O(4) − H(2)	0.74(3) × 2

Table 5. Hydrogen-bond geometry (Å,°) in the structure of genplesite.

$D − H \cdots A$	$D − H$	$H \cdots A$	$D \cdots A$	$\angle(D − H \cdots A)$
O(3) − H(1) ⋯ O(2)	0.78(3)	2.14(3)	2.8761(18)	157(3)
O(4) − H(2) ⋯ O(1)	0.74(3)	2.16(3)	2.834(2)	152(3)

Table 6. Bond-valence calculations for genplesite.

	Sn	Ca	S	Σ	H-bonding	Σ
O(1)			1.47	1.47	+0.17 $^{×3→}$(O(4))	1.98
O(2)		0.35 $^{×2↓}$	1.52 $^{×3↓}$	1.87	+0.16 (O(3))	2.03
O(3) = OH	0.68 $^{×6↓}$	0.24 $^{×4↓}$ $^{×2→}$		1.16	−0.16 (O(2))	1.00
O(4) = H$_2$O		0.17 $^{×2↓}$ $^{×2→}$		0.34	−0.17 $^{×2→}$ (O(1))	0.00
Σ	4.08	2.00	6.03			

Bond-valence parameters were taken from Brese & O`Keeffe (1991) for Sn–O, Ca–O and S–O and from Ferraris & Ivaldi (1988) for H-bonding.

substitution is observed. This could be explained by the stereochemical activity of lone electron pairs on Pb^{2+} cations in fleischerite, which disrupt the centrosymmetry of the whole structure (Origlieri & Downs, 2013).

The existence of two Ge members of the fleischerite group, namely fleischerite, Pb$_3$Ge(SO$_4$)$_2$(OH)$_6$·3H$_2$O, and schaurteite, demonstrates a strong affinity of fleischerite-type structures for Ge^{4+}. Genplesite also contains up to 0.6 wt% GeO$_2$.

The general formula of the fleischerite-group minerals is $A^{2+}_3M(TO_4)_2(OH)_6 \cdot 3H_2O$ with species-defining A = Ca or Pb, M = Ge^{4+}, Mn^{4+}, Sn^{4+} or Sb^{5+}, and T = S^{6+} or As^{5+} (Table 7). In their structures, the heteropolyhedral columns formed by the A- and M-centred polyhedra are topologi-

cally the same as polyhedral columns found in the crystal structures of ettringite-group minerals, which have the general formula Ca$_6M_2$(OH)$_{12}R_{3-4}$·nH$_2$O, in which M = Al^{3+}, Cr^{3+}, Fe^{3+}, Si^{4+}, Mn^{4+} or Ge^{4+} are species-defining cations, R = SO$_4^{2-}$, CO$_3^{2-}$, SO$_3^{2-}$, PO$_3$OH^{2-} or B(OH)$_4^-$ are species-defining anions and n = 11–13 (Pöllmann et al., 1989; Pekov et al., 2012; Chukanov et al., 2016). In the crystal structures of ettringite-group minerals and iso-structural synthetic compounds (all are hexagonal or trigonal, with P unit cells), the columns formed by the M(OH)$_6$ octahedra and trimers of edge-sharing Ca-centred polyhedra are connected with R anions by a complex system of H-bonds. In less hydrated fleischerite-group minerals, topologically similar columns are instead
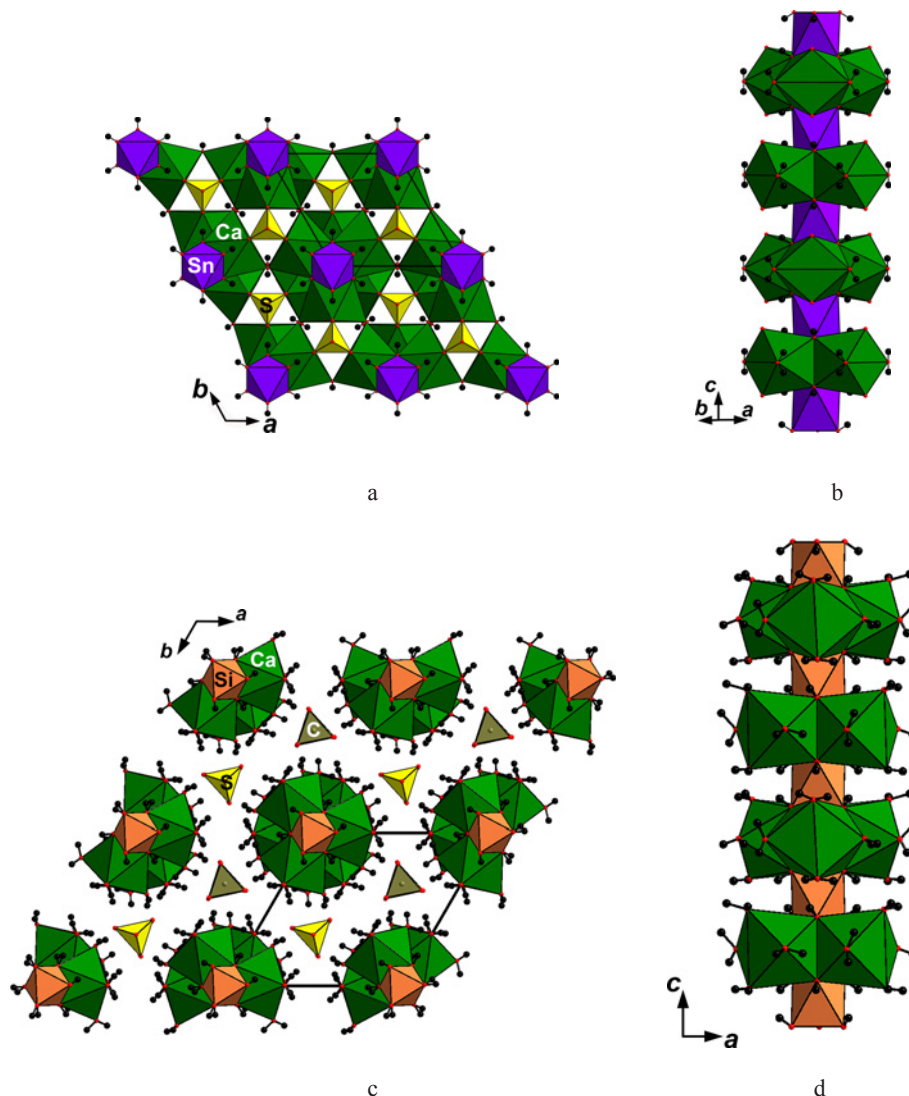
Fig. 5. The crystal structures of genplesite (a, b) and thaumasite (c, d: drawn after Effenberger *et al.*, 1983). Figures (a) and (c) show a general view of the structures projected on the *ab* plane; (b) the column formed by $Sn(OH)_6$ octahedra and trimers of $CaO_2(OH)_4(H_2O)_2$ polyhedra in genplesite; (d) the column formed by $Si(OH)_6$ octahedra and trimers of $Ca(OH)_4(H_2O)_4$ polyhedra in thaumasite. Hydrogen atoms are black circles. The unit cells are outlined.

directly linked *via* SO_4 tetrahedra. This causes a significant difference in the *a* unit-cell parameter between ettringite-group minerals (10.8–11.3 Å) and Ca representatives of the fleischerite group (8.5–8.6 Å), whereas their *c* parameters do not differ essentially: 10.4–10.6 Å (or 21.0–21.9 Å for the ettringite-group minerals with a *c*-doubled unit cell) and 10.8–11.3 Å, respectively: see Table 7 and comparative data reported by Pekov *et al.* (2012) and Chukanov *et al.* (2016). Figure 5 depicts the above-mentioned features of the structure of genplesite as a fleischerite-group member, compared to the most widespread ettringite-group mineral thaumasite, $Ca_3Si(OH)_6(CO_3)(SO_4)\cdot12H_2O$.

Genplesite is a late-stage low-temperature hydrothermal mineral. No sign of influence of supergene processes was observed in this orebody situated at significant depth.

The sulfide ores of the Oktyabr'skoe deposit are relatively enriched in tin and sporadically contain Sn sulfides, cassiterite and numerous intermetallic compounds with species-defining Sn with Pd or Pt (Gorbachev, 2006). Thus the formation of tin minerals in the hydrothermal assemblages related to such ores is not unexpected.

Table 7. Comparative data for fleischerite-group minerals.

Mineral	Genplesite	Schaurteite	Despujolsite	Fleischerite	Mallestigite
Formula	$Ca_3Sn(SO_4)_2(OH)_6 \cdot 3H_2O$	$Ca_3Ge(SO_4)_2(OH)_6 \cdot 3H_2O$	$Ca_3Mn^{4+}(SO_4)_2(OH)_6 \cdot 3H_2O$	$Pb_3Ge(SO_4)_2(OH)_6 \cdot 3H_2O$	$Pb_3Sb^{5+}(SO_4)(AsO_4)(OH)_6 \cdot 3H_2O$
Crystal system Space group	Hexagonal $P6_3/mmc$	Hexagonal $P6_3/mmc$	Hexagonal $P\bar{6}2c$	Hexagonal $P\bar{6}2c$	Hexagonal $P6_3$
a, Å	8.514	8.525	8.54–8.56	8.89	8.938
c, Å	11.141	10.80	10.76–10.81	10.86	11.098
V, Å³	699	680	683	743	768
Z	2	2	2	2	2
Strong lines of the powder X-ray diffraction pattern: d, Å – I, %	7.38–68 4.259–46 3.503–15 3.383–100 2.493–14 2.249–14 2.130–17	7.40–50 4.26–70 3.49–50 3.34–100 2.579–50 2.239–50 2.129–60	7.40–60 4.26–80 3.34–100 2.570–60 2.129–80 2.025–60	7.681–50 3.619–100 3.437–60 2.800–50 2.635–80 2.214–60 1.889–60	7.74–25 6.35–44 3.655–100 3.481–80 3.175–31 2.675–62 2.235–35
Density, g·cm⁻³	2.78 (meas.)	2.65 (meas.)	2.46 (meas.)	4.59 (calc.)	4.91 (calc.)
Optical data					
ω	1.597	1.569	1.656	1.747	1.801
ε	1.572	1.581	1.682	1.776	1.760
Optical sign	–	+	+	+	+
References	this work	Strunz & Tennyson (1967); Origlieri & Downs (2013)	Gaudefroy et al. (1968); Barkley et al. (2011)	Frondel & Strunz (1960); Otto (1975)	Sima (1998)

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