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Apachite and gilalite, two new copper silicates from Christmas, Arizona

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SUMMARY. Both new species are retrograde or mesogene minerals that occur in tactites at the Christmas mine, Gila County, Arizona (USA). Gilalite is green, H = 2, $D = 2.82$. Biaxial (—), 2V small, $\alpha = 1.560$, $\beta = \gamma = 1.635$. No single crystals found; strongest lines at 13.49 Å, (10); 10.97 (5); 7.786 (5). Analysis gave CuO 36.2 %, MgO 2.3, CaO 3.8, MnO 0.5, SiO_2 41.5, H_2O 14.6, close to $Cu_5Si_6O_{17}\cdot 7H_2O$.

Apachite is blue, H = 2, $D = 2.80$. Biaxial (—), 2V small, $\alpha = 1.610$, $\beta = \gamma = 1.650$. No single crystals found. Strongest lines are 12.90 Å (10); 3.168 (7); 7.663 (5). Analysis gave CuO 43.6 %, FeO 0.3, MgO 1.7, CaO 1.8, SiO_2 40.8, H_2O 13.8, close to $Cu_9Si_{10}O_{29}\cdot 11H_2O$.

Occurrence. The Christmas mine in Gila County, Arizona, is a porphyry copper deposit producing ores from a tactite zone developed in Paleozoic carbonate rocks. Sulphide ores, including chalcopyrite, bornite, and sphalerite were introduced into the tactites during metamorphism to the assemblage garnet-diopside-wollastonite. The deposit has been described in detail by Eastlick (1968) and Perry (1969).

An unusual feature of this particular deposit is the presence of numerous copper and zinc silicates including kinoite, stringhamite, junitoite, and clinohedrite. These species are clearly not oxidation products of the primary ores. They formed compatibly with a retrograde or mesogene assemblage including xonotlite, apophyllite, calcite, and tobermorite. This suite has formed at the expense of the prograde calc-silicate and sulphide assemblage. Gilalite and apachite are two more minerals in this suite.

Gilalite encrusts fractures that may be sprinkled with kinoite crystals. It occurs as spherules of radial fibres up to 0.2 mm or more in length. Some spherules are embedded in, sometimes totally isolated within apophyllite. In thin section gilalite is frequently seen coating garnet, or invading it along cracks, or filling the interstices among diopside grains. Gilalite is abundant at the locality, occurring throughout large tonnages of rock.

Apachite occurs similarly but seems confined to certain ill-defined structures that cut the tactite. It may also alter to gilalite. It was usually observed in fractures or crackled zones cutting garnet-diopside rock, replacing both of these silicates along with calcite.

Both species have been approved prior to publication by the Commission on New Minerals and New Mineral Names IMA.

Physical properties. Apachite is a rich Faience blue (RHS—111A) and could be confused with planchéite or shattuckite in hand specimen. Rich seams often show a silky fibrous structure on broken surfaces. The Mohs hardness is 2. The specific gravity is 2.80 ± 0.02 using 11.5 mg on the Berman balance (three trials).

Gilalite is usually green (Chrysocolla green, RHS—129B) but inclines to pale blue-green in some areas. The Mohs hardness is 2. Spherules are easily deformed with pressure from a needle and seem waxy or gummy. The specific gravity is 2.82 ± 0.05 (average of three trials on 11 mg, Berman balance).

Chemistry. Pure spherules of both species were easily obtained for analysis by hand picking. Spectrographic analysis indicated major Cu and Si in both with traces of Ca, Mg, Mn, Fe, and Zn. Since both species are easily soluble in cold, dilute HNO_3 or HCl the analysis proceeded smoothly. The results are presented in Table I.

For both species the relatively irrational ratios of $\Sigma Cu:Si:H_2O$ raise the possibility of incorrect assignment of subscripts in the formulae. The actual ratios found ($\Sigma Cu:Si:H_2O$) are 0.626:0.680:0.769 for apachite, 0.587:0.691:0.813 for gilalite.

TABLE I. *Chemical analysis of apachite and gilalite*

	1	2	3	4
CuO	43.6%	47.26%	36.2%	44.97%
FeO	0.3	—	n.d.	—
MgO	1.7	—	2.3	—
CaO	1.8	—	3.8	—
MnO	n.d.	—	0.5	—
SiO_2	40.8	39.66	41.5	40.77
H_2O	13.8	13.08	14.6	14.26
	102.0	100.0	98.9	100.0

(1) Apachite. Average of two closely agreeing analyses on 1.104 and 2.281 mg for Cu, Fe, Mg, Ca, and on 1.340 and 2.044 mg for Si. H_2O 13.4% TGA, 14.3% Penfield.

(2) Theory for $Cu_9Si_{10}O_{29}\cdot 11H_2O$.

(3) Gilalite. Average of two closely agreeing analyses on 2.117 and 1.922 mg for Cu, Mn, Ca, Mg, and on 2.471 and 2.390 mg for Si. H_2O 14.5% TGA, 14.8% Penfield.

(4) Theory for $Cu_5Si_6O_{17}\cdot 7H_2O$.

TABLE II. *X-ray powder data for apachite and gilalite*

Apachite				Gilalite			
I_{est}	d_{meas}	d_{calc}	*hkl*	I_{est}	d_{meas}	d_{calc}	*hkl*
10	12.89	12.89	100	10	13.4	13.4	100
4	10.62	10.65	101	3	10.97	10.97	110
4	9.556	9.557	002	5	7.786	7.789	120
5	7.663	7.650	102	3	6.684	6.690	200
2	6.441	6.445	200	4	4.790	4.790	040
1	6.050	6.055	010	2	4.031	4.034	141
4	4.491	4.491	$10\bar{4}$	4	3.897	3.895	240
4	4.174	4.185	301	$\frac{1}{2}$	3.687	3.686	032
2	4.002	3.999	212			3.684	150
3	3.830	3.825	204			3.690	321
1	3.656	3.657	105	$\frac{1}{2}$	3.492	3.485	222
7	3.168	3.174	401	3	3.315	3.325	250
2	3.037			3	3.154	3.158	420
4B	2.886			3	2.948	2.948	242
3	2.713			3	2.722	2.722	033
3	2.656			3	2.668	2.667	133
1B	2.484			1	2.578		
2B	2.401			1	2.518		
1	2.232			2B	2.420		
3	1.585			1B	2.248		
2	1.525			$\frac{1}{2}$B	2.110		
				1B	1.842		
				$\frac{1}{2}$B	1.758		
				3	1.584		
				2	1.554		

Now it can be easily shown that other nearly equally satisfactory integers can be proposed to fit these ratios. Were the analytical errors known, doubtless several sets would fit the bill. The ratios used were the closest and of course assume no analytical error.

A small degree of replacement of Cu by Mg and Ca is called for in the formulae. During dissolution both species were watched closely to assure that no dolomite or calcite was present; no effervescence was observed. Although traces of carbonate could be invoked as an impurity most Mg and Ca must occur in the minerals.

X-ray data. Neither species occurs in single crystals, and both give complex X-ray powder patterns. Patterns were taken by Guinier, Gandolfi, and Straumanis methods and all agree well. It was found, however, that overgrinding is easily done and it results in more broad or diffuse lines.

The data were subjected to scrutiny by the Ito method and in each case a cell finally found. These cells index the powder data convincingly, and they show some similarity to each other. The two minerals probably show certain structural similarities. The Ito cells found are as follows: apachite $a = 12.89$ Å, $b = 6.055$, $c = 19.11$, $\beta = 90.42°$; gilalite $a = 13.38$ Å, $b = 19.16$, $c = 9.026$. It is likely that both species are monoclinic and that β is sensibly 90° for gilalite. Optics indicate the lower symmetry.

Indexed powder data for both species are presented in Table II.

Optics. Apachite is a rich blue in thin section but it shows no noticeable pleochroism. Crystals are usually minute twisted or curved blades with γ parallel or nearly parallel to the longest dimension and α nearly normal to the smallest dimension. $2V_\alpha$ is very small and the indices of refraction for Na*D* are $\alpha = 1.610$, $\beta = \gamma = 1.650$. The species closely resembles planchéite in thin section despite the lower indices.

Gilalite also occurs as spherules of bladed fibres that resemble ajoite in thin section. Pleochroism in drab greyish greens is weak with $\gamma > \alpha = \beta$. The blades extinguish up to 8° from γ with α nearly normal to the thin dimension. $2V_\alpha$ is very small with $\alpha = 1.560$, $\beta = \gamma = 1.635$. The inclined extinction observed appears to contradict the orthorhombic indexing found for the powder data. Probably β is very close to 90°.

Thermal behaviour. Despite certain similarities between the two species, several distinct differences appear in their thermal curves. The DTA curve (fig. 1) shows a very sharp loss of water about 92 °C for gilalite and a smooth loss curve for apachite. Because of uncertainties in the formulae it is difficult to interpret the various exo- and endothermic peaks above 600 °C. The endothermic peaks at 683 °C and 688 °C respectively are doubt-

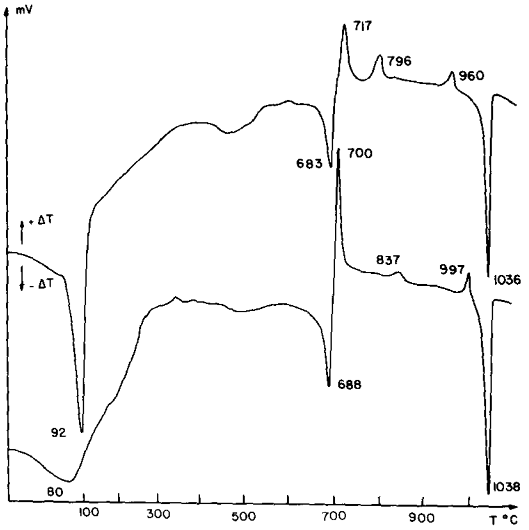

FIG. 1. DTA curves for gilalite (above) and apachite (below). Heating rate 600 °C/hr.

less related to loss of hydroxyl, an especially important feature for apachite. The last important peak, at 1036 °C is due to melting and to the reduction of cupric to cuprous oxide as verified by X-ray diffraction of the final products.

The TGA curve for gilalite shows three stages in loss of water but gives no clue as to OH/H_2O relations. The loss of oxygen by reduction of cupric oxide is poorly defined here since the furnace was nearing its limits, thus the reduction is far from complete for both species.

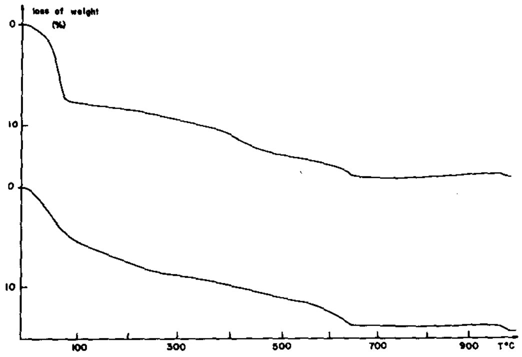

FIG. 2. TGA curves for gilalite (above) and apachite (below). Heating rate about 300 °C/hr.

Discussion. The reader will have noted that for both species the Ito cell, specific gravity, and molecular weight are in conflict. The measured specific gravity is probably within 2 % and the problem lies in the cell or formula subscripts. We prefer to present these conflicting results rather than none at all because it is evident that the quality of the material is inadequate to resolve the disagreement.

The two species have been compared with other copper silicates including shattuckite, planchéite, kinoite, ajoite, and chrysocolla, but clearly differ. Just the optics alone suffice to eliminate most of these species; X-ray data definitely eliminate chrysocolla.

Although both species, especially gilalite, are common at the type locality, the fact that they have not been observed before suggests that they will continue to be uncommon or rare minerals. Their temperature of formation may have been higher than normal for typical oxidation, perhaps coupled with unusual silica activity.

Gilalite had surely been noted by other workers since it gained wide circulation when kinoite was readily available for the locality.

The first apachite specimen was collected by R. A. Jenkins during early stages of the junitoite study. None was seen again until we found it in abundance in February of 1978.

Gilalite is named for Gila County in which the mine is situated. Apachite takes its name from the Indians who inhabit the region.

Type specimens of both species will be provided for the British Museum (N.H.) and the Geological Museum, University of Arizona.

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