

Luddenite, a new copper-lead silicate from Arizona

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ABSTRACT. Found at a small prospect in the Artillery Peaks area, Arizona. Luddenite occurs in oxidized Cu-Zn ores with fluorite, alamosite, and cerussite. Colour nickel green, H = 4, G meas. 4.45.

Strongest X-ray lines are 7.361(10), 3.173(10), 2.918(8), 5.218(7), 4.226(5), 3.411(5), 2.888(5), 3.650(4). A possible cell found by Ito method is $a = 7.85$, $b = 20.06$, $c = 14.72$ Å, $\beta = 90.78^\circ$ (monoclinic). Optically (+), $\alpha = 1.852$, $\gamma = 1.867$.

Chemical analysis by wet methods gave CuO 13.2%, PbO 35.1, SiO₂ 25.7, H₂O 20.5, TiO₂ (leucoxene impurity) 4.7. Not all water need be essential, hence Cu₂Pb₂Si₅O₁₄.nH₂O. The new mineral and name have been approved in advance of publication by the Commission on New Minerals and New Mineral Names, IMA.

Occurrence. Luddenite was observed on a few samples of dump material at a prospect for Ag-Pb-Cu near Artillery Peak, Mohave Co., Arizona in the spring of 1981. The ores exposed by prospecting are in a fault breccia cemented by quartz and abundant fluorite. Only relict nuggets of the primary galena and chalcopyrite occur in the material which is thoroughly oxidized. A major product of oxidation is alamosite, occurring as tabular euhedral crystals up to 10-12 mm across. In some samples the alamosite is veined by fine-grained melanotekite and minor hyalotekite, the three lead silicates then tending to be replaced by massive but nearly earthy cerussite. Chalcopyrite is replaced by chalcosine, then shattuckite, finally by chrysocolla. Vuggy veinlets lined by drusy quartz cut all of the above minerals and the quartz is intergrown with, or coated by patches of luddenite. Again, the luddenite may alter in part to chrysocolla and lovely euhedral cerussite crystals. Stringers of cream-coloured leucoxene may lie within the quartz druses and are thus often trapped within luddenite as well. Rarely, tiny wickenburgite plates are scattered on the drusy quartz.

Other species noted on specimens collected include wulfenite, mimetite, and malachite. These minerals are generally younger, and they seem to belong to a different and 'normal' oxidation assemblage.

Physical properties. All the luddenite found is microcrystalline, individual grains not exceeding 0.01 mm in size. They form in rosettes or fan-shaped aggregates closely packed together. Where individual grains can be discerned, they are scales or plates with wedge-shaped terminations. The colour of the mineral is a constant nickel green (RHS-130B) with a slightly paler streak. The Mohs hardness of massive material is 4. Several minute fragments were tested in Clerici solution giving a measured specific gravity of 4.45, a value close to the upper limit of the method.

Chemical analysis. A tiny, pure fragment of luddenite was examined by XES fluorescence spectroscopy showing only Pb, Si, and traces of Ca. An impure sample submitted to emission spectroscopy yielded no further elements below Z = 13. The only remaining element possible (F) was later proven absent by wet methods.

Because of the scarcity of perfectly pure material, patches of luddenite picked for analysis were used with leucoxene known to be an impurity. More abundant material mixed with quartz was available, of course, but titanium contamination was certainly the lesser of two evils. The results of the wet analysis, performed on 425 µg by Marjorie Duggan, are presented in Table I.

TABLE I. Chemistry of luddenite

	1 (%)	2	3 (%)	4 (%)
CuO	13.2	0.166	14.0	13.7
PbO	35.1	0.157	37.1	38.5
TiO ₂	4.7	—	—	—
SiO ₂	25.7	0.428	27.2	25.9
H ₂ O	20.5	1.138	21.7	21.8
Total	99.2		100.0	99.9

1. Analysis on 425 µg for Cu, Pb, Ti, Si; H₂O by Penfield method on 48.5 µg.

2. Ratios.

3. Analysis 1 recalculated to 100%.

4. Theory for Cu₂Pb₂Si₅O₁₄.14H₂O.

The results lead to $\text{Cu}_2\text{Pb}_2\text{Si}_5\text{O}_{14} \cdot 14\text{H}_2\text{O}$ as a possible formula. However, owing to the fine grained nature of the material, it is possible that some portion of the water found is non-essential.

The reader may note that Cu:Pb:Si could be equally well 3:3:8. The ratio 2:2:5 fits Cu slightly better, and the analysis of this element is considered superior.

Luddenite is not easily soluble in acids. Dissolution even in heated 50% HNO_3 was slow. It readily fuses to a runny lemon yellow slag in the closed tube.

Optics. In thin section luddenite is green, individual grains showing noticeable pleochroism with γ = rich emerald green, $\alpha = \beta$ = yellow green. Optical study was used to ensure purity of material picked for analysis, for impurities could be readily spotted among such colourful grains. Few good optical data could be obtained, however, because of the minute grain size. The high and low indices of refraction determined in oils are $\alpha = 1.852$, $\gamma = 1.867$. Utilizing various grains thought to be reasonably well oriented $2V_\gamma$ was estimated as 40° from partial birefringence.

As noted before, crystals tend to platy habit. The plane of flattening is a cleavage plane. However, some individuals were noted twinned on a plane normal to the cleavage, the twin plane showing maximum extinction of 32° to the fast ray.

X-ray study. Luddenite gives sharp, clear powder patterns. Since purity of fine-grained material is always a concern, several were prepared from different specimens and they gave identical results. Of course leucoxene (anatase) and quartz were sometimes visible as well.

The powder data are presented in Table II. After numerous attempts, a cell was found by the Ito method that indexed the data in a convincing way. Results of this indexing, shown in Table II, are based on a monoclinic cell $a = 7.85^\circ$, $b = 20.06$, $c = 14.72 \text{ \AA}$, $\beta = 90.78^\circ$. If this cell is used to calculate Z , a value somewhat less than 4 is obtained. However, it is possible, as explained earlier, that some H_2O in the analysis is non-essential. There is also surely considerable error in the specific gravity determination. I think it quite possible that the Ito cell is a rational one and that, in its present form, $Z = 4$.

Additional comments. There are several localities in southwest USA where lead silicates have been

TABLE II. X-ray powder data for luddenite
Cr-K α radiation, 114 mm camera

$I_{\text{est.}}$	$d_{\text{meas.}}$	$d_{\text{calc.}}$	hkl	$I_{\text{est.}}$	$d_{\text{meas.}}$
4	10.00	10.03	020	5	2.888
10	7.361	7.360	002	4	2.642
3	5.331	5.331	102	2	2.608
7	5.218	5.218	$11\bar{2}$	4	2.426
5	4.226	4.225	140	1	2.200
1	3.922	3.922	200	2	2.148
4	3.650	{ 3.653	220	2	2.093
		{ 3.653	141	2	2.040
		{ 3.507	043	1	1.985
5	3.515	{ 3.523	052	2	1.886
		{ 3.517	133	3	1.848
5	3.411	{ 3.430	$21\bar{2}$	1	1.809
		{ 3.392	212	1	1.736
2	3.339	3.343	060	1	1.658
1	3.255	{ 3.256	222	1	1.563
		{ 3.260	061		
10	3.173	3.177	$12\bar{4}$		
8	2.918	{ 2.913	015		
		{ 2.912	223		

found in oxidized base metal ores. All of them, so far as I am aware, are characterized by an abundance of fluorite or fluorosilicates (Tombstone, Arizona; Wickenburg, Arizona; Hillsboro, New Mexico). The presence of fluorine may be essential to the formation of lead silicate assemblages. There are, however, innumerable fluorite-lead veins without lead silicates. Other factors must apply but are still unknown.

The chemistry of luddenite sets it apart from any known Cu or Pb silicates. Since it is more common to find alamosite and chrysocolla, the stability field of luddenite must be a small and strictly defined one.

It is a pleasure to name this mineral for Raymond W. Ludden. As the chief geologist for Western Exploration, Phelps Dodge Corp., for many years, he has encouraged mineralogical and petrographical studies, and I believe these sciences owe him a debt of gratitude.

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