

# Lorandite, A thallium sulfosalt

Ramandeep Dhillon

**Abstract**— Lorandite,  $\text{TlAsS}_2$ , occurs with orpiment, realgar and pyrite in barite veins of Carlin, Nevada, type gold deposits. The mineral is named after Professor Lorand Eotvos, a prominent Hungarian Physicist. The crystal of lorandite is deep red in color, gives cherry red streak, and the luster is adamantine. The mineral is monoclinic, space group  $p2_1/a$ ,  $a = 12.28 \text{ \AA}$ ,  $b = 11.30 \text{ \AA}$ ,  $c = 6.10 \text{ \AA}$ ,  $\beta = 104^\circ 5' (2')$ . Its structure consists of complex spiral chains of  $\text{AsS}_3$  pyramids that run parallel to the  $b$ -axis. Electron microprobe analyses gives Tl 59.46, As 21.87 and S 18.67, sum 100.0 weight percent. The mineral usually occurs in small subhedral grains up to about 4 mm in length. The cleavage parallel to (100) is perfect, that parallel to (001) good, and that parallel to (101) fair. In reflected light lorandite is grey-white with bluish tint and is strongly anisotropic.

## 1 INTRODUCTION

Lorandite,  $\text{TlAsS}_2$ , is a thallium sulfosalt which was first observed in 1895 by Professor Krenner of Budapest, Hungary [1]. The first discovered location of the mineral is in Allchar (Macedonia, Yugoslavia); and a second occurrence was later recognized in U.S.A by Dr. Austin F. Rogers of Stanford University from a sample obtained from Rambler mine, Wyoming, in 1912 [2]. Lorandite occurs in low-temperature mineral deposits in association with orpiment, realgar, pyrite and certain other sulfide minerals; the most familiar location is Allchar, Macedonia [3]. It is commonly used in experiments for the determination of the solar neutrino flux via certain nuclear reactions that involves thallium [4].

## 2 COMPOSITION

The composition of lorandite is  $\text{TlAsS}_2$ . With EMX-SM model electron micro-probe, Dr. Radtke of Stanford University, California, performed chemical analysis of lorandite [5]. Electron microprobe analysis gave Tl 59.46, As 21.87 and S 18.67, sum 100.0 weight percent. His results showed the presence of only thallium, arsenic, and sulfur in detectable amounts. Radtke's chemical analysis of five grains of lorandite are given in Table 1.

Table 1. Chemical Analyses (wt percent) of Lorandite from the Carlin Gold Deposit (Radtke, 1974)

Grain No.	1	2	3	4	5	Average	$\text{TlAsS}_2$
Tl	59.6	59.6	59.4	59.5	59.6	59.5	59.46
As	21.6	21.5	21.7	21.6	21.4	21.6	21.87
S	19.0	18.8	18.6	19.0	18.8	18.8	18.67
Total	100.2	99.9	99.7	100.1	99.8	99.9	100.00

## 3 STRUCTURE

Lorandite has monoclinic symmetry with  $a = 12.28 \text{ \AA}$ ,  $b = 11.30 \text{ \AA}$ ,  $c = 6.10 \text{ \AA}$ ,  $\beta = 104^\circ 5' (2')$ , and space group  $p2_1/a$ ,  $z = 4$  [3]. The most recent study on lorandite's structure was done by Dr. Sherif Kharbush of Suez Canal University, Egypt, in 2011. In his experiments he performed Raman spectroscopic investigation of lorandite [6]. His research describes the structure of lorandite (Figure 2) as complex spiral chains of  $\text{AsS}_3$  pyramids that run parallel to  $b$ -axis. Tl

atoms link the the complex chains of  $\text{AsS}_3$  pyramids. Within each  $\text{AsS}_3$  pyramid, two S atoms act as bridges and the third S atom is bonded to Tl [6]. The S atoms that are bridged are coordinated to two Tl and two As (bridging sulfur atoms,  $S_b$ ) and the S atoms that are not bridged are coordinated to three Tl and one As ( $S_n$ ) atom [3].

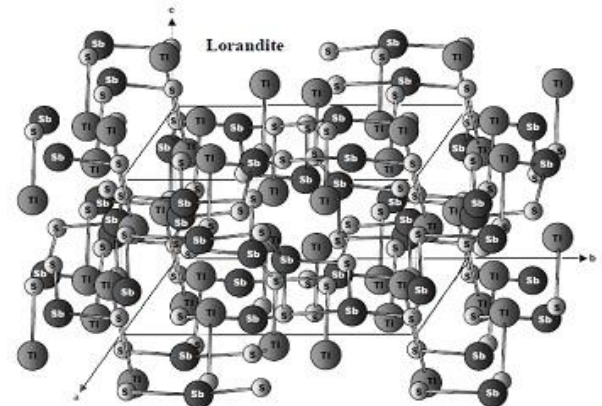


Figure 2. Crystal Structure of lorandite (Kharbush, 2011)

## 4 PHYSICAL PROPERTIES

Lorandite at Carlin, Nevada, as described by Dr. Radtke, is in the form of small subhedral grains up to about 4 mm in length [5]. Despite the low hardness of 2-2.5, it polishes quite well and free of scratches [7]. The mineral's inter-growth occurs with realgar and orpiment in open spaces between tabular crystals of barite [5]. The crystal has a deep red color (figure 3) and easily separates into cleavage lamellae and fibers [8]. Rogers in 1912, determined that the cleavage parallel to (100) is perfect, that parallel to (001) good, and that parallel to (101) fair [2]. In light reflection lorandite crystal is grey-white with bluish tint and is strongly anisotropic [7].

## 5 GEOLOGICAL OCCURRENCE

Lorandite is usually found in low-temperature mineral as-

semblages and is associated with orpiment, realgar, pyrite and certain other sulfide minerals [3]. The tectonic block of Allchar, Macedonia, where lorandite was originally discovered, is an anticline stretch originating from paleozoic sediments of the upper Cretaceous period [9]. During the mineralization processes, presence of andesite rocks caused movements of hydrothermal solutions along the dolomite and andesite contacts enabling the formation of deposits [9]. The separation of arsenopyrite minerals in forms of realgar, orpiment, lorandite, etc, is associated with the mineralization pertaining hydrothermal solutions [10]. Lorandite is a rare hydrothermal mineral that is formed in small quantities in a number of arsenic-thallium bearing gold deposits world wide; some of Nevada occurrences are in Carlin type gold deposits [11].

Figure 3. Lorandite crystal (deep red color) from Allchar, Macedonia.



Source: <http://webmineral.com/specimens/picshow.php?id=689&target=Lorandite>

## 6 BIOGRAPHIC SKETCH

The first discovery of lorandite, from Allchar (Macedonia, Yugoslavia), was announced by Professor Krenner of Budapest, Hungary, in 1895 [1]. He named the mineral lorandite in honor of Professor Lorand Eotvos, a prominent Hungarian Physicist [8]. Eotvos contributed mainly to the field of Physics by his experiments related to gravity and magnetism; the most important invention was Eotvos Torsion balance instrument, which helped in the discovery of hundreds of oil fields during 1920's and 1930's [12]. For his outstanding contributions to the field of physics, University of Budapest, Hungary, was also later re-named to Eotvos Lorand University in 1950.

## 7 LITERATURE SURVEY

The most highly cited paper on lorandite is by M.S. Fleet "The crystal structure and bonding of lorandite,  $Tl_2As_2S_4$ " (1972). Web of science has 27 citations of the journal. In his study, Fleet re-determined the positions of S and As atoms and found it to be different from the previously reported work by Zeemann & Zeemann. The crystal structure representation of lorandite on webmineral uses the structure modeled by Zeemann & Zeemann in 1959, which has a dif-

ferent coordination of S atoms than the later study done by M.S Fleet in 1972, and Kharbish in 2011. Second article that has a high citation list of over 70 is related to LOREX, the acronym of Lorandite Experiment. The journal by Melvin S. Freedman is titled "Solar Neutrinos: proposal for a new test" [13]. The experiment is about using lorandite to determine the solar neutrino flux via certain nuclear reactions involving thallium [4].

## ACKNOWLEDGMENT

This research paper was originally submitted to Dr. Jonathan Snow of University of Houston.

## REFERENCES

- [1] C. William, "Lorandite, a new thallium mineral," *The Chemical News & Journal of Physical Science*, Volume LXXI, No. 1839, Page 91, 1895.
- [2] Rogers Austin, "Lorandite from the Rambler Mine, Wyoming," *American Journal of Science*, Series 4 Vol. 33, February 1912, P.105-106, 1912.
- [3] M.E. Fleet, "The crystal structure and bonding of lorandite,  $Tl_2As_2S_4$ " *Zeitschrift für Kristallographie*, 138: 147. 1972.
- [4] M. Pavicevic, "AMS measurements of  $^{26}Al$  in quartz to assess the cosmic ray background for the geochemical solar neutrino experiment LOREX," *Nuclear Instruments and Methods in Physics Research Section B* 223-224: 660, 2004.
- [5] A.S. Radtke, C.M. Taylor, R.C. Erd, and F.W. Dickson, "Occurrence of lorandite,  $TlAsS_2$ , at the Carlin gold deposit, Nevada," *Economic Geology*, 69, 121-174, 1974.
- [6] S. Kharbish, "Raman spectroscopic investigations of some Tl-sulfosalt minerals containing pyramidal (As,Sb) $S_3$  groups," *American Mineralogist*, Volume 96, 609-611, 2011.
- [7] Ramdohr Paul, *The ore minerals and their intergrowth*, 2<sup>nd</sup> edition. Vol. 2, Pg 732, 1980.
- [8] C. Palache, H. Berman, and C. Frondel *Dana's system of mineralogy*, (7th edition), v. I, 437-439, 1944.
- [9] M.K. Pavicevic, "Lorandite from Allchar - A low energy solar neutrino dosimeter," *Nuclear Instruments and Methods in Physics Research*. Page 287-296, 1988.
- [10] T. Ivanov, Symp. on Postmagmatic Ore Deposit, Prague. Volume 2. Page 186, 1965.
- [11] Castor B. Stephen, Ferdock C. Gregory, *Minerals of Nevada. Nevada Bureau of Mines & geology* 31, page 311, 2004.
- [12] Szabo Zoltan, "Biography of Lorand Eotvos," *The Abraham Zelmanov Journal*. Vol. 1, Pg 7 - 13, 2008.
- [13] Freedman Melvin, "Solar Neutrinos: Proposal for a new test," *Science magazine*. Volume 193, p 1117- 1119, 1976.