

## Research Advances

# Discovery of Lorandite $\text{TlAsS}_2$ at the Distal Au–Tl Deposit in a Skarn system, Fengshan Area, Middle–Lower Yangtze River, Eastern China

XIE Guiqing<sup>1,\*</sup>, MAO Jingwen<sup>1</sup>, HAN Yingxiao<sup>2</sup>, JIAN Wei<sup>1</sup> and HAN Jingyi<sup>1</sup>

<sup>1</sup> MLR Key Laboratory of Metallogeny and Mineral Assessment, Institute of Mineral Resources, CAGS, Beijing, 100037, China

<sup>2</sup> Faculty of Sciences and Mineral Resources, China University of Geosciences, Beijing 100083, China

## Objective

Thallium has been used as an indicator element in geochemical exploration of searching for hydrothermal gold deposits. However, the Tl minerals and mineralization are rare in nature. Lorandite  $\text{TlAsS}_2$ , a relatively uncommon mineral, has been dominantly discovered in some Carlin gold deposits, and minor Sb–Hg, U and Pb–Zn–Ag deposits. It is of a hydrothermal origin and was typically formed at relatively low temperatures. The relationships between these deposits containing lorandite and intrusions remain a highly controversial subject. Recently, two sediment-hosted gold deposits (Caojiashan and Zhulintiang) around the skarn deposits in the Fengshan area, Middle–Lower Yangtze River (MLYR), Eastern China (Fig. 1), have been recognized as the distal products of a skarn system. This work firstly discovered lorandite at Zhulintiang and focused on its characteristics and implications.

## Methods

Lorandite is often intergrown with calcite, fluorite and realgar, native tellurium, barite and celestine. Lorandite crystals up to  $22 \times 28$  mm in size (Fig. 2) were carefully hand-picked under a binocular microscope before the sample (ZLT–13–2) had been crushed and sieved to about 0.9 mm with the purity over 99%. Some lorandite grains were mounted in epoxy resin disk and polished, while other grains were further grinded to about 0.07 mm power in an agate mortar. Power X-ray diffraction (XRD) analysis was performed using a Bruker D8 Advance Diffractometer. Laser Raman spectroscopy (LRS) analysis of two run gains and in situ three grains in disk was carried out using Renishaw System 2000 with 20 mW. Tl, As and trace elements, and sulfur analysis were performed using PE300D ICP–MS, and chemical methods, respectively, at the National Research Center of Geoanalysis, Chinese Academy of Geological Sciences.

## Results

Mineral identification for XRD was carried out through peak comparison against the International Centre for Diffraction Data's (ICDD) Powder Diffraction File mineral database. Figure 3 and 4 show the XRD patterns and LRS spectra of lorandite sample (ZLT–13–2) at Zhulintiang, respectively. The XRD intensity peaks of lorandite at Zhulintiang are similar to those of standard lorandite (01-0712427). The five runs Raman spectrums of lorandite at Zhulintiang correspond to that of lorandite from the Allchar deposit, Macedonia (Journal of Raman Spectroscopy, 2014, 45: 610–617), which is the largest and richest Tl resource

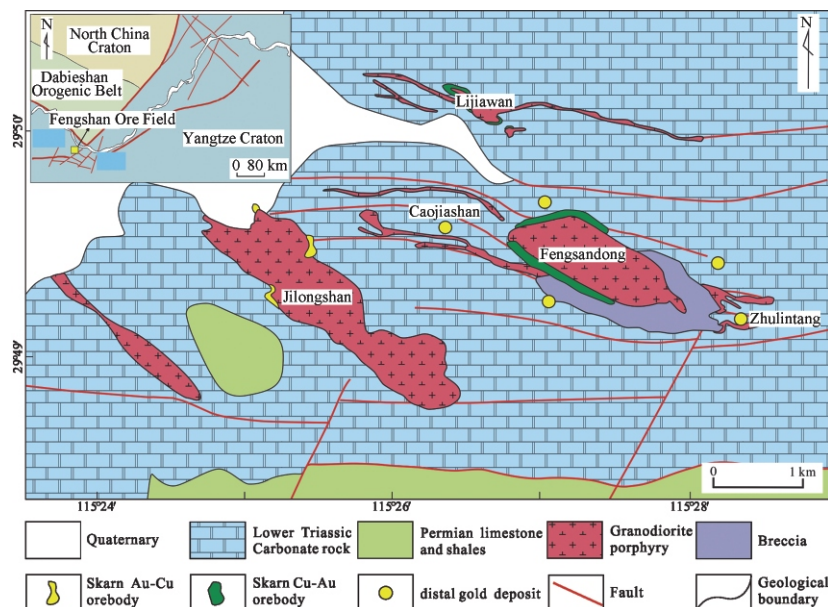


Fig. 1. Simplified geologic map of the Fengshan area, MLYR, Eastern China.

\* Corresponding author. E-mail: xieguiqing@cags.ac.cn

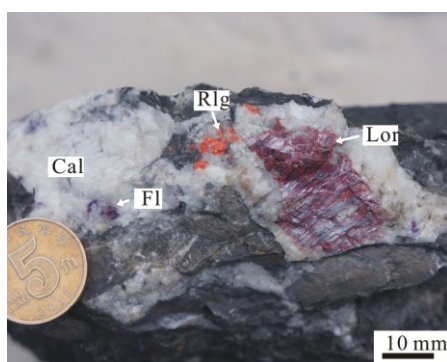


Fig. 2. Specimen of lorandite at Zhulintiang, Fengshan area, MLYR.

Cal, Calcite; Fl, fluorite; Rlg, Realgar; Lor, Lorandite.

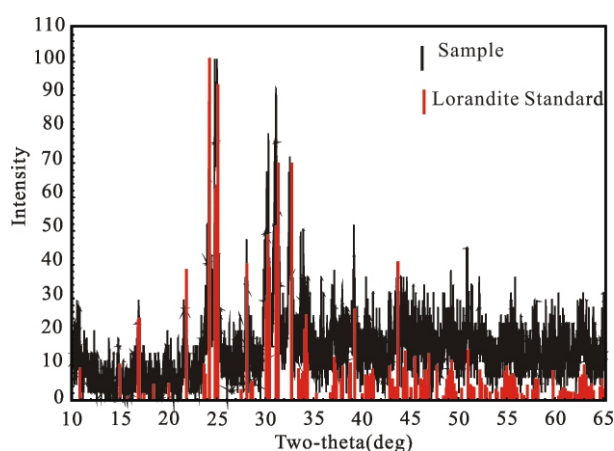


Fig. 3. XRD patterns of lorandite at Zhulintiang in the Fengshan area, MLYR.

known in the world. In addition, lorandite at Zhulintiang contains 600133 ppm Tl, 213467 ppm As and 18.70% S, similar to lorandite from the Allchar deposit (Table 1).

Extremely rare lorandite has been discovered in Carlin gold deposits in Nevada, American and NW Guizhou Province, China. The Allchar Au-As-Sb-Tl deposit is similar to Carlin gold deposits in the Western United States. Visible native gold is absent in these Carlin deposits. Gold ores at Zhulintiang have relatively high Tl contents up to 2016 ppm (our unpublished data), similar to economic Tl grades (1000–5000 ppm) from the Allchar deposit. The lorandite at Zhulintiang have higher Ba (113 ppm), Sr (37.2 ppm), Sb (1407 ppm) and Pb (16.7 ppm) contents than Allchar lorandite, indicating a greater

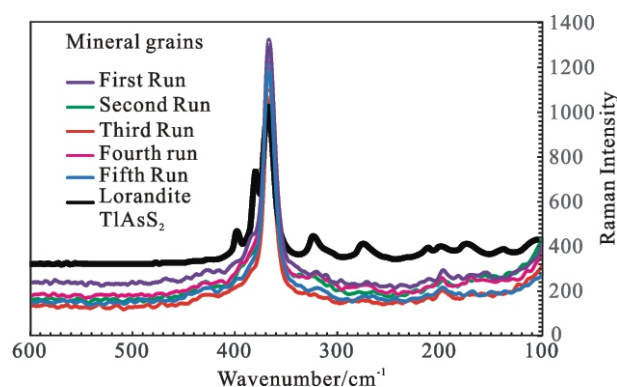


Fig. 4. Raman spectra of lorandite at Zhulintiang in the Fengshan area, MLYR.

magmatic contribution in the mineralizing hydrothermal solutions than is typical of Carlin gold deposits. Native tellurium and coloradoite are present at Zhulintiang close to skarn deposits, similar to the occurrence of coloradoite in the Zarshuran Carlin-like gold deposit, NW Iran. But skarn deposits have been reported 5 km away from the Zarshuran gold deposit.

## Conclusions

Both XRD and Raman spectrums evidence demonstrated the occurrence of rare lorandite at Zhulintiang. Lorandite at Zhulintiang show similar concentrations of Tl, As and S to lorandite from the Allchar deposit, Macedonia, but has higher Ba, Sr, Sb and Pb contents. It is the first reported occurrence of lorandite in a skarn system.

## Acknowledgements

We thank Zhu Qiaoqiao, Fu Bin, Yu Wanming, Deng Yuejin, Xiong Xin and Yang Dan for providing invaluable assistance during our field investigation and analysis. This work was supported by the National Science Foundation of China (grants No. 41372090 and 41573042), the National Special Research Programs for Non-Profit Trades (grant No. 201311136), Basic Scientific Research Operation Cost of State-Leveled Public Welfare Scientific Research Courtyard (grant No. K1203).

**Table 1 Compositions of lorandite from the Zhulintiang distal Au-Tl deposit in the Fengshan area, Middle-Lower Yangtze River, Eastern China**

Sample	S <sup>1</sup>	Tl	As	Li	Cr	Mn	Co	Ni	Cu	Zn	Rb	Sr	Mo	Cd	In	Cs
ZLT-13-2	18.70	600133	213467	0.39	2.26	7.82	0.08	0.79	4.70	10.6	0.46	37.2	0.46	0.07	1.19	0.07
Alshar deposit	18.10	602999	195996	0.125	2.24	1.03	-	0.11	0.17	0.12	-	0.084	0.113	0.501	+	-
Sample	Ba	Pb <sup>2</sup>	Bi	Th <sup>2</sup>	U <sup>2</sup>	Nb	Ta	Zr	Sn	Sb	Ti	W	V	La	Ce	Y
ZLT-13-2	113	16.7	0.16	0.02	0.02	0.37	0.05	1.45	0.30	1407	5.20	70.1	0.42	0.21	0.13	0.07
Alshar deposit	0.051	0.79	-	0.0092	0.039	+	+	+	0.408	0.176	3.4	+	0.68	+	+	+

Note 1, S: %, other elements: ppm; 2, Pb, Th, U contents of lorandite from Alshar deposit measured by mass spectrometry (Nuclear Instruments and Methods in Physics Research, 1988, A271: 251–252), other elements by ICPMS (Geologica Macedonica, 2016, 4: 405–412).-, lower analysis limit; +: no data.