

Liberation of Tl-Rich Minerals From the Ore of the Allchar Mine

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Abstract

The methods are described of selective separation of thallium mineral lorandite from the Allchar hydrothermal-volcanogenic Sb-As-Tl deposit (FYR Macedonia) characterized by relatively complex mineralization. In addition to antimony and arsenic, the Allchar Mine at the village of Majden works one of the richest thallium mineral lorandite deposits. The aim of the research was to separate lorandite as much and as free grain as possible mainly through physical concentration. Thallium is very important because of a possibility to apply its mineral lorandite (TlAsS₂) in obtaining knowledge in fundamental investigations. The reaction between Tl and solar neutrinos, producing Pb, is on the purpose of studying the neutrino flux from the Sun. For this purpose, a thallium-rich mineral is required as the target. Geochemically natural, pure thallium mineral lorandite is used to test solar neutrino under the current, two decades long LOREX Project. The Allchar ore from Crveni Dol contains a comparatively complex association of Sb-As-Tl minerals: pyrite, marcasite, antimonite, arsenopyrite, realgar, auripigmentum, barite, cinnabar, and accessory thallium lorandite, vrbaita, raguinite, picopaulite, parapirotite, rebulite, greigite, tetrahedrite, and various sulphosalts that are found only in Allchar. The research used conventional laboratory methods for mineral fractionation and for liberation of lorandite grains, which included size reduction, sieve analysis, Wilfley table, sink and float analysis (bromoform, methylene iodide), electrostatic separation, electromagnetic separation and centrifugal separator. Gradual separation from successive comminution and classification of fractions allowed separation of the free sink (heavy) product from which nonconductive minerals, including lorandite, were selected.

Keywords: lorandite, Allchar mine, concentration techniques, selective separation, Tl-mineral characterization, mineral liberation

Introduction

Lorandite is the only mineral considered for generation of ecofriendly energy (name after Eotvos Lorand, physicist from Budapest, 1984). This thallium mineral is able to detect 'neutrino' particles from the Sun core, which is used in research of a solar-like energy, a powerful source of free energy generation. Geochemically natural, pure thallium mineral lorandite is used to test solar neutrino (Jelenković et al., 2011) under the current, two decades long LOREX Project (acronym of LORandite and EXperiment). For a continuous research, the monomineral lorandite component has to be separated from the complex Sb-As-Tl ore.

Thallium is an important mineral for the lorandite (TlAsS₂) component used in acquiring knowledge for fundamental investigation. Freedman et al. (1976) propose to use the reaction between Tl and solar neutrinos, producing Pb, for study of the neutrino flux from the Sun. The idea is to quantify the Pb assemblage in thallium minerals. Lorandite is one of the thallium-rich minerals proposed for the purpose (Zendelovska and Stafilov, 2000).

Samples and methods

Mineral samples of the test were collected at Crveni Dol from the only left and abandoned Allchar mine. Allchar, a hydrothermal-volcanogenic

Sb-As-Tl deposit, is located near the Macedonian/Greek border, on the NW Kozhuf Mountain, part of the Serbian-Macedonian metallogenic province, or the Kozhuf ore assemblages (Janković & Jelenković, 1994; Janković et al., 1997; Volkov et al., 2006). Formation of the deposit is associated with the evolution of a complex volcanic intrusion in the Pliocene and the concomitant activity of a hydrothermal ore-bearing system (Jelenković et al., 2011).

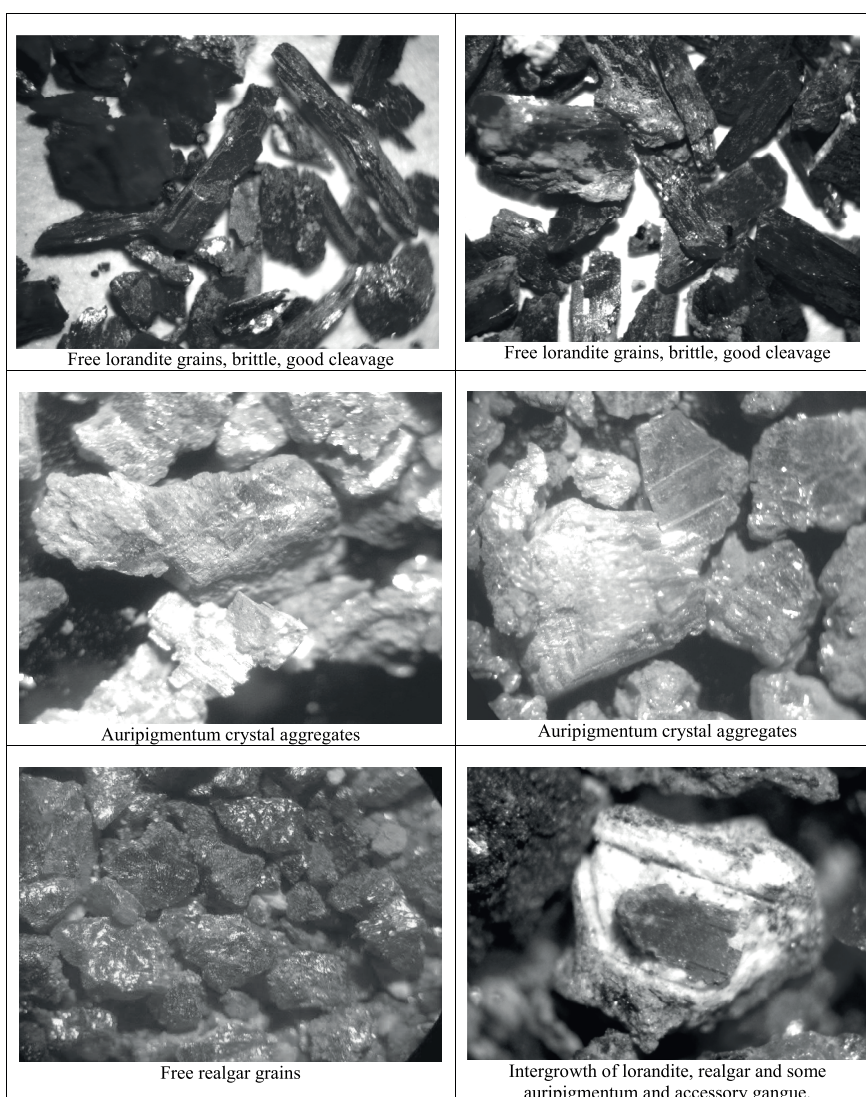
Allchar is a complex mineral deposit. Pyrite and marcasite formed in an early stage, followed by hydrothermal activity that produced arsenopyrite, antimonite and sulphosalt Sb-Pb and the process closed with the formation of realgar, orpiment and Tl-sulphosalt (Pavičević & Goresy, 1988; Serafimovski et al., 1990; Balić-Žunić et al., 1993; Janković, 1993; Beran et al., 1994; Frantz, 1994). The group of identified ore minerals was used to determine geochemical associations of elements in the deposit (Jelenković et al. 2011). The essential ore elements were found to be Sb, As, Tl and Au, associated Hg and Ba, and Pb, Zn and Cu in traces. High Tl concentration is related to parts of the deposit with elevated As, Sb and Hg (Jelenković et al., 2011).

This paper treats lorandite concentration tests on the laboratory scale. The raw material first is

Tab. 1. Paragenetic association of Allchar minerals and their properties

Tab. 1. Paragenetyczne asocjacje minerałów Allchar i ich właściwości

	Name	Formula	Density	Properties
1.	Pyrite	FeS ₂	5,2	$\rho = 10^{-5} \div 10^{-1}$ om m; Conductor;
2.	Marcasite	FeS ₂	4,9	$\rho = 10^{-3} \div 10^{-1}$ om m; Conductor;
3.	Stibnite	Sb ₂ S ₃	4,6	Conductor;
4.	Arsenopyrite	FeAsS	6,0	$\rho = 10^{-5} \div 10$ om m; Conductor;
5.	Native arsenic	As	5,8	Conductor;
6.	Tetrahedrite	Cu ₁₂ (As,Sb) ₄ S ₁₃	4,8	$\rho = 7 \cdot 10^{-4} \div 10^{-1}$ om m; Conductor,
7.	Cinnabar	HgS	8,0	Conductor;
8.	Realgar	AsS	3,6	Nonconductor;
9.	Orpiment	As ₂ S ₃	3,5	Nonconductor;
10.	Barite	BaSO ₄	4,5	Nonconductor;
11.	Lorandite	TlAsS ₂	5,5	Eotvos Lorand, Budapest, nonconductor;
12.	Vrbaite	Tl ₄ Hg ₃ Sb ₂ As ₈ S ₂₀	5,3	Professor Karel Vrba, Prague. Conductor;
13.	Raguinite	TlFeS ₂	6,3	Professor Raguin, Paris. Semiconductor;
14.	Picotpaulite	TlFe ₂ S ₃	5,2	Conductor
15.	Parapirotite	TlSb ₅ S ₈	5,0	Conductor
16.	Rebulite	Tl ₅ Sb ₅ As ₈ S ₂₂	4,8	Sloveian geologist Rebula;
17.	Routhierite	TlHg ₂ As ₂ S ₆	5,8	Conductor, metallic



Tab. 2. Concentrates, monomineral fractions of separated minerals (lorandite, auripigmentum, realgar)

Tab. 2. Koncentraty, frakcje monomineralne minerałów: lorandyt, auripigment, realgar

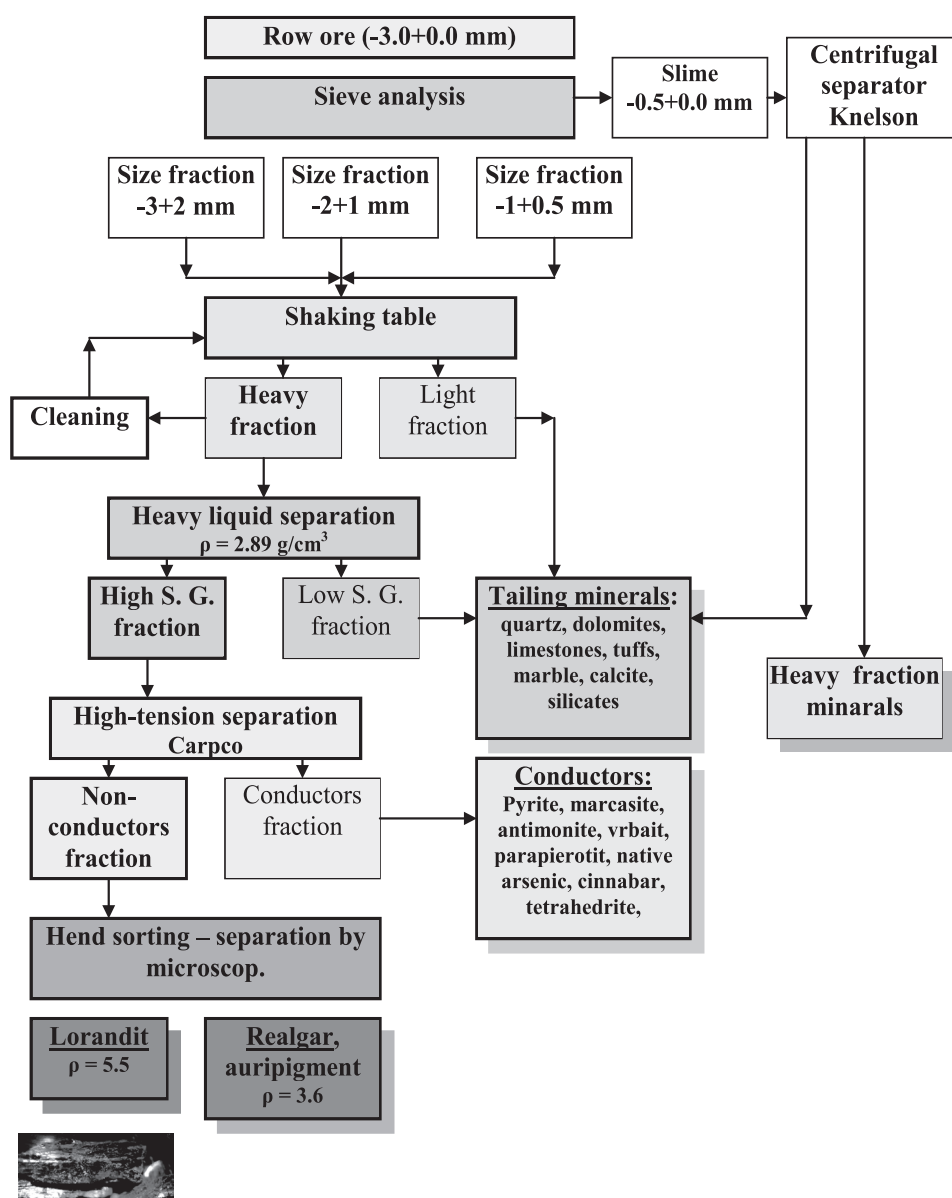


Fig. 1. Flow chart of selective mineral separation testing

Fig. 1. Badanie selektywnej separacji minerałów

successively fragmented and classified to remove lorandite grains before over-communion. Optimum liberation of lorandite from accessory minerals progressed in stages to the final four size classes (-3.00+2.00 mm; -2.00+1 mm; 1.00+0.5 mm; and -0.5+0.00 mm). Each size fraction but slime was sink-and-float analysed in dense liquid (bromoform $\rho = 2.89 \text{ g/cm}^3$, iodoform $\rho = 3.30 \text{ g/cm}^3$). Almost all heavy minerals, sulphides, sulphosalts, and all thallium minerals were separated from the heavy fraction including lorandite. The light fraction consisted of gangue accessories (limestone, dolomite, different silicates, etc.). The heavy mineral fraction, after being washed from the dense liquid and some preparation, was exposed to elec-

trostatic separation that produced opaque minerals (lorandite included) and minerals of good electrical conductivity (all metal sulphides, sulphosalts including thallium, etc.). Electrical conductivities of some minerals from the association are given in Tab. 1. The flow chart of lorandite separation is given in Fig. 1.

Results and discussion

Fractionation of mineral ore in laboratory for separation of free lorandite is based on physical properties of the associated minerals (Tab. 1). Lorandite separation is based on the electrical conductivity or non-conductivity of some minerals, on density, cleavage, colour, or other op-

tical properties. Gradual separation from successive comminution and classification of fractions allowed separation of the free sink product from which nonconductive minerals, including lorandite, were selected; electroconductive (metallic) minerals remained in the other fraction. The process of the monomineral separation is represented in Fig. 1. Table 2 shows microphotographs of the separated monomineral fractions.

Conclusions

Complicated and costly research of neutrino from the Sun core needs continuous refinement of the lorandite concentration process. The laboratory sequence of fractionation of the complex run of mine ore, as proposed in this paper, yields lorandite concentrate of high quality, large grain size, at somewhat lower rate of recovery.

Lorandite loss occurred through separation of slime, the finest size class ($-0.5+0.0$ mm), on the Knelson separator. The separation product was a collective concentrate of heavy minerals containing all thallium minerals including lorandite. For the recovery of thallium, this concentrate can be subjected to leaching. The degree of liberation of very large lorandite crystal aggregates, under 3 mm, even under 2.5 mm, is higher than 98%, whereas that of realgar grains smaller than 2 mm (powder particles in free grains) is lower than 1%. The mass proportion of lorandite concentrate is highest in the coarsest size fractions, and even some ten times lower in the next lower size fractions; the proportion of lorandite is lowest in the finest size fractions. The described process yields best lorandite concentrate of large crystal aggregates, but the treatment is much specialist time-consuming.

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Uwolnienie minerałów tytanonosnych z rudy z Kopalni Allchar

Opisano wybrane metody separacji talu z minerału lorandytu ze złoża hydrotermalnego – wulkanogenicznego Sb-As-Tl w Allchar (Macedonia) charakteryzującego się relatywnie złożoną mineralizacją. Oprócz antymonu i arsenu, kopalnia Allchar w wiosce Majden jest jednym z najbogatszych złóż talu w lorandycie. Celem badań było separacja lorandytu i uzyskanie jak największego uwolnienia minerałów za pomocą separacji mechanicznej. Tal występuje w mineralu lorandyt (TlAs₂). Celem badań jest uzyskanie koncentratu bogatego w tal. Czysty tal w mineralu lorandyt jest używany do badań neutron w promieniowaniu kosmicznym w projekcie LOREX Project, realizowanym od 20 lat. Ruda Allchar z CrveniDol zawiera stosunkowo złożoną kombinację związków Sb-As-Tl: pirytu, markazytu, antymonianu, arsenopirytu, reagliaru, auripigmentu, barytu, cynobru, oraz dodatkowo związków talu lorandytu, vrbaitu, raguinitu, pikopaulitu, parapierrytytu, rebulitu, greigitu, tetrahedrytu i różnych soli siarkowych, które można znaleźć jedynie w Allchar. W badaniu zastosowano konwencjonalne metody laboratoryjne separacji mechanicznej i wydzielania ziaren lorandytu, uwzględniając rozdrabnianie, analizę sitową, wzbogacanie na stole Wilfley'a, analizę granulometryczną (w bromoformie, jodku metylenu), separację elektrostatyczną, separację elektromagnetyczną oraz separator odśrodkowy.

Słowa kluczowe: lorandyt, kopalnia Allchar, technologie wzbogacania, separacja selektywna, minerały Tl, uwolnienie minerałów