Primary Fluid Inclusions in Galena Crystals. I. Morphology and Origin

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Large gas-liquid inclusions are found in the galena crystals from some hydrothermal lead-zinc deposits. Inclusions' vacuoles are negative crystals. Their habit, macro- and micromorphology and arrangement are studied. Inclusions have a primary character. It is assumed that gas bubbles formed in heterogeneous boiling solutions have played an important role in their formation. The galena surface over the outermost inclusions is plastically deformed, and specific depressions, or infrequently bulges, are formed. The causes and conditions of the deformation are discussed. Similar positive plastic deformation is reproduced experimentally. The liquid released by opening the inclusions evaporates rapidly depositing NaCl and KCl in an epitaxic orientation on the fresh galena cleavage surface.

INTRODUCTION

The methods for studying fluid inclusions in crystals of natural minerals were developed and are applied mostly on transparent objects. Data on inclusions in opaque ore minerals, and among them in galena, an ore component of major importance, are quite scarce.

Sometimes in the large crystals from the hydrothermal lead-zinc deposits there are abundant, comparatively large fluid inclusions of specific features. Those are "hidden" inclusions which can be revealed by splitting the galena crystals along the planes of perfect cleavage (100). The first to find and describe such inclusions in galena from Joplin was Buerger (1932). However, as shown in a previous note (Bonev, 1969), the crystal face around inclusions situated near the surface is deformed and this is a direct indication of their location.

One of the fundamental assumptions in studying fluid inclusions for the purposes of geothermometry is that the vacuole volume remains practically constant after the conservation of the inclusion (Roedder, 1967). Galena presents an example of a mineral for which this assumption is not always valid, a fact perhaps unexpected yet perfectly natural.

The present study aims at presenting and discussing the data on the morphology and some aspects of formation of inclusions in galena. In Part II, the methods and the results of a number of chemical analyses of the composition of the liquid and gaseous phases of inclusions from the deposits in the Madan ore district, Bulgaria, are reported.

DEPOSITS AND CONDITIONS OF OCCURRENCE

Fluid inclusions are found in the early (I and II) generations of large galena crystals in the lead-zinc deposits of the
Central Rhodope Mountains and particularly in the two main ore districts, the Madan district (the deposits of Strashimir, Lalkov Choukar, Pechinski, Gradishte, Borieva, Gyudyurska, Petrovitsa, Baram, Mogilata, Ossikovo, Fabrika and others) and the Luki district (the deposits of Kenan Dere, Govedarnika, Djourkovo etc.).

The ore bodies occur there as steep NW or meridional ore zones cross-cutting a Pre-Cambrian metamorphic complex (various gneisses and granite-gneisses, amphibolites, marbles and pegmatites) as well as some Tertiary (Upper Eocene and Oligocene) conglomerates and individual rhyolite dykes (Oligocene). Six large and several smaller ore zones extend over a distance of 10 to 15 km, their thickness varying from 0.5 to 2 and more m. Bed-like, mushroom-shaped and irregular metasomatic ore bodies with manganese skarn pyroxenes are formed in the places where the zones cut through marble beds (1 m to 10-20 m thick).

The mineral composition of the ores is comparatively uniform (Mincheva-Stefanova and Gorova, 1965; Bogdanov and Mincheva-Stefanova, 1974), consisting of galena, sphalerite, pyrite, chalcopyrite, some arsenopyrite, fahlore, quartz, carbonates, barite and other rarer minerals. The mineralization is represented by the following successive parageneses: skarn, quartz-pyrite, quartz-galena (with large cuboctahedral, octahedral or cubic crystals of galena I, sometimes reaching 10 or 15 cm), quartz-sphalerite-galena (with dark sphalerite and galena II as cuboctahedral or cubic crystals up to 1.5 cm in size), late quartz-pyrite-arsenopyrite and quartz-carbonate paragenesis (with late small-grained galena).

In the upper levels mainly, the veins and the metasomatic bodies contain abundant cavities extending to several meters, where crystal druses of sulphides, quartz and carbonates are formed.

According to data on the homogenization of fluid inclusions in quartz (Chernokolov, 1969; Kolkovski and Petrov, 1972) the quartz-sulphide parageneses are formed in the temperature interval 360°-330°-300°C, and in some deposits to 280°C. The final quartz-carbonate paragenesis is lower-temperature: 280°-200°-180°C.

The absolute age of the ores is 35 million years (Bogdanov et al., 1974). From geological and geomorphological data through reconstruction of the position of the Lower Miocene denudation surface (Atanassov et al. 1963) it can be assumed that the intermediate, richest ore levels in the Madan and Luki districts (650 to 800 m) are formed at a depth of about 1000-1200 m from the earth surface of that time. Hence, the pressure during the ore formation, if assumed to be hydrostatic, was of the order of 80 to 100 bars. For a fluid with low salinity (~5% NaCl - see Part II) and T 310°C the vapor pressure is about 100 bars (95.6 bars - Haas, 1971). Therefore, during the main sulphide deposition, the hydrothermal solutions at such a depth, were boiling.

Fluid inclusions similar to those from the Madan and Luki districts were observed also in the galena crystals from Zvezdel and Madjarevo medium-temperature vein deposits (Eastern Rhodopes) as well as from the skarn-polymetallic deposits of Tetyukhe (USSR) and Trepa (Yugoslavia) and from the Kratovo vein deposit (Yugoslavia). Chesnokov (1974) describes similar inclusions in galena from the Beresovskoe gold deposit (USSR). Thus, this type of inclusions may be regarded as comparatively wide-spread in hydrothermal galena.

**MORPHOLOGICAL CHARACTERISTICS OF THE INCLUSIONS**

The vacuoles including the fluid in the galena are typical negative crystals. They are bounded by the (100) and (111) faces of galena and their corners and edges are rounded. In general appearance they resemble the inclusions in transparent minerals.

**Size**

The vacuoles are visible with the unaided eye. They vary in size from fractions of