

FLUID AND MINERAL INCLUSIONS AND INCLUSION ZONES OF CAVE CALCITE FROM KORSNÄS MINE, WESTERN FINLAND

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Inclusions and crystal forms of calcite crystals from a cave in the Korsnäs lead-lanthanide mine in western Finland have been studied. The primary fluid inclusions in the scalenohedral yellowish calcite show homogenization temperatures of 79° to 103°C and salinities of 3.6 to 4.9 eq. wt. % NaCl. The prevailing crystal form is scalenohedron. In some specimens it reveals a rhombohedral phantom. Four mineralization stages are proposed on the basis of correlation between inclusion zones in multiple-zoned calcite crystals.

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Introduction

During mining operations in the Korsnäs lead-lanthanide mine (closed 1972), situated about 30 km south of the town of Vaasa in western Finland, a cave was found 190 m below the earth's surface (Tuominen 1961). The cave (0.5 m × 1.5 m × 30 m) is part of a vertical fracture zone. Its walls were partly covered by euhedral crystals of calcite, harmotome, apophyllite, pyrite and apatite; the main mineral was calcite. A small amount of euhedral quartz and ancylite was also found. Apophyllite and harmotome have been described by Sahama (1965) and Sahama and Lehtinen (1967). An age of 88 Ma was determined for yellow apophyllite by the

K/Ar-method (Dr. Eric Welin, written communication in 1975). The isotopic composition of the galena indicates an age of 1770 Ma for the sulphide ore (Isokangas 1975).

The cave mineralization was studied by collecting information from the fluid and mineral inclusions of different zones in individual calcite crystals. On the basis of the mode of occurrence of the inclusions an inclusion »stratigraphy» was established that is comparable to the sphalerite »stratigraphy» described by Roedder (1977) as a result of a study of sphalerite zoning and paragenesis at Creede, Colorado. The calcite »stratigraphy» established gives an overall view of the cave mineralization in the Korsnäs mine.

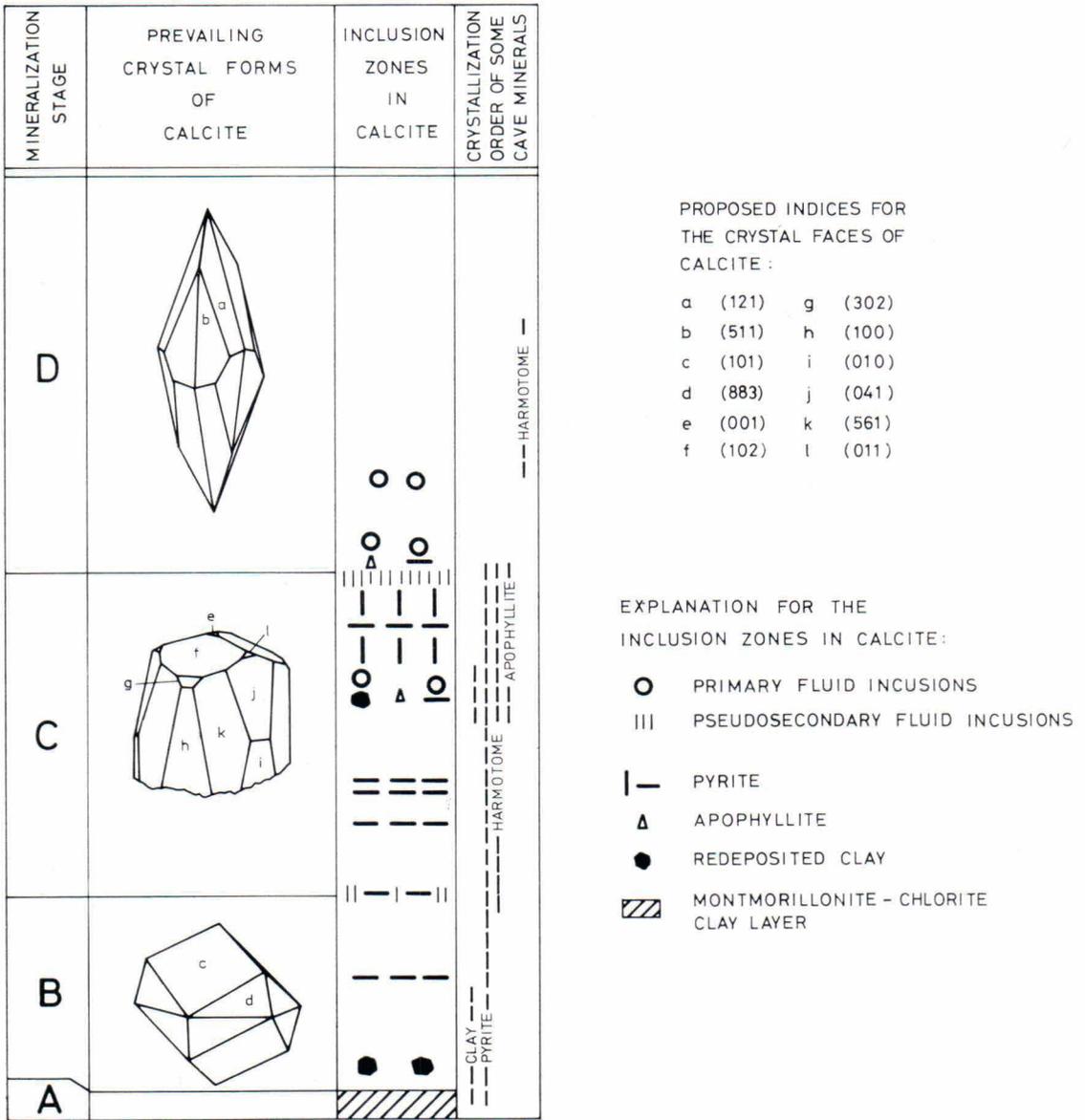


Fig. 1. The proposed mineralization stages, prevailing crystal forms of calcite, inclusion zones in calcite and the suggested crystallization order of the main cave minerals.

Materials and methods

Thirty euhedral calcite crystals, varying in length from 2 to 7 cm, were examined. Calcite shows parallel growth, and most of the specimens exhibit scalenohedral morpho-

logy. Some of these yellowish translucent scalenohedrons contain a white pyrite-covered rhombohedral phantom marking the earlier growth stage of the crystal. Individual rhombohedral calcite crystals were also found. A few of the calcite crystals are

yellow and either transparent or translucent. The transparent crystals are characterized by a basal plane. In some crystals the pyramidal faces are curved. The three prevailing crystal forms are depicted in Fig. 1.

The homogenization temperatures of the fluid inclusions were determined with a Leitz 350 heating stage and a Chaixmeca microthermometry apparatus. The Chaixmeca stage was also used for the freezing point determinations. The temperature readings were calibrated with organic melting point standards. The accuracy of the temperature measurements was $\pm 2^\circ\text{C}$, at 50° to 150°C , and $\pm 0.1^\circ\text{C}$ at -5° to 0°C .

Mineralization stages

The cave mineralization was divided into four stages on the basis of the mineral paragenesis and the prevailing crystal forms of calcite (see Fig. 1). Mineralization stage A is characterized by the crystallization of montmorillonite-chlorite clay, stage B by the crystallization of rhombohedral calcite and pyrite, stage C by the crystallization of scalenohedral calcite, harmotome and apophyllite and stage D by the crystallization of yellowish scalenohedral calcite. The crystallization order of the cave minerals was inferred from the mineral inclusion zones in calcite crystals, the mineral crystallizing in the cave often having been trapped inside growing calcite.

Inclusion zones

The crystal habit of pyrite is distinct and hence characteristic in the different inclusion zones of the proposed mineralization stages (Fig. 1). This observation was utilized in correlating the fluid inclusion zones found in

individual calcite crystals. In mineralization stage A the pyrite inclusions simulate a cube; in stage B they are elongated cubes. The calcite generation of mineralization stage C contains pyrite inclusions showing parallel growth. The oldest pyrite generation in this mineralization stage is a cube whose growth started with the formation of the (112) crystal face. In the following zones of stage C, pyrite exhibits parallel growth along the triad axis. The habit of pyrite in the fifth and sixth inclusion zones is similar to that of the first. The youngest pyrite of stage C shows parallel growth along the triad axis. The pyrite in the youngest calcite from stage D is combination of a cube and a pentagonal dodecahedron.

Apophyllite and clay are found in three different inclusion zones (Fig. 1). Primary fluid inclusions were usually formed in these zones when pyrite, apophyllite or clayey material disturbed the growth of the crystal faces of calcite. Calcite crystals of similar habit have similar outermost inclusion zones, which confirms their contemporaneous crystallization.

Pseudosecondary fluid inclusions characterize two of the inclusion layers situated between the mineralization stages. At the end of stage B white calcite with a rough surface had crystallized over the rhombohedron in a layer about 0.5 mm thick that was found to contain appreciable pseudosecondary fluid inclusions. Before the youngest calcite generation crystallized, a fracture layer about 0.2 mm thick developed on some of the faces of the calcite crystals. Pseudosecondary fluid inclusions are abundant in these fractures as well.

Fluid inclusions

The primary fluid inclusions in calcite were found to be concentrated in specific inclusion

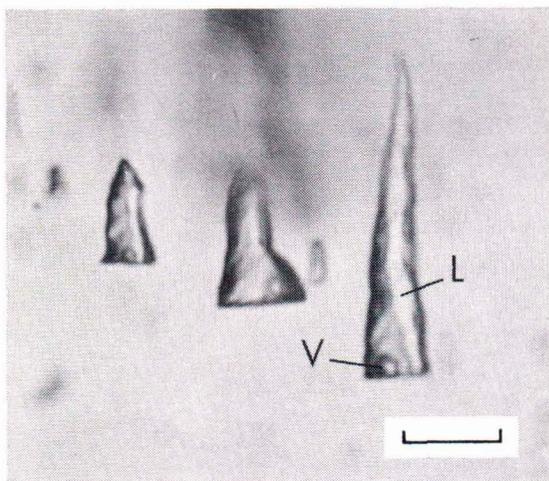


Fig. 2. Photomicrograph of typical primary fluid inclusions with liquid (L) and vapour (V) in yellowish scalenohedral calcite; homogenization temperatures 92°C , 93°C and 88°C ; freezing temperatures -2.4°C , -2.4°C and -2.3°C corresponding to salinities of 4.5, 4.5 and 4.3 eq. wt. % NaCl. Transmitted light, one nicol, bar length $10\ \mu\text{m}$.

zones (Fig. 1). At room temperature these inclusions usually consisted of liquid and a small bubble of vapour; in stage D, however, the primary fluid inclusions often contained only liquid. At room temperature the inclusions are metastable (cf. Roedder 1971).

The shape of the primary fluid inclusions tend to resemble the crystal form of the host calcite (negative crystals, Fig. 2). Some of these primary inclusion cavities are as much as 1 cm long in stage D. The inclusions with a length of over $150\ \mu\text{m}$ were almost always leaked as a result of fracturing.

The homogenization and freezing temperatures were measured from the primary fluid inclusions embedded in the scalenohedral calcite of mineralization stage D (see Fig. 1 for location). The homogenization temperature of about 100 inclusions was 79° to 103°C , with the maximum frequency at 90° to 95°C . All these inclusions homogenized to liquid. The freezing temperature of 17

inclusions was -1.9° to -2.7°C , corresponding to a salinity of 3.6 to 4.9 wt.% NaCl equivalent. During cooling many of the inclusions decrepitated when ice was crystallized at about -50°C .

The homogenization temperature of about 600 secondary fluid inclusions in the calcite of mineralization stages B and C ranges from 50°C to about 80°C . In addition, microcracks have been found to radiate from some of the primary fluid inclusion cavities of mineralizing stage D. These cavities contain secondary fluid filling with a freezing temperature of about 0.0°C .

Conclusions

The study of fluid and mineral inclusions of 30 euhedral calcite crystals from a cave in the Korsnäs mine shows that the inclusion zones in individual multiple-zoned calcite crystals can be correlated. The crystallization order of the main cave minerals could also be inferred from the inclusion zones in calcite. The prevailing calcite crystal form is yellowish scalenohedron which in some specimens reveals a white rhombohedral pyrite-covered phantom. The mode of growth of calcite and pyrite has varied in different mineralization stages, and inclusions are usually located in the zones where the calcite habit has changed. Homogenization temperatures of primary fluid inclusions varied from 79° to 103°C .

The homogenization temperatures obtained allow the following estimates to be made for the formation temperature under different pressure conditions in a 5-percent NaCl solution (Potter 1977, Fig. 2): 200 bar 110° — 130°C , 400 bar 130° — 150°C , 1000 bar 170° — 190°C , and 2000 bar 235° — 255°C . The authors consider the pressure estimate from 200 bar to 400 bar to be the most probable because of the low solubility of calcite at

temperatures above 150°C (cf. Holland 1967). Our estimate for the formation temperature is, therefore, between 110° and 150°C. Thus, we suggest endogenic heat derivation because the geothermal gradient alone cannot explain the rise in temperature if the fluid pressure was near hydrostatic. According to the K/Ar age determination (88 Ma), the heat deriva-

tion might be attributed to Cretaceous tectonic movements.

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