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MICROTHERMOMETRIC ANALYSIS OF UPPER TRIASSIC CARBONATES  
IN THE UPPER SILESIA AREA, POLAND

**Abstract:** The Upper Triassic Woźniki Limestone was investigated. Primary and secondary two-phase fluid inclusion studies indicated the presence of three main types of solutions: low, medium and high salinity fluids. These fluids had their origin in a) saline lakes and/or dissolution of evaporates and/or formation brines, b) meteoric waters and c) hydrothermal ascending mineralized solutions from which the carbonates precipitated. These three fluids mixed during calcite precipitation.

**Keywords:** fluid inclusions, mixing, Woźniki Limestone, Upper Triassic

INTRODUCTION

The origin of the carbonates in the Upper Triassic was unknown until Bogacz et al. (1970) suggested that these limestones, containing insignificant amounts of zinc and lead sulfides, may represent lake deposits which were supplied with large quantities of calcium carbonate from springs. Dżułyński (1976) also implied that the Woźniki Limestone might be an end-product of CaCO<sub>3</sub> precipitation from diluted hydrothermal solutions, which were responsible for the deposition of the Upper Silesia Zn-Pb ore deposits. Gradziński et al. (2003) distinguished four facies within the Woźniki Limestone: travertine, aluvial, lacustrine and pedogenic. These authors dated the carbonates as Norian-?Rhaetian. Słowakiewicz (2002, 2003) has made an attempt to evaluate the hypothesis proposed by Bogacz et al. (1970). He concluded the Woźniki Limestone precipitation might have been connected with the main stage of Zn-Pb mineralization.

Samples of calcite cements were collected in the Woźniki Limestone of all the accessible outcrops in order to analyze fluid inclusions (Słowakiewicz 2003). Primary and secondary fluid inclusions were found mainly in calcite associated with travertine and lacustrine deposits.

METHODS OF INVESTIGATION

Double polished wafers about 0.16-0.2 mm thick were glued with epoxy on 1.6 mm glass plates. After microscopic examination, the wafers were removed from the plates using acetone and placed on a sapphire plate for heating and freezing as well as Raman microspectroscopy analyses.

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Microthermometric data were obtained with a Linkam THMSG 600 heating-freezing stage mounted on a Nikon Eclipse E600 and an Olympus B60 microscopes equipped with 20x, 50x and 100x (Nikon), and 10x, 40x, and 100x (Olympus) long working distance objectives. Three replicate measurements were made for each inclusion with accuracy of ca 1<sup>0</sup>C for heating and ca 0.1<sup>0</sup>C for freezing.

## RESULTS

Primary and secondary (in terms of calcite cement generations) fluids preserved in fluid inclusion assemblages were taken into consideration. Fluid inclusion assemblage is a group of fluid inclusions which have various shapes and sizes, and were entrapped as a single homogeneous phase at the same time, under the exact same conditions (Goldstein, Reynolds, 1994).

The size of the studied inclusions ranged from 5 to 50 $\mu$ m. Primary liquid-vapor fluid inclusions were entrapped by early fibrous and secondary liquid-vapor and all-liquid fluid inclusions by late equant calcite cements. Early fibrous calcite cements predate equant ones and are associated with the very first stage of calcite precipitation.

Fluid inclusions in early calcite cements are mainly distributed throughout and confined to early growth zones; but also some are preserved in five fluid inclusion assemblages of tetrahedral, elongate in the direction of growth zones.

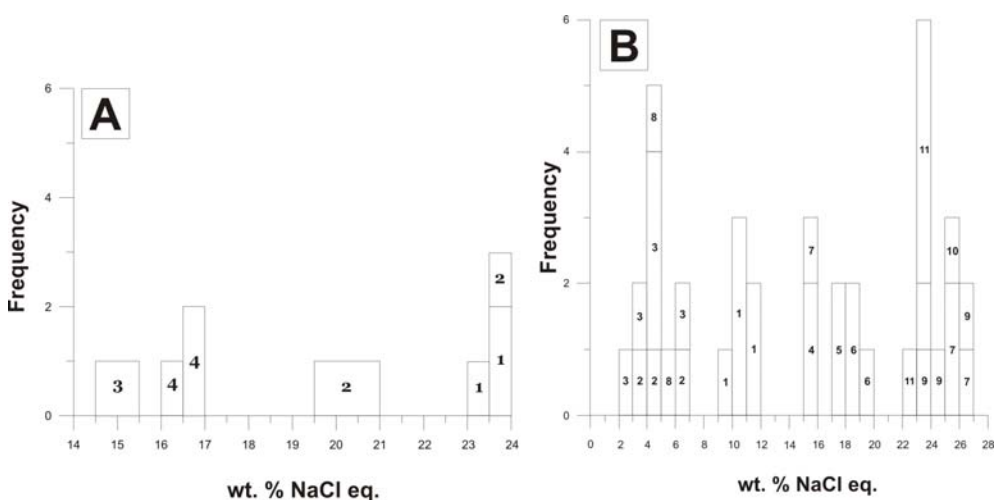


Fig. 1. Histogram of  $T_{m_{ice}}$  data for fluid inclusions in fibrous (A) and blocky (B) calcite cements. Numbers indicate fluid inclusion assemblages.

During cooling runs temperature of eutectic ( $T_e$ ) was identified on the basis of first recognized formation of liquid on warming of completely frozen fluid inclusion.  $T_e$  in the early calcite cement studied ranges from -60.2<sup>0</sup>C to -37<sup>0</sup>C. It may indicate the presence of  $Ca^{2+}$  and  $Mg^{2+}$  cations in brines. The next observable

phase is hydrohalite (NaCl·H<sub>2</sub>O), which typically melts at temperatures from -26.3<sup>0</sup>C to -20.8<sup>0</sup>C (T<sub>m<sub>HH</sub></sub>). The last melting phase is ice which melts at temperatures from -22.5<sup>0</sup>C to -11<sup>0</sup>C (T<sub>m<sub>ice</sub></sub>). On heating runs fluid inclusions in the early calcite cements homogenized (Th) to liquid from 64.8<sup>0</sup>C to 85<sup>0</sup>C. Two-phase fluid inclusions gave Ths and salinities in the following regions (Fig. 1a):

- a) Poręba: Th = 77-85<sup>0</sup>C; salinity 23.24-24.28 wt. % NaCl eq.; characteristic of FIA1;
- b) Woźniki: Th = 65-72<sup>0</sup>C; salinity 16.46-16.90 wt. % NaCl eq.; characteristic of FIA4;
- c) Cynków: Th = 67-78.5<sup>0</sup>C; salinity 14.97-23.27 wt. % NaCl eq.; characteristic of FIA3;
- d) Nowa Wieś: Th = 64.8-78.5<sup>0</sup>C; salinity 23.24-24.28 wt. % NaCl eq.; characteristic of FIA2.

Three main types of salinities are indicated (Fig. 1a): a) medium-salinity fluids with salinities from 14-17 wt. % NaCl eq.; b) medium-to-high-salinity fluids with salinities from 19 to 21 wt. % NaCl eq.; and c) high-salinity fluids with salinities from 22 to 24 wt. % NaCl eq.

On the basis of T<sub>m<sub>HH</sub></sub> calculated salinity in relation to NaCl + CaCl<sub>2</sub> which is from 18 to 21 wt. %.

Fluid inclusions in the late equant calcites were studied from ten recognized fluid inclusion assemblages which contain both one-phase and two-phase fluid inclusions at room temperature. Fluid inclusions are mainly distributed to early growth zones. One-phase fluid inclusions are typically smaller than the two-phase inclusions and tend to nucleate bubbles upon refrigeration. Thus, one-phase fluid inclusions are interpreted to be metastable. Two-phase fluid inclusions in fluid inclusion assemblages gave Ths from 48<sup>0</sup>C to 63<sup>0</sup>C and salinities as regards NaCl from 1.75 to 26.77 wt. % NaCl eq. Two-phase fluid inclusions gave Ths and salinities in the following regions (Fig. 1b):

- a) Nowa Wieś: Th = 43-48<sup>0</sup>C; salinity 19.33-25.38 wt. % NaCl eq.; 15-23 wt. % NaCl + CaCl<sub>2</sub>; characteristic of FIA6, 7 and 8;
- b) Cynków: Th = 54-63<sup>0</sup>C; salinity 3.73-15.92 wt. % NaCl eq.; 13-22 wt. % NaCl + CaCl<sub>2</sub>; characteristic of FIA1, 2 and 3;
- c) Woźniki: salinity 15.54-19.97 wt. % NaCl eq.; 22 wt. % NaCl + CaCl<sub>2</sub>; characteristic of FIA4 and 5;
- d) Poręba: salinity 13.05-26.77 wt. % NaCl eq.; 14.5 wt. % NaCl + CaCl<sub>2</sub>; characteristic of FIA9;
- e) Lipie Śląskie: salinity 22.12-25.38 wt. % NaCl eq.; 21-23 wt. % NaCl + CaCl<sub>2</sub>; characteristic of FIA10 and 11.

Four main types of solutions can be distinguished (Fig. 1b): a) low-to-medium-salinity fluids with salinities from 1 to 12 wt. % NaCl eq.; b) medium-to-high-salinity fluids with salinities from 15 to 20 wt. % NaCl eq.; c) high-salinity fluids with salinities from 23 to 27 wt. % NaCl eq.

## DISCUSSION AND CONCLUSIONS

The results obtained point out that the Woźniki Limestone precipitated from three different types of solutions:

- a) 3-12 wt. % NaCl eq., with temperature range at 43-63<sup>0</sup>C, fluids resulted in mixing of meteoric with evaporated and/or diluted ascending hydrothermal solutions;
- b) 15-20 wt. % NaCl eq., with temperature range at 65-85<sup>0</sup>C, diluted hydrothermal solutions with depleted Zn and Pb, which precipitated the Upper Silesia Zn-Pb ore deposits by mixing in water horizon (Kozłowski, 1995);
- c) 22-27 wt. % NaCl eq., with temperatures from 64.8 to 77<sup>0</sup>C, solutions generated in saline lakes from evaporation and/or from dissolution of evaporates (the presence of gypsum in the upper part of the Woźniki Limestone), and/or formation brines.

The interpretation is in agreement with evidence presented by Kozłowski (1995) for a model of Zn-Pb precipitation in the Upper Silesia area. It is also in good coincidence with that an arid climate existed in the late Norian and early Rhaetian times. The fluids precipitating the Woźniki Limestone are related to the main stage of mineralizing solutions which precipitated Zn-Pb ore deposits.

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