

Composition and temperature of fluid inclusions in calcite veins in mudrocks of the Upper Devonian Duvernay Formation, Western Canada Sedimentary Basin, Alberta, Canada, and implication for hydrocarbon charge

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Summary

This study aims to analyze the structural sets of calcite veins, and the composition and temperature of fluid inclusions trapped within them. The veins occur in the organic-rich mudrocks of the Upper Devonian Duvernay Formation of the Western Canada Sedimentary Basin. We use the preliminary results of this study to discuss how the composition and temperature of fluid inclusions in calcite veins can be correlated with the burial history and hydrocarbon charge evolution. Results indicate a complex evolution of fluid composition and temperature during the progressive burial of the mudrocks including two episodes of hydrocarbon charge.

Introduction

The core of the Duvernay mudrocks was studied in 5 boreholes at TVD 3200 m – 3530 m in the Kaybob area, which are located in the late mature zone of condensate, wet gas, and locally, light oils, with T_{max} 450-460°C. The objectives of this study are to describe different sets of calcite veins in the core of the Duvernay mudrocks in the Kaybob area and to document the composition and temperature of the fluid inclusions trapped in the calcite veins and analyze their variations. An understanding of the composition and temperature evolution of the fluids that promoted the precipitation of the fracture-filling calcite can help to develop a better understanding of the burial history and hydrocarbon charge of the mudrocks of the Duvernay Formation.

Data and Methods

Ten core samples of calcite-filled fractures in organic-rich mudrocks were collected from the Upper Devonian Duvernay Formation in five vertical wells (TVD 3200 m – 3530 m) in the Kaybob area. We use standard transmitted light microscopy, SEM-EDS mineralogy, BSE microscopy (Milliken et al., 2014), fluid inclusion thermometry, and Raman spectroscopic analysis to analyze the composition of fluid inclusions and their host minerals and interpret temperatures of homogenization and ice-melting (Goldstein and Reynolds, 1994; Goldstein, 2003, 2012).

Results

The fluid inclusions were studied in core samples in the matrix of mudrocks and in subvertical and horizontal fractures filled with blocky calcite with presence of bitumen and large euhedral pyrite in veins. The authigenic mineral composition of mudrock matrix in the studied core samples of the Duvernay Formation is dominated by low-Mg calcite and dolomite that are replaced by high-Mg calcite and the dolomite to ferroan dolomite. Partial dissolution and recrystallization of these early

mineral phases is associated with brine salinities of about 5-12 wt.% NaCl equivalent at temperatures ranging from 73 to 122°C.

The sub-vertical calcite veins are composed of mostly low-Mg blocky calcite crystals with well-defined and closely packed coarse to medium euhedral crystals and subordinate high-Mg calcite crystals. These calcite veins contain the gas-aqueous inclusions that display high-liquid and high-methane content with peak at 2910-2912 cm^{-1} and D (1344 cm^{-1}) and G (1606 cm^{-1}) peaks of bitumen in the Raman spectroscopy results. The inclusions in vertical calcite veins were trapped at minimum temperatures of 141-167°C from brines with salinities of up to 16 wt.% NaCl equivalent.

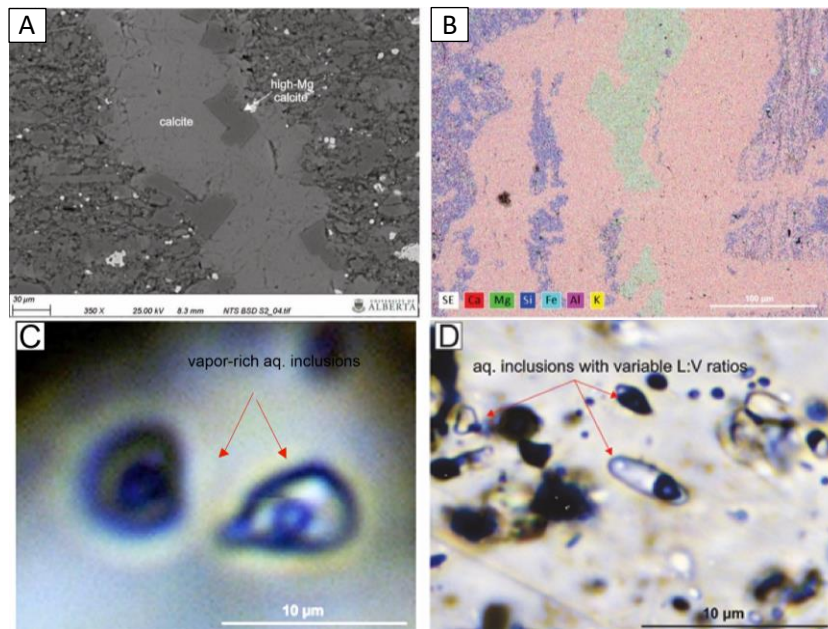


Fig. 1. A-B: BSD micrograph EDS elemental map of the crystals that infilled the vertical fracture, (sample 9, 3284 mKB). C-D: Fluid inclusions entrapped in the calcite crystals in the sub-vertical veins in organic-rich mudrocks of the Duvernay Formation (sample S1, 3448 mKB).

Conclusions

The analysis of fluid inclusions may help to document the history of fluid composition and temperature in organic-rich mudrocks of the Duvernay Formation. We document a complex fluid history during the progressive burial of the formation. In particular, the reflux of hypersaline brines that may have been hotter than surrounding formation fluids through the sub-vertical fractures in the formation appears to have resulted in immiscible gaseous-aqueous fluids. This immiscibility may have served as a key mechanism for hydrocarbon mobilization as well as density separation between the gaseous and liquid hydrocarbon phases.

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