Diagenetic F-rich ferroan calcite and zircon in the offshore Scotian Basin, eastern Canada: Significance for understanding thermal evolution of the basin

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ABSTRACT

In the Scotian Basin, offshore eastern Canada, an unusual combination of high heat flow in the Cretaceous and the abundance of halite has resulted in unusual diagenetic minerals such as sphalerite. The Newburn H-23 well is the most distal well in the basin with good core samples and has two previously unknown diagenetic mineral occurrences: fluoro-rich ferroan calcite and diagenetic zircon. This study uses SEM backscattered electron images and EDS analyses, EMP WDS mineral analyses and Raman spectroscopy to determine mineral chemistry and textures to investigate the diagenetic and thermal significance of these minerals.

Late diagenetic Fe-calcite contains 1–2.5 wt% fluorine, mostly from adsorption, but rarely as small fluorite crystals. Fluoride is also adsorbed on the surfaces of some framework minerals and chlorite. Fluoride was transported in highly saline formation brines derived from the Argo salt Formation. Zircon grains, 20–40 μm in size, have crystal outlines that are straight adjacent to pores, partially lobate filling porosity, and cross cutting other grains: these may be diagenetic. Some zoned detrital zircon grains show 1–3 μm wide diagenetic outgrowths. Neoformation of diagenetic zircon requires temperatures of >250 °C. Transport of zirconium is favored by ligands in low-pH solution, principally fluoride and phosphate anions, with zirconium mobilized during the alteration of metamict detrital zircon under low-grade metamorphic conditions. The presence of diagenetic sphalerite and the documented mid-Cretaceous thermal event in the Scotian Basin indicate conditions that could have been suitable for the formation of diagenetic zircon in this well. Suitable geological conditions for such diagenetic formation of zircon will be found in a subsiding rift basin with early evaporites that are affected by a subsequent phase of volcanism due to new rifting or subduction.

Keywords: Diagenesis, zircon, ferroan calcite, fluorine, Scotian Basin

INTRODUCTION

Diagenetic minerals preserve an important record of fluid flow and paleotemperatures in the development of hydrocarbon basins. The Scotian Basin (Fig. 1) is a passive continental margin basin with an unusual diagenetic history. Thick halite accumulated during Late Triassic rifting (Holser et al. 1988), and as a consequence, formation waters in the basin are highly saline. The Jurassic basin was located at the northeast end of the incipient Atlantic Ocean, and the thermal effects of subsequent rifting between the Grand Banks and Iberia in the Cretaceous were felt throughout the basin (Bowman et al. 2012). In the latest Jurassic and early Cretaceous, the basin was a uniquely large depocenter on the eastern North American margin, accumulating several kilometers of sandy deltaic sediment derived from the uplift of the Labrador rift (Zhang et al. 2014). This sediment loading drove an active salt tectonic system (Alberty et al. 2010), with salt detachments and extensional listric faulting providing pathways for diagenetic fluids (Pe-Piper et al. 2015).

The unusual combination of high heat flow some 100 Ma after initial rifting of the basin, and the abundance of halite in the basin has resulted in unusual diagenetic minerals in wells in the more proximal parts of the basin on the Scotian Shelf, including sphalerite and Mn-rich siderite (Pe-Piper et al. 2015). In this study, we investigate diagenesis in the only deep-water well in the Scotian Basin with a long record of sandstone diagenesis in sidewall cores, the Newburn H-23 well, drilled in 977 m water depth to a total depth of 6070 m. This well provides the most basinward set of sandy core samples of any well in the Scotian basin. Therefore, as diagenetic fluids originated in the deep basin depocenter and migrated up-dip through the basin, this well provides information about the early fluids. The purpose of this study was to investigate diagenetic minerals in the most basinward setting possible. Particular attention is paid to two diagenetic minerals, zircon and a fluorine-rich ferroan calcite (F-rich Fe-calcite), to better understand the evolution of both temperature and diagenetic fluids in the basin.

REGIONAL GEOLOGICAL SETTING

The early stages of Triassic rifting in the Scotian basin produced syn-rift clastic successions and salt deposits (Fig. 2). As rifting continued into the Jurassic, the deposition became dominated by carbonate rocks. This was followed by fluvial, deltaic, and shelf deposition of the sandstones and shales of the Upper Jurassic and Lower Cretaceous Mississauga and Logan Canyon Formations (Wade and MacLean 1990), with principally shales and some sandy turbidites in deep water. Later deposits in the Upper Cretaceous and Cenozoic are shales and lesser chalks.

The Scotian Basin has been strongly influenced by salt tectonics...