Origin of carbonate cements in Flemish Pass Basin sandstone reservoirs: controls on porosity development

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The Flemish Pass Basin is a deep water basin located on the continental passive margin of the Grand Banks, approximately 400 km east of St. John's, Newfoundland, which is currently a target of hydrocarbon exploration. Calcite cement acts as a main factor controlling reservoir quality in the Flemish Pass sandstones, and this study investigates the origin of carbonate cements in the Ti-3 Member, a primary clastic reservoir interval of the Bodhrán Formation (Upper Jurassic) in the Flemish Pass Basin.

The Ti-3 sandstones are quartzarenites to sublitharenites, and contain a high volume of intergranular poikilotopic (300–500 μm) and minor fracture-filling (0.375–2 mm) calcite cements. Grain contact feature and high minus-cemented porosity (or intergranular grain volume, IGV) suggest that the calcite cements precipitated in an early stage of the diagenetic history. Petrographically, these cements postdate feldspar leaching process, and were followed by the corrosion of quartz grains. The intergranular cement exhibits bright to moderate luminescence under cathodoluminoscope with non-concentric zoning. All-liquid inclusions are common in the core of the intergranular calcite cement crystals, while primary two-phase (liquid and vapor) fluid inclusions occur along the rims of calcite crystal in the intergranular calcite cements and in fracture-filling calcite cement. Two-phase fluid inclusions in intergranular calcite cements have mean homogenization temperatures (T_h) of 70.2 ± 4.9°C and salinity estimates of 8.8 ± 1.2 eq. wt.% NaCl, while inclusions in fracture-filling calcite cement have the higher mean T_h of 136.5 ± 1.8°C and salinity estimates of 10.0 ± 1.8 eq. wt.% NaCl. Fluid-inclusion gas ratios (CO_2/CH_4 and N_2/Ar) are consistent with diagenetic fluids that originated from modified sea. The profiles of the shale normalized REE (REE_{SN}) of calcite cements are similar and exhibit slightly negative Ce anomalies. The $\delta^{18}O$ and $\delta^{13}C$ isotopic mean values of calcite cements are -8.31 ± 1.23‰, VPDB and -3.02 ± 1.32‰, VPDB, respectively. The combined evidences from petrographic, microthermometric and geochemical analyses suggest that (1) the intergranular calcite cements precipitated from diagenetic fluids of mixed marine and meteoric waters in suboxic conditions; (2) $\delta^{13}C$ values of intergranular calcite cements reflect influence of organic matter, associated with the dissolution of bioclasts or fossil fragments within sandstone beds or adjacent silty mudstones; and (3) circulating hot basinal fluids were probably involved in the forming of the intergranular calcite cements.

Over 75% of initial porosity loss in Ti-3 sandstones was due to early calcite cementation. The reopening of secondary porosity (mostly moldic, enlarged pores) and throats by major calcite dissolution was the key process in improving reservoir quality. Highly porous horizons occur below silty mudstone beds with coal stringers, which suggest that the acid was released after organic maturation and that dissolution of calcite by organic acids played a significant role in porosity development.

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