A Petrographic and Geochemical Investigation into the Dolomitization of the Jeptha Knob Structure, Kentucky

Ethan S. L. Davis, Dr. Gina Lukoczki

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Introduction

- Jeptha Knob stands as a topographic high in Shelby County, Kentucky, forming a semi-circular monadnock of ca. 2.65 mi diameter, which is a fault-ringed central uplift surrounded by a series of annular extensional faults bisected and offset by multiple radial faults (Cressman, 1981).
- Having formed in the late Ordovician or early Silurian, Jeptha Knob sits on the western limb of the Cincinnati Arch and is composed of Ordovician carbonate megabreccias capped by flat-lying, lower Silurian dolomites (Seeger, 1969).
- Jeptha Knob was historically interpreted as a cryptovolcanic explosion, but magnetic and gravimetric data show lack of evidence of igneous activity (Seeger, 1969).
- Today, Jeptha Knob is most commonly interpreted as a Paleozoic complex impact crater (Andrews and Thompson, 2012), although definitive evidence remains elusive. Alternative origin hypotheses include an overpressured gas explosion (Pope and Read, unpublished manuscript) and a positive flower structure (Patchen et al., 2006).

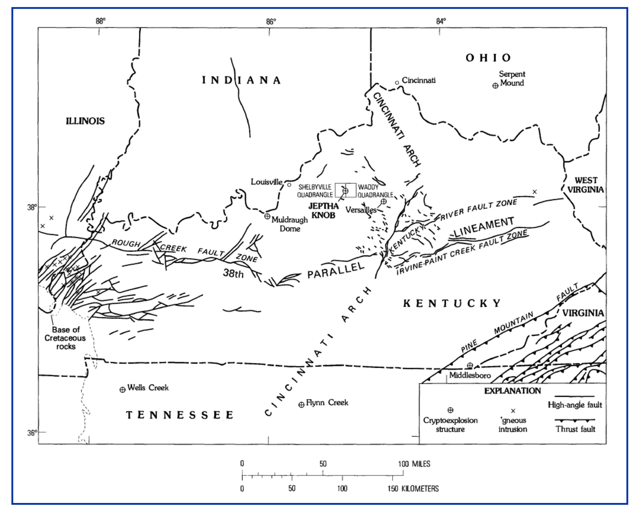

Figure 1a. Map of Kentucky displaying select structural features, including ring-faulted features previously interpreted as "cryptoexplosion structures." Jeptha Knob is found near the center of the figure. From Cressman, 1981.

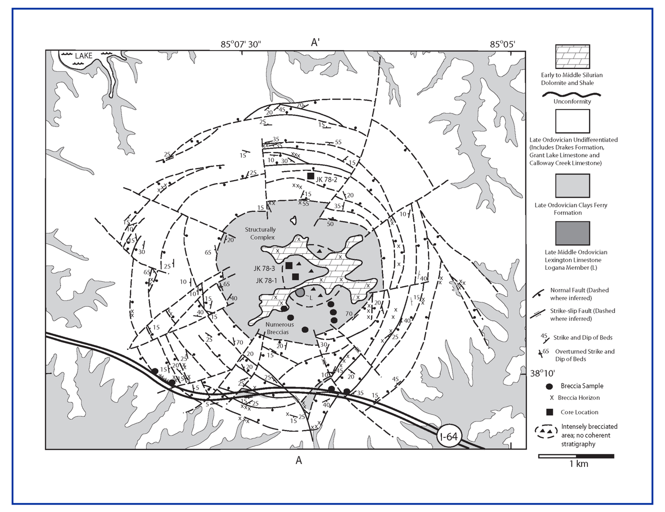

Figure 1b. Generalized geological map of Jeptha Knob structure and locations of core drilling sites. Adapted from Pope and Read (unpublished manuscript).

Objective

- With dolomitization of multiple carbonate units restricted to Jeptha Knob, this project aims to improve our knowledge of the dolomitization process, which in turn may provide new insights into the origin of the structure and how the dolomitizing fluid relates to regional basin brines.
- This project hypothesizes that the dolomitization of the Jeptha Knob carbonates occurred during burial-diagenesis via basinal fluid flow through fault zones.

Methods

- Thin sections prepared from three mineral exploration cores (JK-1, JK-2, JK-3) drilled by the Ozark Mahoning Company in 1987 (Figures 1b and 2a).
- Petrographic analysis via plane-polarized light (PPL), cross-polarized light (XPL) and ultraviolet (UV) excitation.
- Cathodoluminescence (CL) petrography of polished thin sections to examine carbonate zoning.
- Scanning electron microscopy (SEM) with energy dispersive X-ray spectrometry (EDS) to determine unidentified mineral phases.
- Analysis of stable carbon and oxygen isotopes.
- Additional stable carbon and oxygen isotope ratios, homogenization temperatures, and fluid inclusion salinity data incorporated from Patchen et al. (2006).

Results

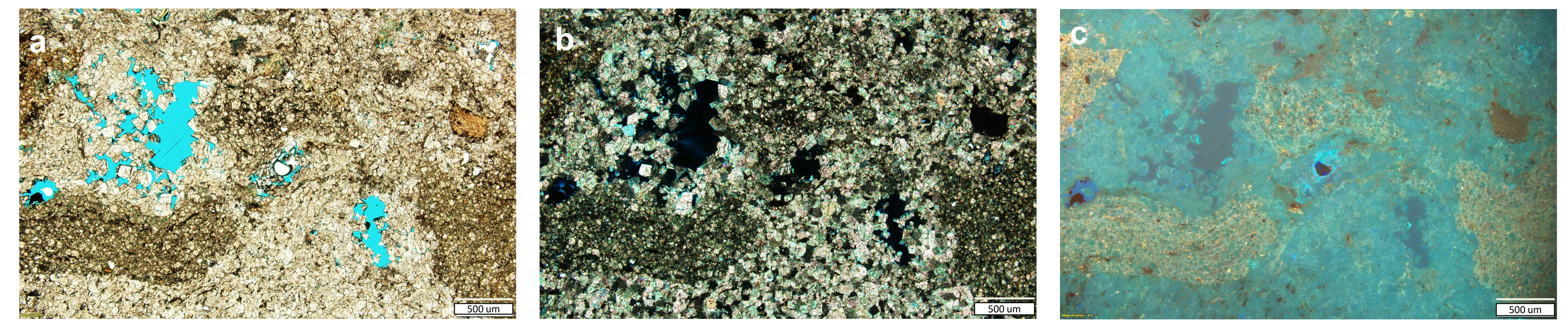

Figure 2. Photomicrograph of dolomite sample in PPL (a), XPL (b), and UV (c) showing two dolomite populations (fine and medium crystalline), vuggy porosity, euhedral dolomite cement grown into pore spaces (filled with blue epoxy) and a cryptocrystalline apatite fragment (brown fragment on right in a).

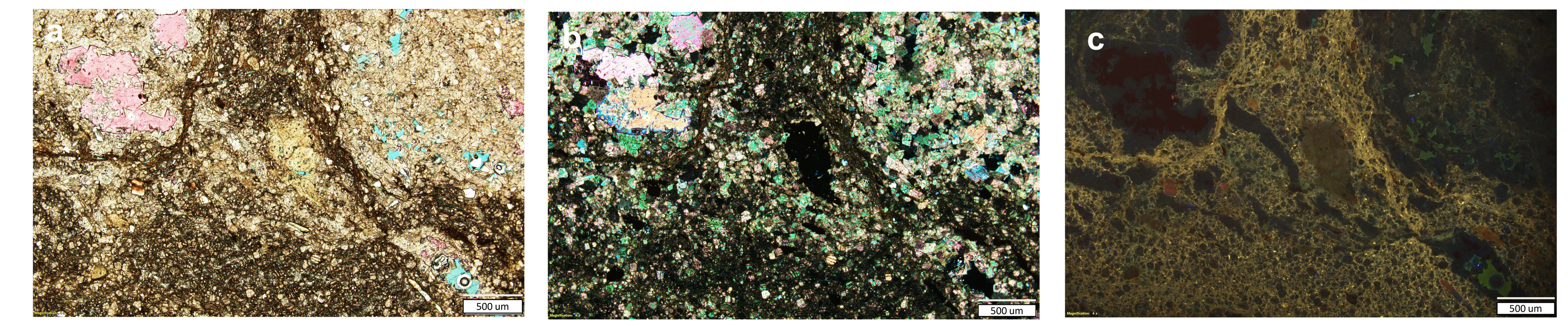

Figure 3. Photomicrograph of an argillaceous dolomite sample in PPL (a), XPL (b), and UV (c) showing two dolomite populations (fine and medium crystalline), vuggy and intercrystal porosity, and calcite cement (stained pink).

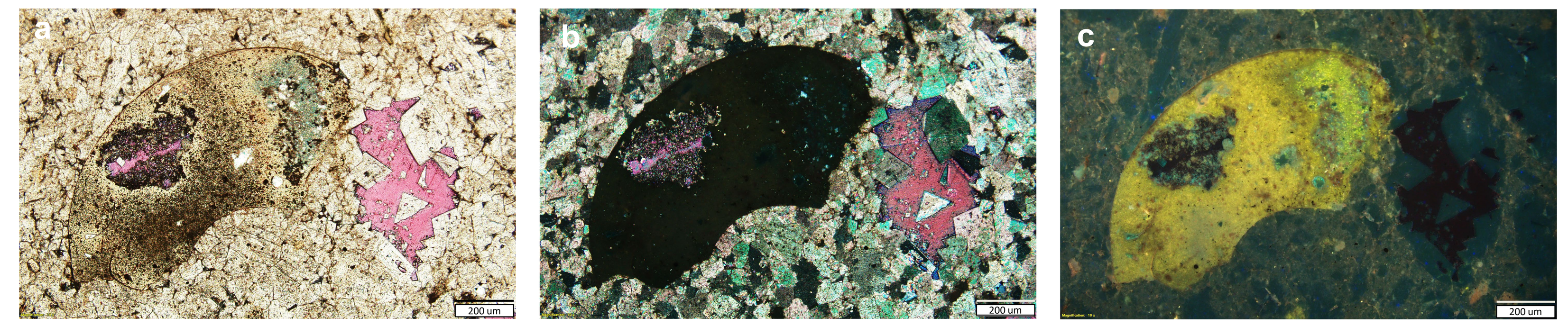

Figure 4. Photomicrograph of a dolomite sample in PPL (a), XPL (b), and UV (c) showing a fossil fragment replaced by cryptocrystalline apatite, locally dissolved and replaced with calcite and dolomite. The rock is made up of planar dolomite containing small vugs filled with dolomite and calcite cements, with calcite partially replacing dolomite in the pore.

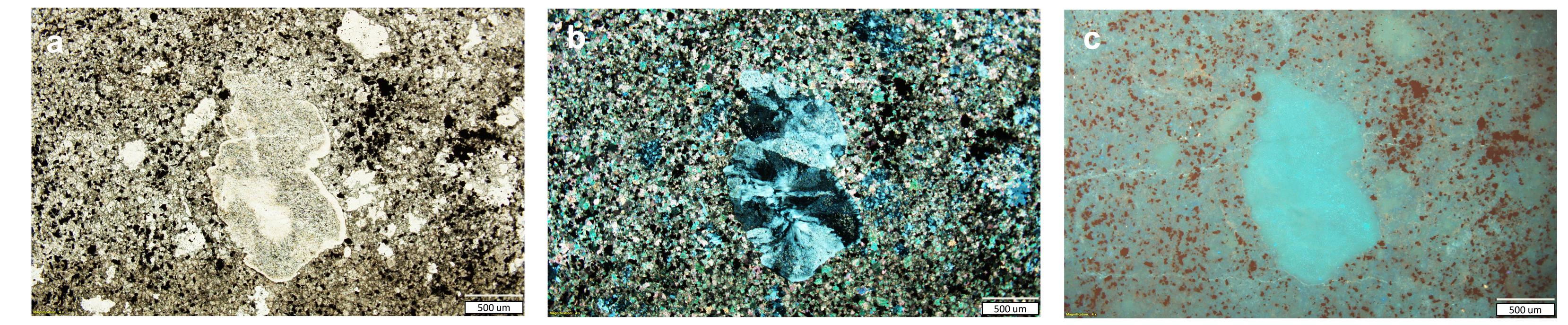

Figure 5. Photomicrograph of a dolomite sample in PPL (a), XPL (b), and UV (c) showing chalcedony that likely precipated into pore spaces. Dolomite matrix is partially replaced by pyrite.

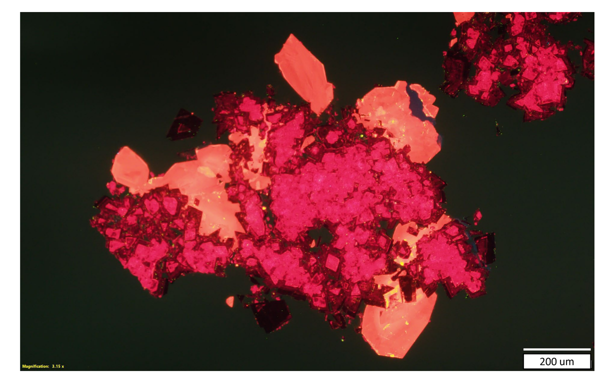

Figure 6. Photomicrograph in CL showing sectoral zoning of calcite cement and concentric zoning of euhedral dolomite that lines pores.

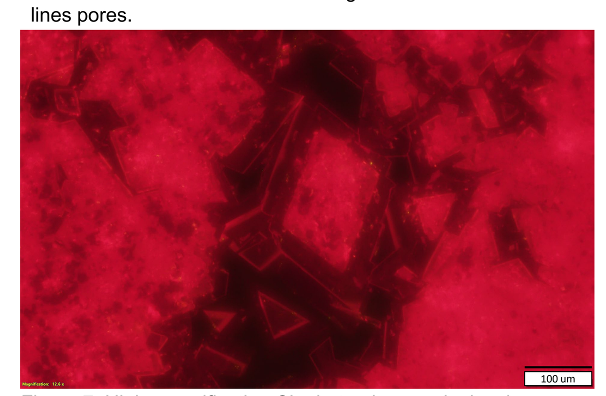

Figure 7. High-magnification CL photomicrograph showing concentric zoning of euhedral dolomite crystals that line pores.

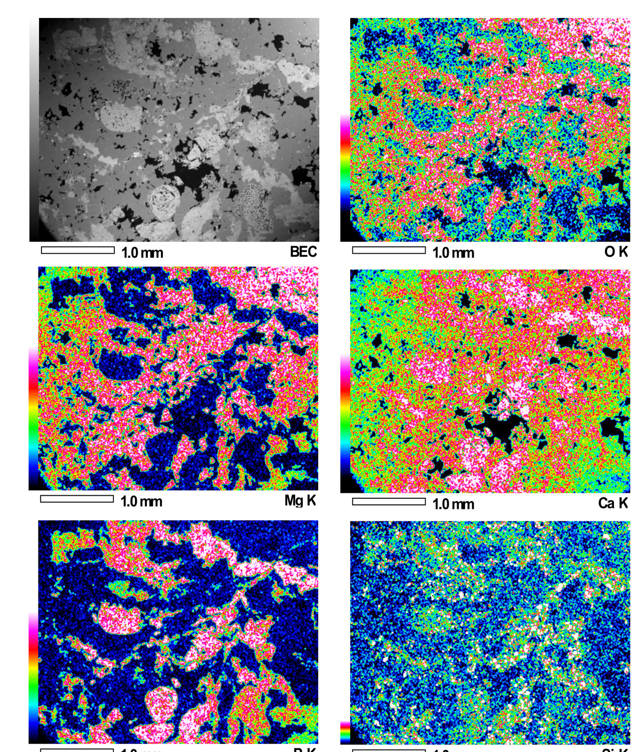

Figure 8. EDS maps revealing cryptocrystalline apatite fragments in dolomite matrix with vuggy porosity.

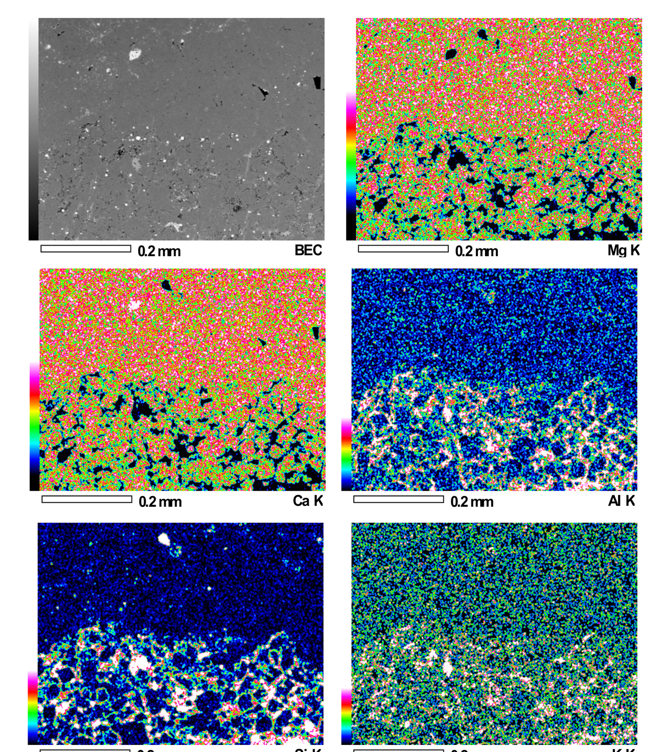

Figure 9. EDS maps displaying two dolomite populations – top of image displays coarser, sub-to-euhedral population and bottom portion displays argillaceous population.

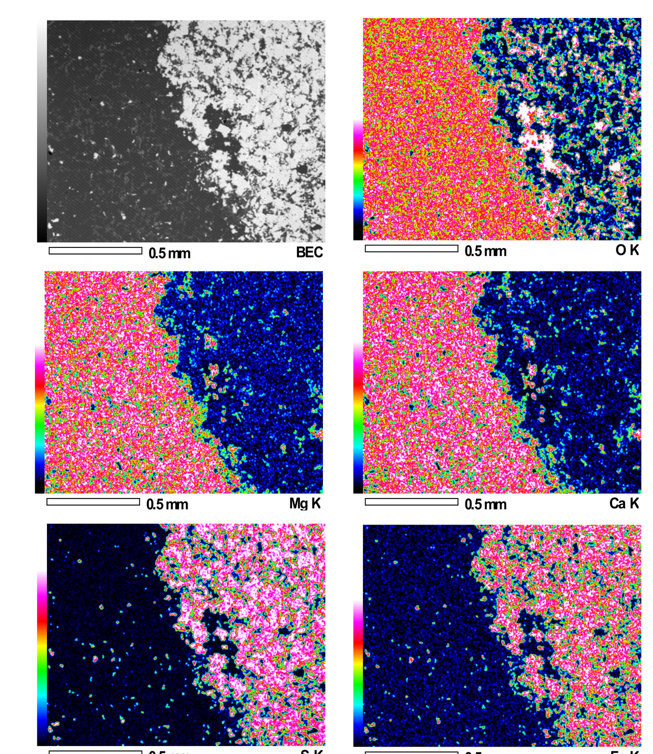

Figure 10. EDS maps highlighting dolomite matrix to the left and pyrite replacement of dolomite matrix to the right.

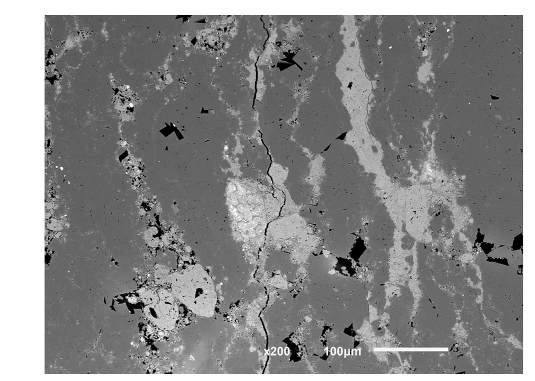

Figure 11. BSE image of three different apatite textures within porous dolomite matrix.

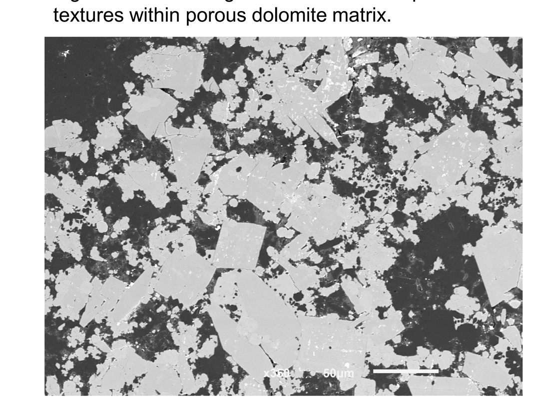

Figure 11. BSE image of pyrite pseudomorph after dolomite, prismatic quartz crystals, chert, and original dolomite matrix.

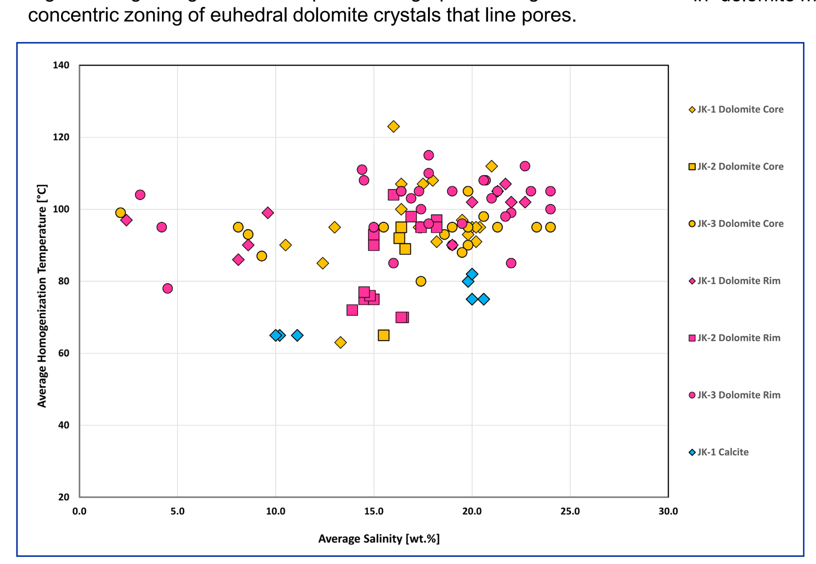

Figure 12. Plot of average salinity (wt. %) vs. average homogenization temperature (°C) of fluid inclusions. Data from Patchen et al. (2006).

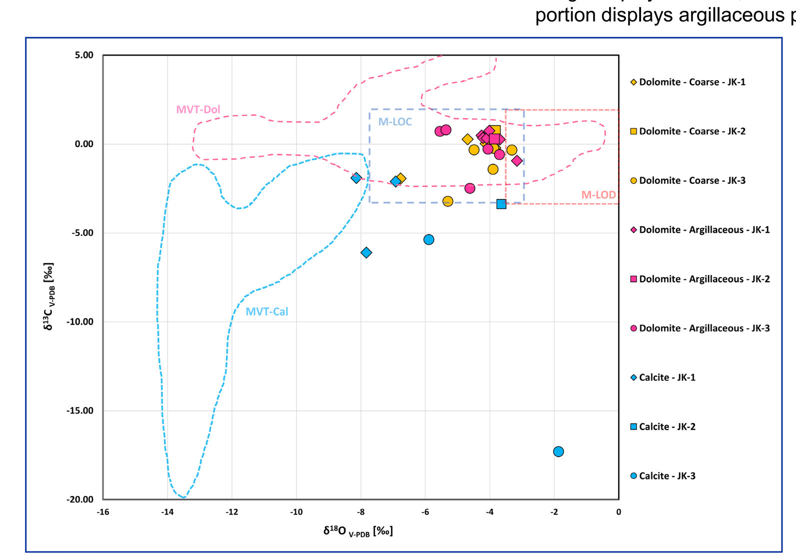

Figure 13. Plot of oxygen isotope ratios vs. carbon isotope ratios. MVT-Dol and MVT-Cal outlines show trends of Mississippi Valley Type of replacement dolomites and late calcite cements, respectively (adapted from Keller et al., 2000). M-LOD and M-LOC outline isotopic ranges of Late Ordovician marine dolomites and calcites, respectively (adapted from Savard et al., 1999).

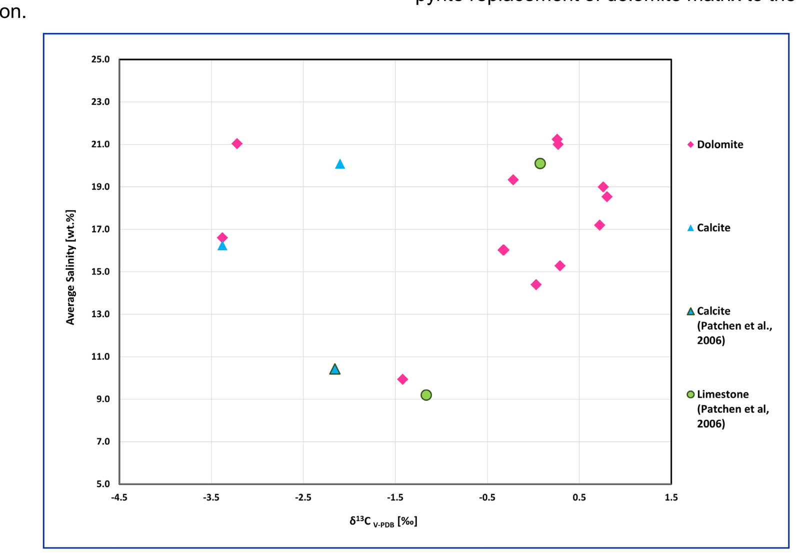

Figure 14. Plot of carbon stable isotope ratios vs. average salinity (wt. %). Salinity data from Patchen et al. (2006).

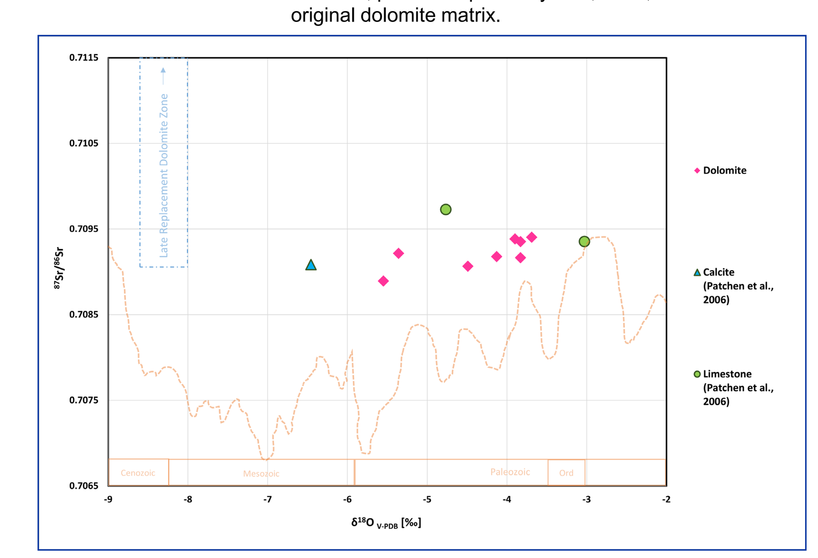

Figure 15. Plot of oxygen stable isotope ratios vs. strontium isotope ratios. Curve shows average $^{87}Sr/^{86}Sr$ variation of marine waters throughout the Phanerozoic (adapted from McArthur et al., 2012). Late replacement dolomite zone outlines trend of Mississippi Valley Type late replacive dolomite endmember (adapted from Shelton et al., 2009).

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Summary

- Planar euhedral to subhedral fabric destructive dolomite textures suggest dolomitization by warm fluids, which is supported by the $\delta^{18}O$ values (this study) and fluid inclusion data (Patchen et al., 2006).
- Uniform $\delta^{18}O$ – $\delta^{13}C$ values of the two dolomite texture types points to a single dolomitization event.
- Zoned dolomite cement likely indicates continued dolomite precipitation by the same fluid following complete replacement of the precursor limestone.
- Calcite cementation succeeded dolomitization possibly following Mg-depletion of the dolomitizing fluid.

Acknowledgements

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