Travertine Deposition on Silurian Reefs: A Response to a Large-Scale Diagenetic Flow System in the Michigan Basin

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The diagenesis of Silurian reefs was largely controlled by the existence of a large-scale diagenetic flow system resulting from evaporative drawdown in the Michigan Basin. In this model the evaporation of seawater in the increasingly restricted basin created a significant hydraulic head difference between the basin and the surrounding inner shelf platform, which were separated by a continuous barrier reef system. Seawater from the platform refluxed down into the underlying Guelph and Lockport formations, towards the basin and up through the pinnacle and patch reefs, resulting in a mantle of travertine deposits. The proper recognition of these deposits provides important information with respect to the timing and mechanics of diagenetic fluid flow within the basin.

Travertines are commonly interpreted in the literature as stromatolites or algal in origin due to their laminated fabric, which is not unexpected considering that travertines typically have a significant microbial component. In the subsurface of southwestern Ontario, travertines occur within a restricted marine “reef cap” facies, which also includes laminated mudstones-wackestones, peloidal wackestones and true stromatolites. Travertine intervals range from 1 to 10 m in thickness and exhibit laminar, brecciated, and pisolitic fabrics. Laminar fabrics include horizontal to high-angle flowstones (Fig.1A) with conformable laminae. Other laminations are more diffuse and resemble stromatolites (Fig.1B). Travertine breccia fabrics include crackle breccias cemented by evaporite, and mosaic to rubble packbreccias (Fig.1C) with a muddy, intraclastic matrix. Rubble floatbreccias composed of travertine fragments suspended in anhydrite cement are also found. Travertine pisoliths are developed around intraclasts of laminated carbonate. Microscopically, the travertine facies mostly consists of thin laminae (0.25 mm - 1.0 mm), composed of equigranular and occasionally fibrous (Fig.1D), 100-400 μm dolomite crystals, alternating with micritic dolomite. Laminae in partially dolomitized reefs include mosaics of anhedral calcite crystals averaging 50 μm in size, and spherulitic (Fig.1E), ray and palisade aggregates composed of elongate calcite fibres averaging 150 μm in length.

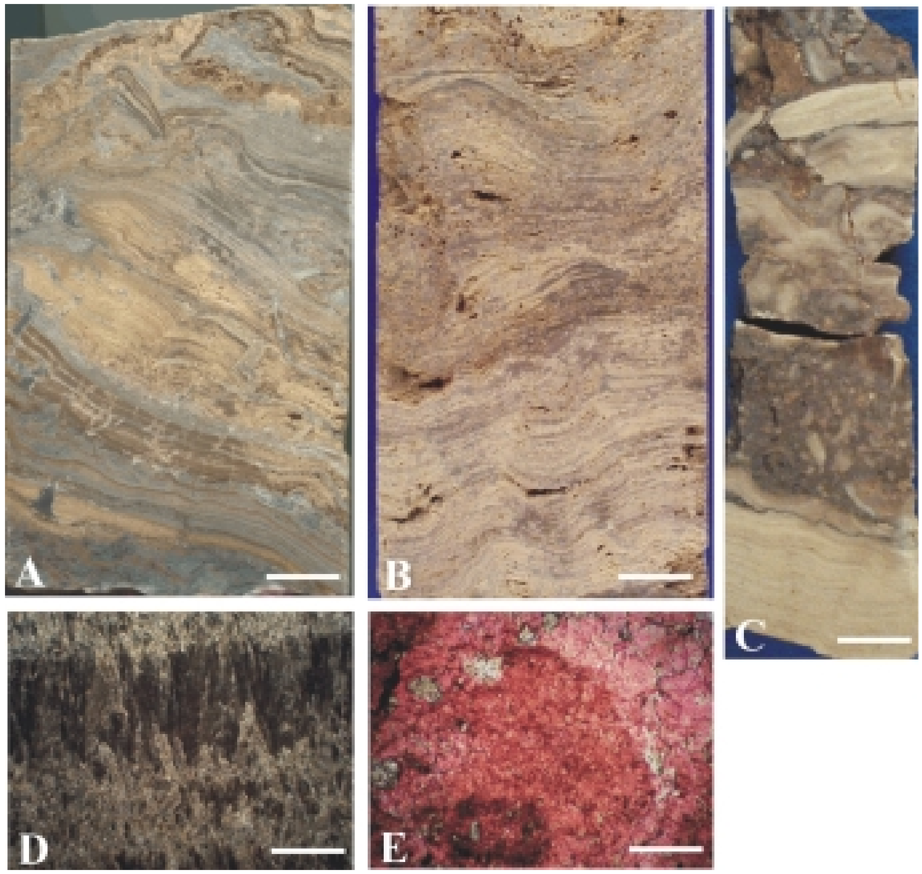

Figure 1. Travertine fabrics. **A.** Core photograph (Enniskillen28-563 m) of laterally continuous and discontinuous laminae with internal sediment and brecciation (scale bar 2cm) **B**. Core photograph (Enniskillen28-564 m) porous, undulating and discontinuous laminae (scale bar 2cm) **C.** Core photograph (Payne-618.5 m) of rubble pack breccia composed of travertine and algal fragments (scale bar 1 cm) **D.** Photomicrograph (xpl.) of a layer of fibrous cement alternating with anhedral microcrystalline dolomite (scale bar 250µm) **E.** Photomicrograph (ppl.) of a spherulitic calcite crystal surrounded by anhedral calcite mosaic and scattered dolomite (scale bar 250 µm).

The evaporative drawdown-related flow system was evidently long-lived and affected Middle Silurian reefs throughout their diagenetic history (Fig.3). Early upward fluid flow through the reefs resulted in travertine formation (Fig.2) as well as porosity destruction from pore-filling calcite and evaporite cements. Dolomitization in underlying strata along the groundwater flow path formed calcium chloride basinal brines. As this brine exited the reefs it mixed with sulfate-rich marine brines causing precipitation of anhydrite (Fig.2), similar to the process described for the Elk Point Basin in Western Canada (Kendall, 1989).

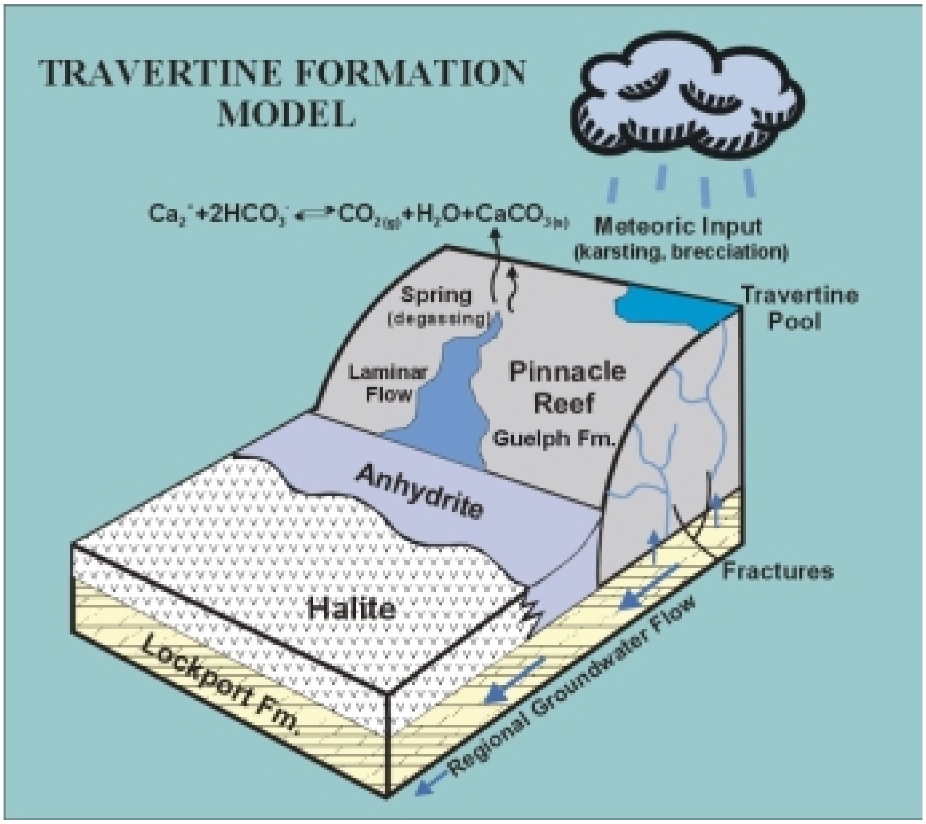

Figure 2. Model for formation of travertine deposits on pinnacle reefs in southwestern Ontario. Groundwater flows up through subaerially exposed reefs via porous reef facies in underlying strata and fractures created by basement tectonics. As the carbonate saturated waters exit the reefs, degassing of CO_2 causes calcite precipitation as travertine. Meteoric water effects include karst dissolution and brecciation. This diagram also illustrates an anydrite envelope, interpreted to have formed from brine mixing.

Later, the same hydrogeologic conditions controlled porosity enhancing dolomitization within the reefs followed by porosity destructive dedolomitization (Zheng, 1999). Bailey (1999) evoked a similar upward-flow model to explain the dissolution of porosity destructive Salina salt, which was emplaced during the Late Silurian.

The variability among the reefs with respect to travertine formation and subsequent diagenesis (e.g., dolomitization, porosity, salt removal, etc.) resulted from the reefs' connectivity to the regional flow system. Factors affecting connectivity through time, and therefore interaction with diagenetic fluids, include reef position in the basin, fractures controlled by basement tectonics, and permeability of reef facies.

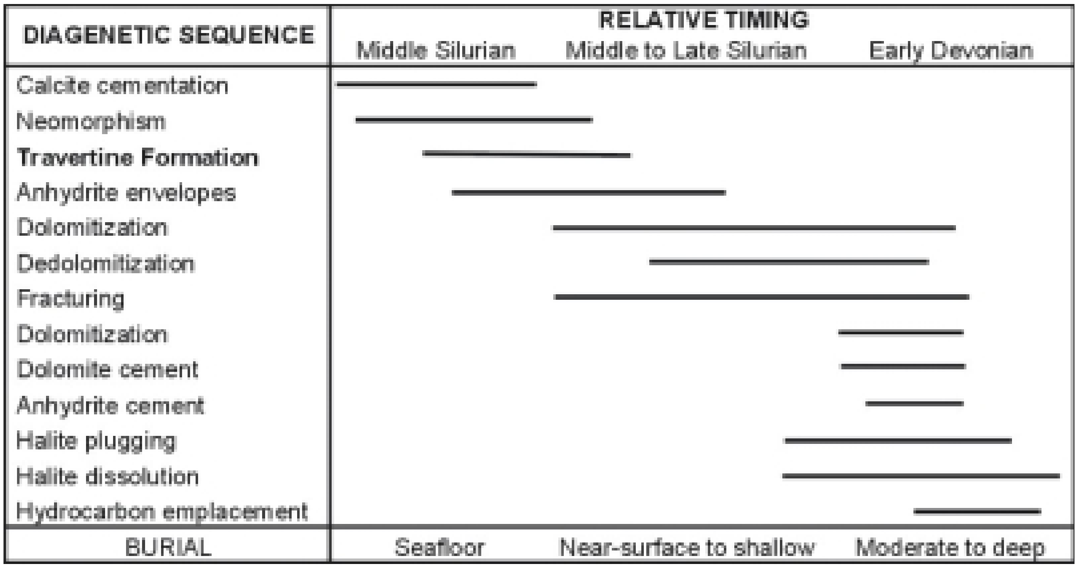

Figure 3. Simplified paragenetic sequence for a Silurian pinnacle reef in the Michigan Basin. Diagenesis is controlled by a long-lived hydrogeological flow system. Modified from Zheng (1999).

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