Effects of Seepage-Reflux Diagenesis on Porosity Modification in Carbonate Reservoirs

Robert H. Goldstein, David Fowle, and students

STATUS: Long-term project in progress
TIMING: Significant results to be reported – Results currently available to membership
FUNDING: Partial

Purpose
Evaporative concentration of seawater at the surface leads to chemical evolution of the fluids, increased reactivity, and density inversion that leads to sinking of brines downward through less dense fluids. The process, which was originally introduced as seepage-reflux, a mechanism of dolomitization proposed by Adams and Rhodes (1960), is now known as a widespread process with major effects on oil and gas reservoir rocks.

The purpose of this research is to systematically evaluate the effects and distribution of refluxing systems in carbonate reservoir rocks, as a means for predicting porosity distribution.

Project Description
For many years, reflux was one of those undersubscribed diagenetic processes. It is now known that very little evaporative concentration is required to have refluxing fluids penetrate deeply into carbonate platforms. Now, we know that reflux is common, a major diagenetic process, and that it requires very little evaporation. It leads to dolomitization, anhydrite precipitation, and calcite cementation. This process has had a major effect on many large and small carbonate reservoirs around the world.

On the Great Bahama Bank, for example, it is well known that during certain times of the year, salinity becomes slightly elevated above that of normal seawater (Traverse and Ginsburg, 1966). Reflux of this bank water is taking place today, and has taken place in the past. In their study of karst of the eastern part of the bank, Whitaker and Smart (1990) demonstrated that saline waters of the lagoon sink to depths of about 150 m and discharge eastward into the Tongue of the Ocean. In the subsurface from 60 to 1100 m depth, west of the bank margin, salinity is high (up to 62 ppt; Kramer et al., 2000). Calcite cement from the Pliocene section of the Clino core contains saline fluid inclusions indicating an origin from reflux (Goldstein et al., 1998). It is interpreted that refluxing fluids dolomitized sediment updip leading to calcite cementation downdip.

Some of the dolomite from deep core of Enewetak Atoll is best explained by deeply sinking moderate salinity refluxing brines (Goldstein, 1996). Enewetak consists of 1400 m of carbonate overlying volcanic basement. Two cores have been taken and sample all the way down to basement. There is porous dolomite near the base of the section that owes its origin to deeply refluxing, relatively recent fluids, on the basis of dolomite Sr isotopic compositions, oxygen isotopic compositions, and fluid inclusions ranging from 44-85 ppt.

If surface waters on a carbonate platform reach high salinities, initially, it is expected that refluxing brines would dolomitize the host sediment. Downdip, however, reactive transport models suggest that anhydrite should precipitate and plug significant amounts of pore space (Jones and Xiao, 2005). This process appears to be an excellent explanation for early
anhydrite plugging in some systems. In repeated examples of ancient systems, however, reflux appears to result in updip dolomitization and downdip calcite cementation, which exerts major controls on reservoir porosity. In the Permian and Pennsylvanian rocks of western Kansas, for example, brine reflux led to dolomite reservoirs close to the source of refluxing brines (Luczaj and Goldstein, 2000), but down section, about half of the reservoir porosity was occluded by the same brines farther along their flow path (Goldstein et al., 1991). This process, resulting from reflux, dolomitization, and microbial sulfate reduction, appears to be among the most important diagenetic processes in large-scale reduction of porosity by calcite cementation.

The project proposes to systematically examine regionally extensive reflux systems from the surface and subsurface. It will reconstruct the flow path using cathodoluminescence cement stratigraphy, stable isotope geochemistry, and fluid inclusion microthermometry. These data will be used to calibrate reactive transport models for diagenetic alteration of carbonate systems.

**Deliverables**

This project will provide quantitative data on the effect of reflux processes on carbonate reservoir rocks. It will concentrate first on developing conceptual models for porosity modification, such as top-down and bottom-up patterns related to fluid flow. It will provide ground truth for manipulation of reactive transport models to quantitatively predict distribution of dolomite, anhydrite, and calcite cement related to this process.

**References**


Figure 1. Regional fluid flow model for dolomitization and calcite cementation in Permian and Pennsylvanian reservoirs, Kansas.
Figure 2. Example of bottom-up diagenetic pattern of dolomitization related to flow of dense fluids along base of aquifer system.