

THE SIGNIFICANCE OF CELESTITE: A NEW MECHANISM FOR CREATING POROSITY IN PLATFORM DERIVED SEDIMENTS

Peter K. Swart, Sean Murray, Angela Slagle¹, and Gregor P. Eberli

¹) LDEO, Columbia University, NY

PROJECT OBJECTIVES

- Investigate the relationship between bacterial sulfate reduction and the formation and dissolution of celestite.
- Determine the role of celestite in the preservation and creation of porosity in platform derived sediments.

PROJECT RATIONALE

Modern sediments deposited adjacent to carbonate platforms contain large amounts of Sr-rich aragonite. This has also been the case during certain other periods of geologic time when, like the Modern, aragonite was the primary shallow-water carbonate being precipitated. Once buried in the

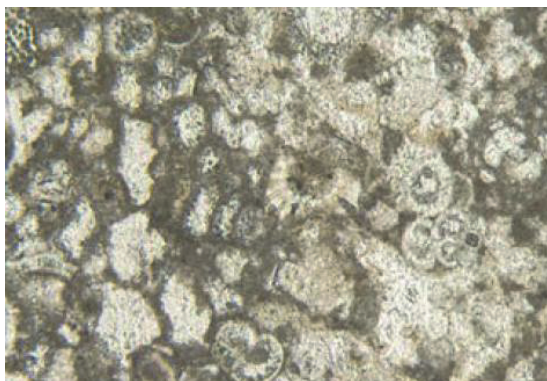
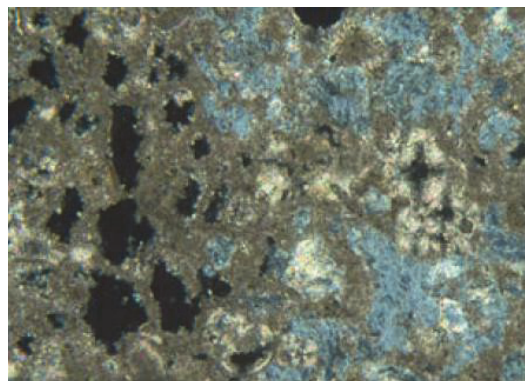


Figure 1. A) Photomicrograph of sediment from a depth of 320 mbsf at Site U1471 (field of view $\approx 250 \mu\text{m}$). Photomicrograph from Betzler et al. (2016).



B) Same region as in Figure 1A under x-nichols. The colored region shows celestite filling porosity. Unfilled porosity is black.

marine realm aragonite tends to dissolve releasing Sr into the pore fluids and, because this Sr is excluded from diagenetic calcite, the concentrations rapidly build up in the pore waters until saturation is reached with respect to SrSO_4 (celestite). Consequently the mineral celestite has been documented in numerous sites drilled adjacent to carbonate platforms (Guzikowski, 1987; Kramer et al., 2000; Swart and Burns, 1990; Swart and Guzikowski, 1988). As a result of the lower distribution coefficient for Sr during its incorporation into abiogenic LMC, celestite can also be found in pelagic sediments as they are recrystallized (Baker and Bloomer, 1987). Celestite is also common in ancient periplatform sediments such as those of Permian age in China (Yan and Carlson, 2003) where it is a local curiosity known as Chrysanthemum stone frequently being carved into ornamental features. Because celestite is well behaved thermodynamically, unlike carbonate minerals such as calcite

and aragonite, it forms almost immediately saturation is attained, and dissolves as soon as the pore fluids become unsaturated. This behavior makes celestite an unappreciated partner in the creation of economically important hydrocarbon reservoirs.

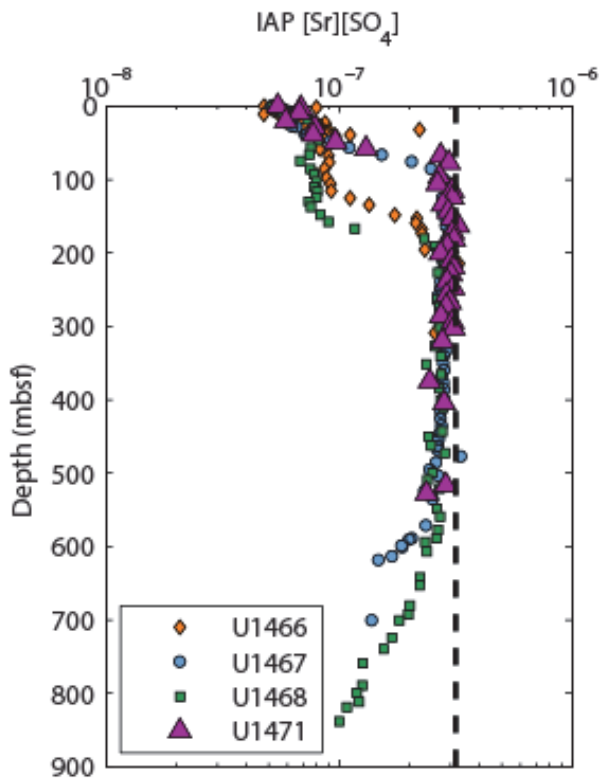


Figure 2. The IAP product of SrSO_4 in the pore fluids for three sites in which abundant celestite was found. At Site U1468 we can expect to see celestite being dissolved below 600 mbsf leading to an increase in porosity. Figure from Betzler et al. (2016).

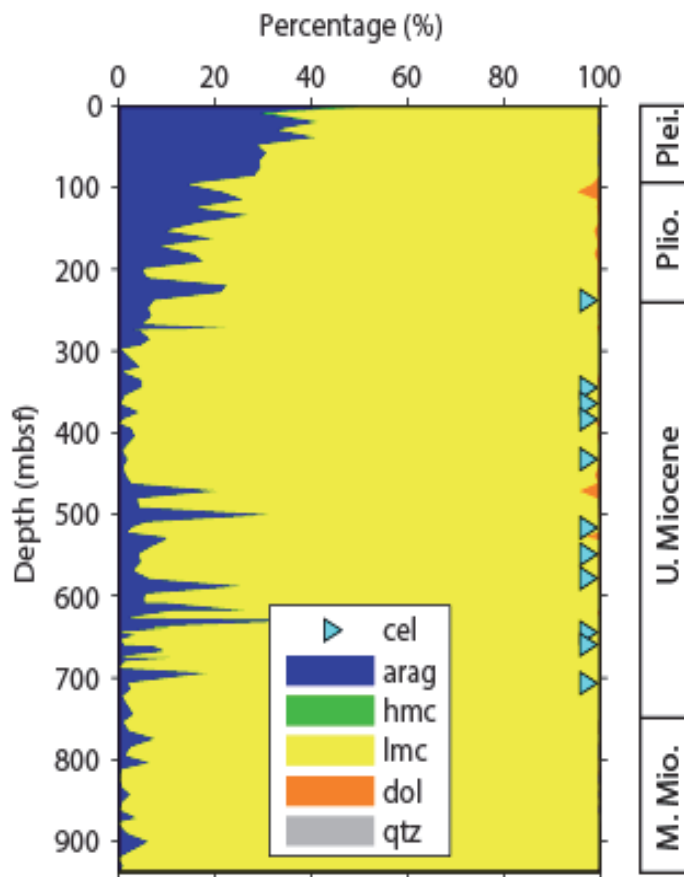
We propose that the mineral celestite forms relatively early during marine burial of aragonite dominated carbonate sediments as a result of the dissolution of aragonite driven by bacterial sulfate reduction. This celestite mainly fills pore space thereby reducing the porosity. At the same time the surrounding carbonate sediment is converted to low-Mg calcite (LMC) and cemented. An example of this can be seen in Figure 1 which show celestite filling porosity in a sample collected from Site U1471 at a depth of 500 mbsf. As the sediment is buried and the aragonite becomes completely converted to LMC, the supply of Sr diminishes. At the same time the concentration of SO_4^{2-} in the pore water continues to decrease as a result of bacterial sulfate reduction (BSR). An example of this can be seen in Figure 2, which shows the ion activity product of SrSO_4 at several of the sites drilled. With increasing depth the IAP decreases meaning that in this interval the celestite is dissolving, creating porosity. As a result of these processes, and the

diffusion of Sr^{2+} from regions with high Sr^{2+} to regions with low Sr^{2+} , secondary porosity is created as celestite dissolves.

SCOPE OF WORK

During Expedition 359 in the Maldives, celestite was identified throughout several of the cores drilled. Figure 3 shows data from U1467 which documents celestite throughout the zone between 150 and 400 mbsf. We propose to record the distribution of celestite in greater detail using XRD on the physical property samples and the formation microscanner images (FMS) from Site U1467. These data will be correlated with the porosity logs (where available) and the porosity measured on board the JOIDES Resolution (Betzler et al., 2016). These data will then be compared with the interstitial water chemistry in order to document the interval of fluid over-saturation. We will document the presence of BSR by measuring SO_4^{2-} and the $\delta^{34}\text{S}$ of

the pore waters and in the celestite itself. Our hypothesis is that below the zone of saturation the mineral will disappear and porosity will increase. With increasing depth and cementation this porosity could be occluded once again as the porosity is filled with calcite. This mechanism could explain why many of the celestite nodules found in ancient settings such as the Permian, have frequently been replaced by LMC (Yan and Carlson, 2003).



SIGNIFICANCE

The work outlined here aims to understand one of the

mysteries of carbonate sediments, namely the preservation of porosity to great depths. We contend that this process outlined here may be common adjacent to all carbonate platforms, particularly during periods of aragonite seas like the Neogene, Carboniferous, Triassic, and Permian. Such time periods may therefore have inherently higher porosity potential than periods of calcite seas.

Figure 3. Mineralogy from U1471. Distribution of celestite is shown by blue triangles. Figure from Betzler et al. (2016).

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