THE FORMATION AND DISSOLUTION OF CELESTINE: A POSSIBLE MECHANISM FOR CREATING SECONDARY POROSITY IN PLATFORM-DERIVED SEDIMENTS

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PROJECT OBJECTIVES

- To understand the importance of celestine formation on the occlusion and preservation of porosity.
- To understand the influence of celestine upon the pore water geochemistry during and subsequent to its formation.

PROJECT RATIONALE

The formation and occlusion of porosity in sediments deposited along the margins of carbonate platforms is an important process in controlling the hydrocarbon potential of a reservoir. However, the processes which govern the development of porosity in carbonate reservoirs are poorly understood and frequently large variations occur, the reasons for which are not immediately obvious. In the proposed work, we will investigate a new process related to celestine formation and later dissolution, which we believe is important in controlling porosity development in marginal sediments deposited adjacent to carbonate platforms.

BACKGROUND

Celestine ($SrSo_4$; often referred to as celestite) is a common mineral forming during the marine burial diagenesis of platform-derived sediments as the Sr, which is more abundant in biogenic carbonates, is excluded during neomorphism and recrystallization (Swart, 2016). Celestine saturation is common in the deep-sea record and about 10% of all sediments cored by the DSDP-ODP-IODP show saturation with respect to this mineral (Hoareau et al., 2010). Celestine is also common throughout the geological record (Hanor, 2004) and in some instances forms large concretions, up to one meter in diameter, that are often replaced by calcite (Yan and Carlson, 2003). While the origin of celestine in deep sea environments is well

Fig. 1: Specimen of celestine in sample from Site U1467.

understood, its occurrence in coastal and evaporitic settings is more problematic (Hanor, 2004; Taberner et al., 2002).

SCOPE OF WORK

We will analyze samples collected during IODP Expedition 359 (Betzler et al., 2016) and from ODP Site 1005 (Leg 166 in the Bahamas) (Eberli et al., 1997). Expedition 359 drilled eight sites adjacent to the Maldives and penetrated up to 1000 m of strata below the sea floor (mbsf) reaching sediments of Late-Oligocene age. These sites are located close to ODP Site 716 drilled during Leg 115 where celestine was also detected (Fig. 1). In the cores from Exp. 359, celestine was detected using X-ray diffraction (XRD) at four of the sites; U1466, 1467, 1468, and 1471 (Fig. 1). The greatest abundance of celestine was measured at Site U1471, although it should be emphasized that samples were only analyzed every ~ 9 m and therefore celestine may be more prevalent than recorded. Coincident with the pore waters attaining supersaturation with

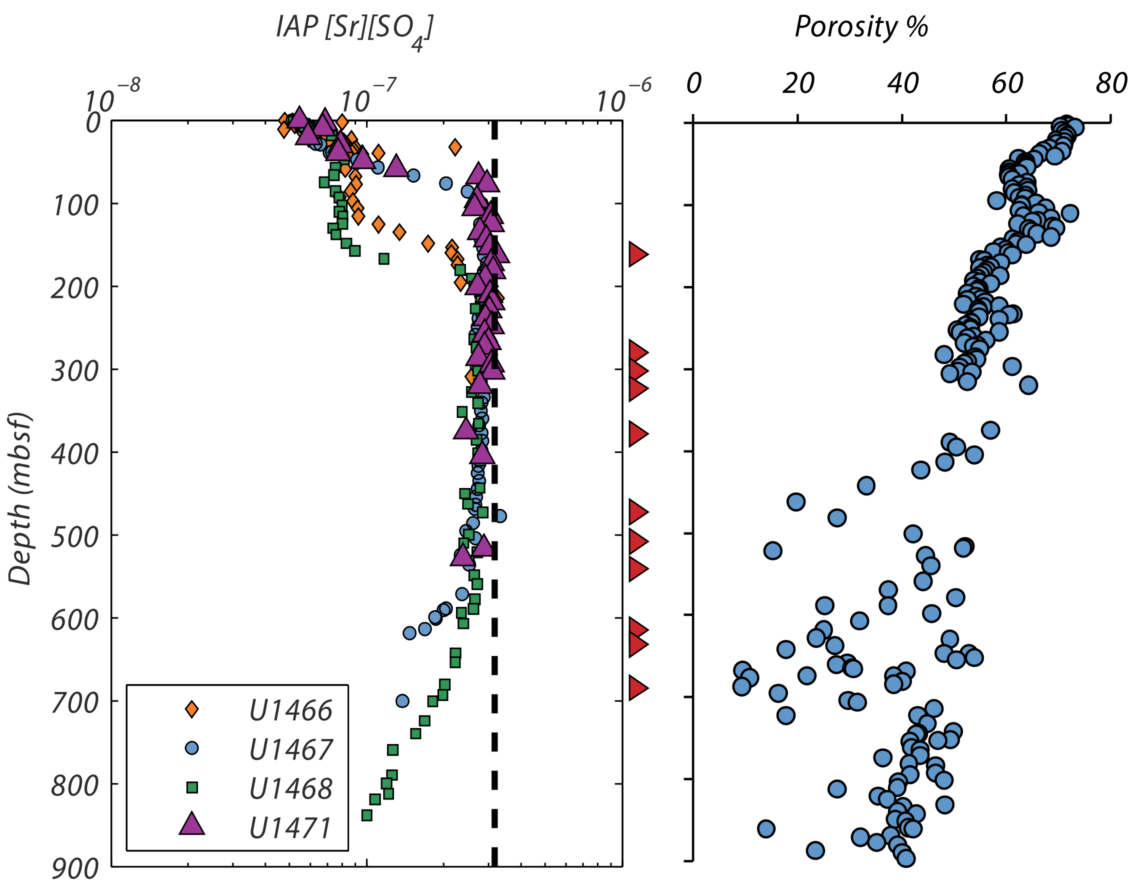

Fig. 2: Left: Ion activity product (IAP) of celestine from four sites drilled during IODP Exp 359. On the right is the porosity of the sediments from Site U1471. The increase in the abundance of celestine (red triangles) coincides with the large decreases in porosity. We propose that the decrease in porosity is caused by infilling of pore space with celestine. Lower in the core (below 700 m) when the pore fluids are no longer saturated with respect to celestine, the mineral dissolves increasing the porosity. The main feature of celestine is to first prevent compaction and at greater depths produce secondary porosity as celestine dissolves.

respect to celestine at this site, the nature of the change in porosity as a function of depth alters from one in which porosity is gradually decreasing as a result of compaction and cementation, to one in which the porosity shows large erratic drops (Fig. 2). We suspect that these decreases in porosity are a result of localized celestine precipitation filling the pore space. Similar behavior was observed at some of the Leg 166 sites drilled adjacent to the Great Bahama Bank. At Site U1467 in the Maldives the hole was logged using a formation microscanner (FMS) and the presence of numerous nodules was noted and interpreted as being celestine. A detailed analysis of the FMS log should be able to quantify how much celestine is present at this site.

Ancient Occurrences: As part of this study we will investigate the formation of celestine nodules from geological sections in the Permian of China (Yan and Carlson, 2003). A geochemical comparison of nodules from the Bahamas and China will be accomplished using methods such as the isotopic analysis of S and Sr (Fig. 3).

Fig. 3a: A celestine sample from core Clino in the Bahamas. The $\delta^{34}S$ value is ~10 ‰ more positive than ambient seawater indicating bacterial sulfur reduction (BSR).

Fig. 3b: A celestine nodule from the Permian in China with drill holes for $\delta^{34}S$ analyses. Values are elevated relative to Permian seawater also indicating BSR.

SIGNIFICANCE

The occurrence of celestine, while well known, has been mainly regarded as a curiosity. The proposed study will be the first to recognize its potential as a major and important creator of secondary porosity. We propose that this mineral forms early in the paragenetic sequence, filling porosity and thus preventing sediments from becoming compacted and filled with carbonate cement. Once the surrounding carbonate sediments become lithified and the sediment is buried below the zone in which the pore waters are super saturated, the celestine dissolves and the porosity of the rock becomes available once more. Furthermore, this process occurs preferentially in sediments derived from aragonite precursors and therefore should be more prevalent in sediments that formed during periods of the Earth's history which had higher Mg/Ca ratios in so-called aragonite seas (Lowenstein et al., 2001; Sandberg, 1983).

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