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Brine induced low-Magnesium calcite formation at cold seeps

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Low-Mg calcite (LMC; $<$ 5 mol% Mg), commonly observed during time intervals of "calcite seas," since the beginning of the Paleozoic Era, is a good indicator of low Mg/Ca ratio ($<$ 2) in seawater. Calcite seas were coincident with times of active seawater-basalt interactions along mid-ocean ridges at high temperatures, which extract Mg from seawater and release Ca to it. In the modern aragonite sea, most carbonate minerals precipitate at the seafloor, including deposits from cold seep environments are primarily either aragonite or high-Mg calcite (HMC). Here, we report the finding of non-skeletal LMC from cold seeps in Alaminos Canyon block 601 (AC 601), 2200 m below the sea surface on northern Gulf of Mexico (GOM) continental slope. Low-Mg calcite usually represents the only carbonate mineral in the studied samples. Dominant allochems in these seep carbonates are peloids, grain aggregates, pelagic forams, and fragments of mollusks and echinoids. The limestone is heavily cemented. The observed cements include micrite, microspar, mosaic, bladed, fan, and needle cements. The dissolution of grains and cements was observed. Not only originally aragonitic mollusks shells, but also carbonate cement have been dissolved. The aerobic oxidation of reduced chemical species such as methane and H_2S is responsible for an increase in pCO_2 and a decrease of pH, leading to local carbonate dissolution. The occurrence of oxic conditions is confirmed by the presence of negative Ce anomalies of the carbonates. Further, we report on analyses showing that the ambient porewater Mg/Ca ratio actually governs the carbonate mineralogy. The occurrence of LMC may be attributed to the brine fluids, which is relatively Mg-depleted (Mg/Ca mole ratio is below 0.7) compared to pore fluid of the subsurface sediments from the reference site (Mg/Ca mole ratio is above 4.1) that usually produce HMC. The $^{87}Sr/^{86}Sr$ values of LMC (mean = 0.708001, sd = 0.000034, n=2) are significantly lower than that of the seawater (0.709175). Strong deviation of the Sr isotope ratios of LMC from seawater is interpreted as the modification of the strontium from less radiogenic sources like older marine sediments and/or the locally abundant Jurassic salt. Therefore, we speculate that the seep fluids at the studied site most likely have a deep origin and may also have been influenced by dissolved halite during their ascent through conduits along the margins of salt bodies. The understanding of the processes that control the LMC precipitation in the GOM will also contribute to an improved understanding of the presence or absence of LMC in other oceans margin settings today, and in geological deposits as well.