Geophysical Research Abstracts
Vol. 18, EGU2016-11923, 2016
EGU General Assembly 2016

Deep aquifer as driver for mineral authigenesis in Gulf of Alaska sediments (IODP Expedition 341, Site U1417)

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Bacterial sulphate reduction plays a key role in authigenic mineral formation in marine sediments. Usually, decomposition of organic matter follows a sequence of microbial metabolic pathways, where microbial sulphate reduction leads to sulphate depletion deeper in the sediment. When sulphate is consumed completely from the pore waters, methanogenesis commences. The contact of sulphate- and methane-containing pore waters is a well-defined biogeochemical boundary (the sulphate-methane transition zone, SMTZ). Here authigenic pyrite, barite and carbonates form. Pyrite formation is directly driven by bacterial sulphate reduction since pyrite precipitates from produced hydrogen sulphide. Barite and carbonate formation are secondary effects resulting from changes of the chemical milieu due to microbial activity. However, this mineral authigenesis is ultimately linked to abiotic processes that determine the living conditions for microorganisms.

At IODP Site U1417 in the Gulf of Alaska, a remarkable diagenetic pattern has been observed: Between sulphate depletion and methane enrichment, a $\sim$250 m wide gap exists. Consequently, no SMTZ can be found under present conditions, but enrichments of pyrite indicate that such zones have existed in the past. Solid layers consisting of authigenic carbonate-cemented sand were partly recovered right above the methane production zone, likely preventing continued upward methane diffusion.

At the bottom of the sediment succession, the lower boundary of the methanogenic zone is constrained by sulphate-rich pore waters that appear to originate from a deeper source. Here, a well-established SMTZ exists, but in reversed order (sulphate diffusing up, methane diffusing down). Sulphur isotopes of pyrite reveal that sulphate reduction here does not occur under closed system conditions. This indicates that a deep aquifer is actively recharging the deep sulphate pool.

Similar deep SMTZs have been found at other sites, yet mostly in geologically active environments such as ridge flanks or above subduction zones. Therefore Site U1417, in a relatively inactive intraplate environment, represents a so far under-sampled geochemical setting. Calculated accumulation times for authigenic minerals in the deep SMTZ are on the same order of magnitude as the onset of subduction-related bending of the Pacific Plate, suggesting that both processes are linked. Plate bending could create fractures in the overlying sediments allowing seawater to penetrate and recharge a deep aquifer. Our study provides insights into a newly discovered geological process suitable for delivering sulphate-rich water deep into the sediments and installing diagenetically active environments where microbial activity would otherwise be very limited.