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Microbial alkalinity production and clay mineral alteration in marine methanogenic sediments: implications for diagenetic carbonate formation

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A numerical reaction transport model was developed to simulate the effects of microbial activity and mineral reactions on the composition of the porewater in a 150-m-thick sedimentary interval drilled in the Peruvian deep-sea trench (Ocean Drilling Program, Site 1230). This site shows a zone of intense methanogenesis below 10 m sediment depth. The simulation shows that microbial activity accounts for most alkalinity production of up to 150 mmol/l, while the excess of CO_2 produced during methanogenesis causes a strong acidification of the porewater. Ammonium production from organic matter degradation significantly contributes to alkalinity production, whereby ion exchange was simulated to compensate for hidden ammonium production not otherwise accounted for. Although clay minerals are reacting far too slowly to equilibrate with the porewater over millions of years, additional alkalinity is provided by alteration of chlorite, illite, and feldspar to kaolinite. Overall, alkalinity production in methanogenic zones is sufficient to prevent dissolution of carbonates and to induce carbonate formation either continuously as disseminated cryptic dolomite or episodically as hard lithified beds along a supersaturation front. The simulation presented here provides fundamental insight into the diagenetic effects of the deep biosphere and may also be applicable for the long-term prediction of the stability and safety of deep CO_2 storage reservoirs.