Rate of growth of isolated bubbles in sediments with a diagenetic source of methane

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ABSTRACT: Observation of bubbles in estuarine and coastal sediments indicates that bubbles at or below 10 cm depth grow on seasonal time scales (May-October). In order to determine the controls on this growth rate, we have constructed a diffusion-reaction model that accounts for the dynamics of methane formation, its diffusion through pore waters, its incorporation into a bubble, and the consequent growth of the bubble. The model produces an explicit equation for the radius of a growing bubble, R(t), with time using mean parameter values and under the assumption that the mechanics of the sediment response to growth can be neglected: [equation]. where w is the porosity, D is the tortuosity-corrected diffusivity, cg is the concentration of gas in the bubble, S is the rate of methanogenesis near the bubble, R1 is the half-separation distance between bubbles (R1 k R), c1 is the ambient CH4 concentration, c0 is the pore-water CH4 concentration at R, t is time, and R0 is the initial bubble radius, if not zero. The effects of the source S and supersaturation (c1 2 c0), thus, appear as separate contributing terms, and this formula can then be applied even in those cases where apparently c1 ø c0. The model is applied to three sediments where bubbles have been previously studied, i.e., Cape Lookout Bight (USA), White Oak River (USA) and Eckernfo¨ rde Bay (Germany). In all three cases, using the site-speci→c time-averaged parameter values, the model predicts seasonal growth rates, consistent with the observations. Furthermore, the source term dominates the rate of growth at the →rst of these two sites, whereas diffusion from the ambient supersaturation dominates at the German location. Real bubbles may follow a more complicated growth history than predicted by the above equation because of the mechanical properties of sediments; nevertheless, the overall growth times are concordant with ultimate diffusion control. The effects of recti→ed diffusion, that is, the pumping of gas into a bubble by pressure oscillations, e.g., from waves and tides, were also examined. Existing models for that process suggest that it is negligible, due to the low frequency of these types of oscillations.

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