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The Physics of Methane Bubbles in Cohesive Sediments

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Methane bubbles in sediments can be generated by methanogenesis and catagenesis and by the melting of gas hydrates. Regardless of their origin, the formation and rise of bubbles requires that they displace sediment, and the response of this geo-material, in turn, dictates the physics of growth and rise. Our observational and experimental results show that cohesive sediments are surprisingly well described by linear elastic fracture mechanics, i.e. brittle elastic behavior, during bubble growth. These dynamics explain the highly eccentric disk-shape of these bubbles. Such bubbles (1) can grow far faster than spherical bubbles of the same volume, (2) can cease to grow even when a source of gas is present, and (3), must reach a critical size before they can rise. Bubble rise through cohesive sediment also appears to be achieved by propagating a fracture; yet the inferred rise speed of bubbles indicates that cohesive sediment acts approximately as a Kelvin-Voigt material, with sediment viscosity as the rate controlling parameter for rise speed. Pressure variations, such as those generated by tides, play no significant role during the initial formation of a bubble; however, if the rise path is not fully annealed between bubble formations events, tidal pressure changes can significantly speed bubble formation and release rates from sediments.