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Shape and size of methane bubbles in muddy aquatic sediments and their dependence on sediment fracture toughness: a modeling approach

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Shallow gassy marine sediments abundantly found on continental margins of Israel and worldwide, are a source of a major concern for their contribution to the destabilization of coastal and marine infrastructure, air pollution, and global warming. Bubbles are different in the different sediment types. Size of the bubbles residing in the fine-grained muddy sediment exceeds significantly the grain size of sediment, and its shape can be approximated by a large oblate spheroid surrounded by sediment saturated with water.
Experimental results indicate that bubble growth is accompanied by fracturing of the fine-grained muddy sediment. Modeling reveals that fracture toughness of the muddy sediments significantly affects bubble shape and size evolution prior its ascent. Small fracture toughness is responsible for generation of the small bubbles with highly asymmetric configuration and with fracturing concentrated mostly on the bubble head. In contrast, bigger fracture toughness is responsible for generation of the large, more symmetric bubbles. Moreover, growing bubble demonstrates a positive allometry resulting in a bigger rate of growth of its surface area that is responsible for the effectiveness of the solute supply from pore water to the bubble interior. This scaling demonstrates a strong correlation with sediment fracture toughness as well. Cross-section of the buoyant bubbles evolves from the elliptic profile to the one resembling an 'inverted tear drop'. Calculated bubbles characteristics in different sediments types demonstrate a good agreement with values reported in the literature.