Biokinetic and Sediment Structural Controls on Gas Release from NAPL-Contaminated Sediments

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Background/Objectives. Research in our laboratory and by others over the last two decades has established the important role gas ebullition plays in mobilizing sediment-bound hydrophobic organic compounds to the overlying water column. According to biogenic gas fracture mechanics theory (BGFMT), gas ebullition results in soft cohesive sediment primarily from methane gas produced by mixtures of Bacteria and Archaea at rates sufficient to cause sediment fracture and bubble rise to the surface. Although both gas production biokinetics and sediment strength play a role in controlling gas ebullition, the relative impact of these two factors on overall process kinetics is not clear. While measuring methane production and some sediment strength properties such as fracture toughness in situ can be challenging, in principle these measurements can be made. However, the application of BGFMT in highly contaminated sediments with non-aqueous phase liquids (NAPLs) necessitates understanding how NAPLs impact methane production and sediment mechanical properties. Thus our objective in this research is to quantitatively assess the impact of gas biokinetics, sediment strength, and NAPLs on BGFMT.

Approach/Activities. BGFMT was developed based on linear elastic sediment fracture coupled with biogenic gas production. Our approach to achieve the objective is to first perform a sensitivity analysis of all parameters in the BGFMT gas bubble formation model. A large homogenized pool of test sediment was used for all experiments. A suite of sediment properties was measured for the test sediments both in the presence and absence of a model NAPL (mineral oil) to determine the impact of NAPL on sediment strength and methane production. We then measured evolved gas from sediment columns of various depths in the laboratory to assess gas ebullition rate and compared results to BGFMT model predictions for confirmation. Quantitative sensitivity analysis was performed using numerical simulations with varying parameters.

Results/Lessons Learned. Together, these experiments allow us to elucidate the impact of NAPL presence, gas production biokinetics, sediment confining pressure, and mechanical properties on gas ebullition rate, while the relative importance of these parameters to gas ebullition was determined by sensitivity analysis. Discussion of results is focused primarily on methanogenesis rate, sediment elasticity, fracture toughness, and the significant impact of NAPL on sediment strength.