Thermal Conductivity Measurements in Unsaturated Hydrate Bearing Sediments

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Enhanced understanding of thermal properties of hydrate bearing sediments provides the basis to explore natural gas hydrate both as a promising energy resource and as potential risks to global climate and large-scale seafloor stability. Current database remain limited and few previous studies on methane hydrate bearing sediments have not been able to capture the sequential changes in thermal properties during hydrate formation and dissociation, whereas vigorous phase changes occur in this unsaturated system particularly during gas production. This study reports the thermal conductivity of methane hydrate bearing sediments at various hydrate/water/gas saturations using transient plane source technique (TPS). We propose and validate a simplified model to obtain thermal properties from single-sided TPS signatures. Results reveal that lithological stress controls the thermal properties of water-saturated hydrate bearing sediments; yet gas saturation becomes a dominant role in unsaturated specimens. Although hydrate and water have almost the same conductivity, the increase in thermal conductivity due to hydrate formation remains true in unsaturated sediments as observed in saturated conditions. Differently, the thermal conductivity of unsaturated hydrate bearing sediments has an evident increase when hydrate saturation exceeds ~30%, shifting from the geometric mean model prediction upward to a Pythagorean type model with the fitting parameter α = ~0.15. We also observe thermal conductivity hysteresis in sediments experienced hydrate formation and dissociation, which may have caused water redistribution. During hydrate dissociation, the sediments thermal conductivity temporarily increases when hydrate and water coexist in the pores. These observations imply that the decrease in sediments thermal conductivity during gas production may be larger than expected, particularly when the hydrate saturation drops below ~30% creating a thermal barrier for further hydrate dissociation. These data can also improve current simulators to capture the thermal behavior of hydrate reservoirs during gas production.