Quantitative Evaluation of Component Content in Hydrate-bearing Artificial Sediment with Clay

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Abstract — Dielectric logging, with its high sensitivity and not affected by pore water mineralization, has become a promising tool for evaluating component content in natural gas hydrate reservoirs, which are a potential clean energy source. In this paper, a modified multilayer nested Wagner model was used to model and fit the complex dielectric constant of hydrate-bearing clay sediments measured by open-ended coaxial probe method. Firstly, considering the addition of clay, the formation and dissociation processes of hydrates in sediments were microscopically divided into three nested forms: 1) In the absence of THF hydrate, where quartz sands are enveloped by clay and embedded in THF solution; 2) When hydrates coexist with the solution, wherein quartz sands are encased by clay, leading to the formation of double-layer confocal particles. The particles are subsequently encapsulated within THF hydrate and integrated into THF solution; 3) In the absence of THF solution, where quartz sands are wrapped in clay, forming double-layer confocal particles, which are embedded in THF hydrate. Secondly, we introduced surface conductivity into the outermost layer of the solid to modify the Wagner model, and used the modified multilayer nested Wagner model to fit the complex dielectric constant of hydrates.

Figure 1: Schematic diagram of the nested forms of each phase in the dissociation process of hydrate-bearing clay sediments sample.
at different stages. Finally, the model parameters were extracted to obtain sediment component content, porosity, hydrate saturation and other parameters. The quantitative evaluation of parameters such as hydrate clay sediment porosity and hydrate saturation can be further achieved. Overall, this study provides valuable insights into the use of complex dielectric constant and dielectric logging to evaluate hydrate reservoirs, particularly those containing clay sediments.

Figure 2: The complex permittivity is compared with Wagner’s fitting results in the process of hydrate dissociation. (a) The 1st minute. (b) The 100th minute. (c) The 160th minute. (d) The 225th minute.