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Permeability of Laboratory-Formed Hydrate-Bearing Sand

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Abstract

Methane hydrate was formed in moist sand under a confining stress in a long, x-ray transparent pressure vessel. Three initial water saturations were used to form three different methane hydrate saturations. X-ray computed tomography (CT) was used to observe location-specific density changes caused by hydrate formation and flowing water. Gas permeability was measured in each test for the dry sand, moist sand, frozen sand, and hydrate-bearing sand, and results of these measurements are presented. Water was flowed through the hydrate-bearing sand, and the changes in water saturation were observed using CT scanning. Inverse modeling will be performed using these data to extend the relative permeability measurements.

1.0 Introduction

Gas hydrate-bearing deposits present in the permafrost and in suboceanic environments have been identified as potential sources of natural gas. The production of natural gas from hydrates will pose many challenges, among which is the economic viability of producing gas from a particular resource. This interest in gas hydrates has induced many laboratory studies focused on various aspects of gas hydrates in the natural environment.

Pristine samples of natural gas hydrates have been difficult to retrieve and make measurements on because the hydrates are not stable at atmospheric conditions and require cold temperatures or high gas pressures to stabilize them. Pressure coring has been successfully performed, retrieving the most representative samples so far, however, these are not readily available for all studies, or in some cases not amenable to the needed study.

Several techniques are used to make gas hydrates for laboratory study. In the ice-to-hydrate method (*Stern et al.*, 1996), ice is contacted with methane at the appropriate pressure, and then melted resulting hydrate forming. The hydrate can then be pulverized and mixed with a mineral substrate and compacted. In the excess gas method (*Handa and Stupin*, 1992), water is distributed throughout a mineral substrate (ie. sand or silica gel) and the mixture is brought to hydrate-stable conditions causing hydrate to form. In the dissolved gas method (*Tohidi et al.*, 2001), water containing sufficient dissolved guest molecules is brought to hydrate-stable conditions and hydrate forms.

Permeability (the resistance to fluid flow under a pressure gradient) and relative permeability (the effect of the presence of other phases such as gas hydrate that interfere with the flow of the fluid of interest) are among the most important parameters governing gas production from a hydrate-bearing reservoir. From the gas production perspective, a large gas hydrate reserve with low permeability can be less desirable than a smaller reserve with higher permeability. Understanding the effects of the presence of gas hydrate in the porespace on permeability and water and gas relative permeability is necessary to more accurately predict natural gas production and economic viability from hydrate-bearing reservoirs.

Very few permeability and relative permeability measurements of hydrate-bearing sediments have been performed. Jaiswal (2004) measured the permeability of samples of two sands having different hydrate saturations. Prior to hydrate formation, the sands were drained in a controlled manner to provide different initial water saturations, and gas hydrate was formed using the excess gas method. The permeabilities inferred from these unsteady state core floods were thought to encompass not only resistance to flow, but also effects of dissociation instabilities caused by fluid flow, fine particle migration and local