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가스하이드레이트 형성 과정의 비저항 모니터링

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Electrical Resistivity Monitoring of Gas Hydrate Formation

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Abstract : Electrical resistivity in hydrate-bearing sediments is sensitive to porosity, gas hydrate saturation, gas content, pore fluid composition, and temperature, so electrical measurements such as well logs and electromagnetic surveys have been used to explore gas hydrate-bearing formation. The high pressure tomography cell is designed considering the effect of electrode configuration and electrical shielding on tomography measurements and the safety. The evolution of electrical conductivity during CO_2 hydrate formation and dissociation reflects the combined effects of concurrent changes that include ionization of dissolved CO_2, temperature-dependent ionic mobility, changes in the degree of saturation, ion exclusion, surface conduction, and porosity changes. Measurements during hydrate formation and dissociation require careful analysis to properly interpret signatures, in particular when out-of plane conductivity anomalies prevail.

1. Introduction

Natural gas hydrate is recently recognized as a potential energy resource, and demands on knowledge regarding the exploration and production of gas hydrates in sediments have motivated many studies. Electrical resistivity in hydrate-bearing sediments is sensitive to porosity, gas hydrate saturation, gas content, pore fluid composition, and temperature, so electrical measurements such as well logs and electromagnetic surveys have been used to explore gas hydrate-bearing formation[(1)]. Laboratory studies on hydrate-bearing sediments also have adopted electrical measurements in monitoring the processes[(2-3)]. Electrical tomography measurements together with continuous monitoring can give insights on the spatial distribution and the fate of pore water, natural gas, hydrate, and ions in sediments during formation and dissociation process, which are crucial information on natural gas production design from gas hydrate in sediments. This chapter documents a series of process monitorings and tomography measurements and analyses during hydrate formation and dissociation in sediments.

2. Experimental Setup

The gas pressure is regulated by the high pressure gas regulator (max. working pressure = 25MPa) attached at gas cylinder. Gas is injected

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through the top cap and ejected through the bottom cap. The electrodes are connected to signal generator and data logger through the electric circuit box. The high pressure tomography cell is designed considering the effect of electrode configuration and electrical shielding on tomography measurements and the safety. The cell body is constructed from stainless steel (SS316) to resist both high pressure and corrosion. Detailed dimension and specifications are depicted in Lee and Santamarina 2009.

3. Experimental Results

Dissolved CO_2 is in equilibrium with carbonic acid, which subsequently ionizes. Consequently, the conductivity of pore water increases as CO_2 dissolves in water .The contribution of dissolved CO_2 in water to the pore water conductivity, following simple experiment is performed. About two third of the cell is filled with tap water, and the cell is pressurized with CO_2 upto 4.2MPa at a room temperature. The voltage is monitored during CO_2 dissolution in a closed system. The pressure decrease and resistance decrease indicate the gradual dissolution of CO_2 into water. However, the contribution of the dissolved CO_2 in water probably not homogenous throughout the specimen but rather concentrated at the interface forming a diffusion front.

To examine the temperature effect, water is placed in the cell, and the voltages are monitored while the temperature of water changes from 20°C to 5°C. As temperature decreases, the resistance increases due to reduced ionic mobility.

Comments on the hydrate formation and dissociation experiment follow. Upon pressurization, the resistivity decreases due to ionization of dissolved CO_2. However, as temperature decreases, the mobility of ions decreases and the resistance increases correspondingly. The resistance further increases upon hydrate formation. As the temperature is raised for dissociation of hydrate, the resistance decreases due to the increase in the mobility of ion and further decreases upon the dissociation.

4. Conclusions

The evolution of electrical conductivity during CO_2 hydrate formation and dissociation reflects the combined effects of concurrent changes that include ionization of dissolved CO_2, temperature-dependent ionic mobility, changes in the degree of saturation, ion exclusion, surface conduction, and porosity changes. Measurements during hydrate formation and dissociation require careful analysis to properly interpret signatures, in particular when out-of plane conductivity anomalies prevail.

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