MODELING STUDIES OF HYDRATE MOUND, MISSISSIPPI CANYON BLOCK 118, GULF OF MEXICO

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Previous work

- McGee et al. (2008) reported chemical analyses from vent gas and a hydrate sample.
- Vent gas: methane 95%, ethane 3%, propane 1%
- Hydrate: methane 70%, ethane 7.5%, propane 15.9%
- Structure II hydrate.
- Differences in gas composition due to molecular fractionation
Prediction of hydrate equilibrium for multi-component systems

- Gas Gravity Method
  Computationally fast, but cannot model molecular fractionation.

- Ki value method

- Statistical method
  Computationally intensive and not suitable for use with a numerical simulator
Preliminary calculations (1)

- Equivalent gas (gas gravity method)
- Hydrate stability curve computed using CSMHYD program (Sloan, 1998) for a 3-component gas mixture (methane 95%, ethane 4.3%, propane 0.7%).
- Stability curve incorporated into 1-D hydrate simulator (THROBS)
- Calculations to examine effects of gas supply, gas fraction of upflow, salinity, and temperature gradient.
Gas Supply

• Gas supply needed to create 3-phase conditions near the sea-floor. Calculations are parameterized by the upward gas mass flux ($10^{-8}$, $2\ 10^{-8}$, $3\ 10^{-8}$, $4\ 10^{-8}$, and $5\ 10^{-8}$ kg/s-m$^2$).

• Distributions of hydrate at t=2000, 5000, and 10,000 years displayed in next figure.

• For the highest gas flow, the hydrate reaches the seafloor at about 3200 years.
Comparison of hydrate distribution with depth for the same total mass of gas upflow but different rates
Summary: Preliminary Parametric calculations

- Presence of gas venting and high salinity fluids modeled due to the existence of 3-phase (hydrate, liquid, gas) near sea-floor.
- If the upflow is essentially all gas, hydrate formation leads to high salinities in the hydrate zone.
- If the flow contains a large fraction of liquid, the salinity distribution tends to get smoothed.
- High salinity upflow results in a shoaling of the HSZ.
Multi-Component hydrate simulator

• 3 gas components (methane, ethane, propane plus brine
• Existing Ki correlations have a limited pressure/temperature range of validity
• Approach: Use CSMHYD program to characterize 3-phase equilibrium and formulate new correlations.
Comparison of equilibrium pressure predicted by CSMHYD and an existing Ki correlation (Feed gas: 96% CH4, 3% C2H6, 1% C3H8)
New correlation variables (1)

- Gas composition
  \[ H = \frac{\langle Ethane \rangle + \langle Propane \rangle}{\langle Methane \rangle + \langle Ethane \rangle + \langle Propane \rangle} \]

- \[ G = \frac{\langle Propane \rangle}{\langle Ethane \rangle + \langle Propane \rangle} \]

- Hydrate gas composition
  \[ H^* = \frac{\langle Ethane^* \rangle + \langle Propane^* \rangle}{\langle Methane^* \rangle + \langle Ethane^* \rangle + \langle Propane^* \rangle} \]

- \[ G^* = \frac{\langle Propane^* \rangle}{\langle Ethane^* \rangle + \langle Propane^* \rangle} \]
New correlation variables (2)

- Salinity
- \( S = \frac{\text{dissolved NaCl mass}}{\text{dissolved NaCl mass} + \text{liquid H}_2\text{O mass}} \)
- Adjusted temperature
- \( T_{adj} = T + 60 \times S \)
- Effect of non-zero salinity is to raise the equilibrium pressure; this effect is represented by using an adjusted temperature.
Effect of feed gas composition, salinity, temperature on equilibrium pressure

Gaseous phase composition:
- $G = 0.1$ H = 0.05
- $G = 0.2$ H = 0.05
- $G = 0.3$ H = 0.05
- $G = 0.4$ H = 0.05
- $G = 0.5$ H = 0.05

\[ G = \frac{\text{<Propane>}}{\left(\text{<Ethane> + <Propane>}\right)} \]
\[ H = \frac{\text{<Ethane> + <Propane>}}{\left(\text{<Methane> + <Ethane> + <Propane>}\right)} \]

where "<Gas>" denotes "moles of 'Gas' in gaseous phase"
Effect of feed gas composition, brine salinity, temperature on solid hydrate methane content
Propane versus ethane content ofhydrate
Summary: Correlations

• At a fixed temperature, the equilibrium pressure tends to decline with an increase in the fraction of heavier components in the feed gas.

• Heavier components fractionate preferentially into the solid hydrate phase.
Future work

• Complete work on the constitutive description (Given $P$, $h$, $S$, and mass fractions, compute phase saturations, temperature, etc.)

• Incorporate the constitutive model into 1-D THROBS and 3-D STAR simulators.