Wellbore Stability Model (WBS) for Sediments containing Gas Hydrates, Gulf of Mexico DOE-JIP

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Project: Wellbore Stability Model for drilling through sediments containing gas hydrates

Phase I: Feasibility Study (Completed)

Identify:

- existing potential WBS modeling software;
- WBS software model building contractors and capabilities
- existing appropriate hydrate datasets
  - Literature review
  - Industry experts
  - Government organizations
  - Universities
  - Compile and report findings

Evaluate Existing WBS Modeling Software

- Determine hydrate modeling requirements
- Scorecard of existing WBS modeling software

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Project: Wellbore Stability Model (WBS)

Phase II: Build Prototype Wellbore Stability Model (Ongoing)

Richard Birchwood is developing a WBS model (next presentation)

Phase III: Validate Prototype Wellbore Stability Model (Ongoing)

This Phase is ongoing with the building of the Model and using experimental data from Georgia Tech.

Incorporation of data from the first wells to be drilled in Q2, 2004

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Possible Drilling Related Problems in Marine Environments

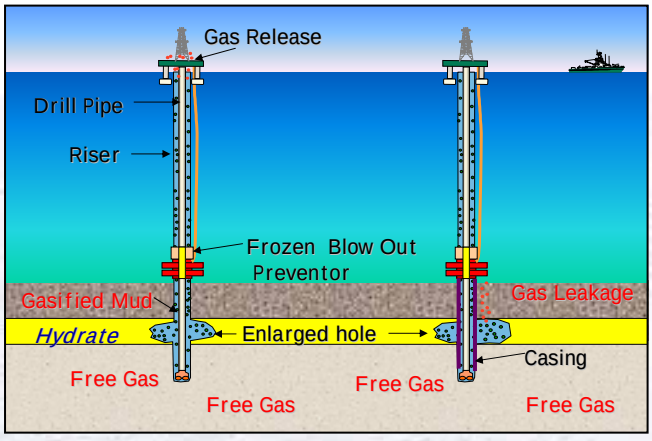

Fig. modified from: Collet & Dallimore, 2002 & others

Hydrate decomposition:

- Hole washouts
- Cement hydration heat
  - Underground Blowouts
  - Poor cement bonding
- Gas release, fires
- Sloughing
- Casing collapse

Some Remedies

- Reduce temperature of drilling fluids
- Run casing after penetrating gas hydrate zone
- Use cement with low heat of hydration
- Use small downhole drilling motors to reduce mud temperatures
- Use mud additives to stabilize gas hydrates

Hole enlargement = poor logging data quality

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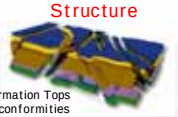
Wellbore Stability: Mechanical Earth Model

Rock Mechanical Parameters

Structure



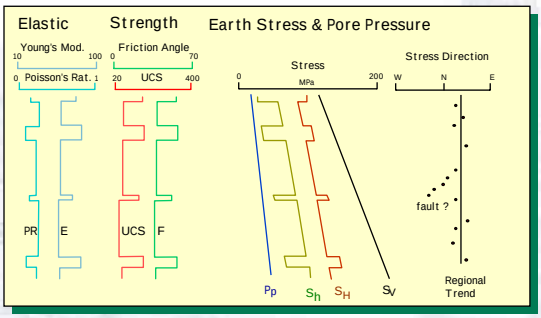
•Formation Tops
•Unconformities
•Faults
•Field Scale

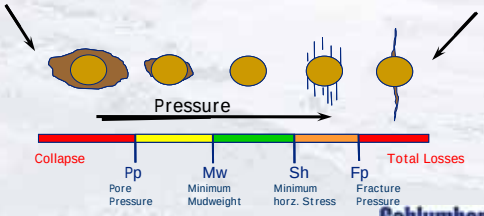
+

Mechanical Stratigraphy

- Grain-Support Facies
- Clay-Support Facies
- Deformation Mechanisms

Temperature





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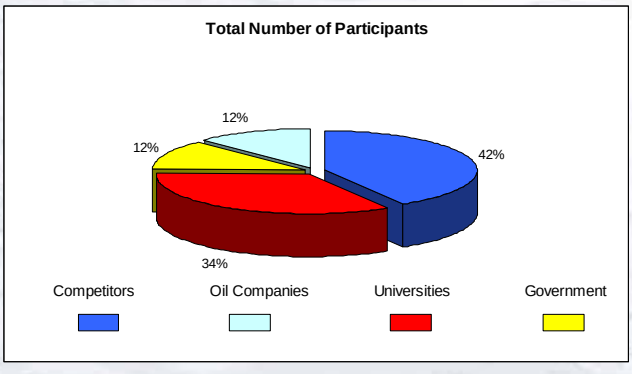
Wellbore Stability Model (WBS): Results of Feasibility Study, Phase I

Questionnaire for score carding existing WBS



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Wellbore Stability Model: Results of Phase I

Phase I: Feasibility Study

No existing software that deals with the specific problems of drilling through sediments containing gas hydrates.

Aspects to be considered:

In the GoM, gas hydrates occur <=1000 m below seafloor:

- Methane is thermogenic & biogenic
- Unconsolidated soft sediments!!!!
- Gas hydrates in numerous textural modifications (veins, nodules, lenses etc)
- Contribute to the strength of the rock, gas hydrate content is important

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Wellbore Stability: Some Challenges

Weak-Ductile Materials containing hydrates

- Not addressed in commercial WBS models
- Include time dependence-temperature, poro-plasticity
- Mechanical testing of weak materials with hydrates
- Validating stability models
- Risk of dissociation

Poorly characterized stress & material properties near the sea floor

- Pore Pressure and Fracture Gradient
- Principal stress magnitudes-Validate Sv, Sh
- Thermal properties-expansion/conductivity
- Rock characterization from geophysical measurements

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Wellbore Stability Model:
Results of Feasibility Study, Phase I

Ideal Wellbore Stability Model should be embedded within a MEM incorporating the following hydrate related issues:

- Data on physical properties of soft sediments and hydrates (density, strength, porosity, permeability, thermal conductivity, thermal capacity)
- Simulation of pressure and temperature changes during drilling and their effects on gas hydrate stability.
- Gas hydrates gasify the sediment and drilling mud, so that phase changes, gas flow etc. have to be accounted for (multi-phase fluid flow modeling).
- The WBS software should include elasto-plastic mechanical behavior, since gas hydrates are associated with soft sediments that have ductile-compactive behavior.

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Wellbore Stability Model
Phase II: Building of Prototype WBS

Schlumberger is building a prototype WBS with the following aspects:

- The WBS will assume stable hydrates; i.e., wellbore stability is modeled based on the mechanical properties of sediments that contain non-dissociated hydrates. Different hydrate concentrations contribute differently to rock strength.
- Complex phase changes and gasification of sediments and drilling mud by dissociating hydrates will not be incorporated in this prototype.
- Elasto-plastic mechanical behaviour is modeled.
- Temperature effects by circulating fluids are accounted for.
- Appropriate p and T control will prevent hydrates from dissociating.

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Wellbore Stability Model

Phase II: Building & Validation of Prototype WBS

Input and validation data:

- Results from mechanical stress & strength tests on hydrates in different concentrations in different types of sediment (presently conducted at Georgia Tech. University).
- Data from wells drilled in Q2 of 2004.
- Data from existing field studies.

Richard's presentation of WBS

Wellbore Stability Model

Future Developments / Outlook

Wellbore Stability Model (WBS)
"Next Steps" and Future Developments

- Borehole stability:
  - identifying mud weight for well bore stability along proposed trajectory
  - managing Equivalent Circulating Density (ECD) in real time.
- Breakout and fracture gradient predictions along well trajectory:
  - understanding local stresses, overburden changes, bed dipping, time dependent factors
  - correlating to experience gained from drilling to date.
- Optimum operational mud weight window:
  - minimize hole instability, prevent kicks and minimize lost circulation
  - possible gas hazards
- Address operational procedures for:
  - preventing hydrate dissociation or
  - minimizing hydrate dissociation impact on borehole stability
  - preventing hydrate formation in drilling fluids
- Discussion of potential hazards in vicinity of the BSR

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Wellbore Stability Model
Future Developments

- Build a refined Geomechanics model - Mechanical Earth Model (MEM)
  - (i) Improves general understanding of geological context
  - (ii) Enables continuous updating with incorporation of new well information and lab tests
  - (iii) Reduces risk when planning new wells
  - (iv) Incorporation of such diverse elements as:
    - Hydrate distribution,
    - Mud volcanos?
    - Overpressure
    - Faults
    - Dipping beds
    - Flow Focusing / Centroid

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Wellbore Stability Model
Future Developments (cont.')

- Characterization of the Unconsolidated Formation and assessment of hydrate distribution.
- Develop new methods for extracting properties of hydrate bearing formations from geophysical measurements.
- Build a fully 3D elasto plastic wellbore stability model
  - (i) Fast finite-element model of borehole deformation in a 3D geometry.
  - (ii) Predict the stress state of a borehole of any orientation
  - (iii) The code will utilize sophisticated constitutive laws consistent with the results of available mechanical tests on hydrate-bearing sediments
  - (iv) Incorporation of core data from drilled holes in the GoM