Fluid-Driven Fracture Initiation During Loss of Control Situations

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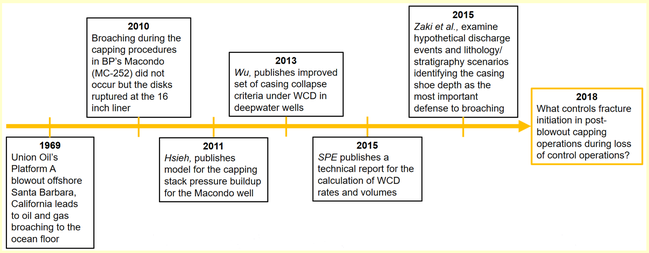
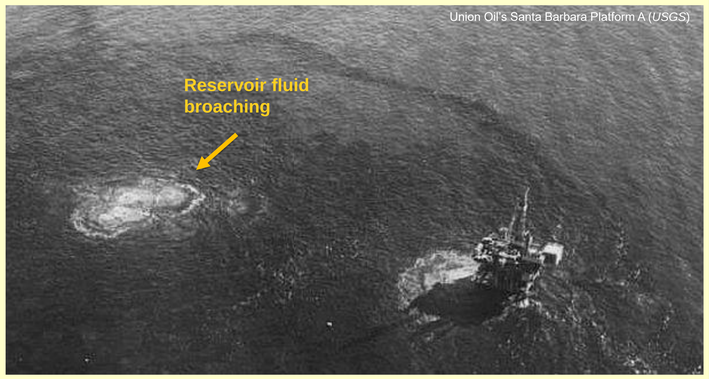
1 WORST CASE DISCHARGE (WCD)

- Defined by BOEMRE as, "the maximum daily flow rate from an offshore well in the event of a blowout"
- In prominence after BP's '10 Macondo oil spill
- Determined using an inflow/outflow assessment of all zones capable of flow (multiple IPR curves and one VLP)



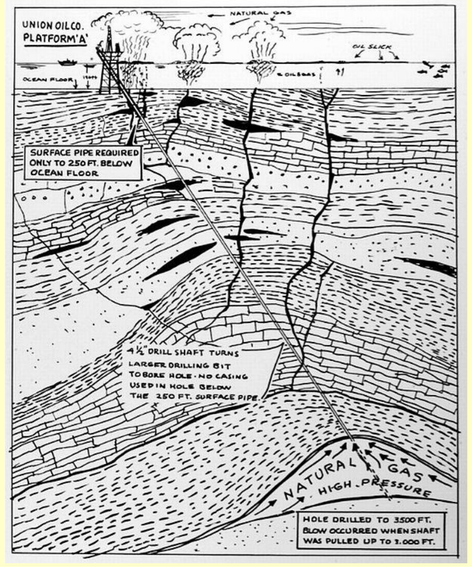
2 1969 SANTA BARBARA OIL SPILL

- Union Oil ran casing over a shallow portion of the A-21 well
- After loss of control which resulted in a blowout, reservoir fluids were discharged from the well at 1,500 psi
- Pressure build-up during capping caused fracturing which led to broaching of reservoir fluids on the seafloor
- Major ecological disaster



3 LOSS OF WELL CONTROL

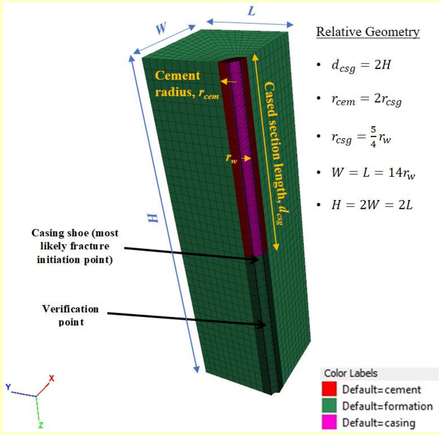
- During drilling kicks may lead to blowouts and uncontrolled discharge of reservoir fluids gushing from the wellbore.
- The wellbore pressure drop during discharge may cause casing collapse at several points
- Subsequent capping attempts can lead to fracture initiation below the casing shoe, or at places where casing collapse had occurred via which reservoir fluids can broach to the seafloor.

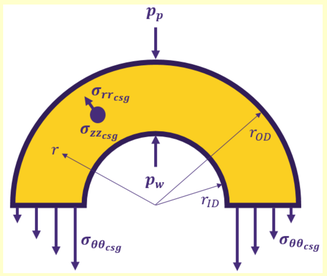


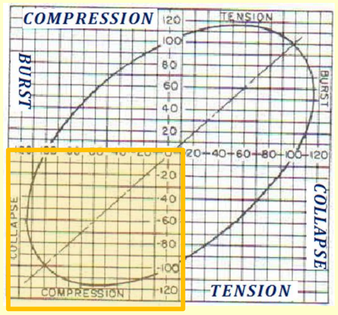
Dick Smith photo collection, UCSB, 1969-1971

4 MODELING APPROACH

- Finite volume "quarter block" model of a semi-cased, non-perforated wellbore
- Different mechanical properties for casing and cement (linearly-elastic) and formation (linearly-elastic or poroelastic)





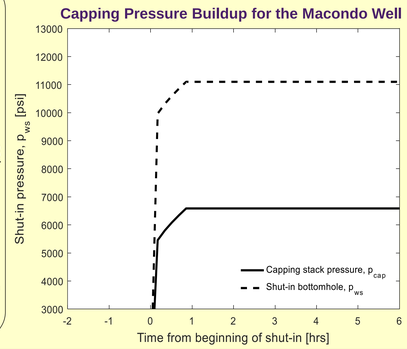


- Lamé equations for stresses inside casing

$$\sigma_{\theta\theta_{csg}} = \frac{p_w {r_{ID}}^2 - p_p {r_{OD}}^2}{{r_{OD}}^2 - {r_{ID}}^2} + \frac{{d_{ID}}^2 {d_{OD}}^2 (p_w - p_p)}{4r^2({d_{OD}}^2 - {d_{ID}}^2)}$$

- Von Mises analysis to determine casing failure

Capping Pressure Buildup for the Macondo Well

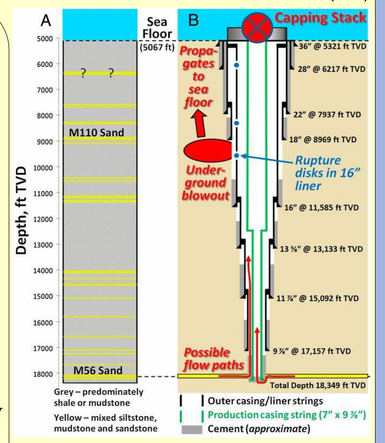


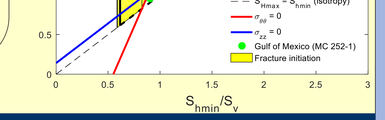
- MATLAB model for wellbore pressure build-up during "soft shut-in"
- Calculates the pressures at capping stack on sea floor and the bottomhole
- Compared with the actual capping pressure build-up observed at the BP's Macondo well → Excellent matching!

5 2010 MACONDO DISASTER

- Fears that failed rupture disks may lead to underground fracture initiations at shut-in
- Government and BP agreed that duration of the wellbore integrity test (soft shut-in) should depend on capping stack pressure level-off
- Capping stack pressure reached 6,600 psi

Hickman et al. (2012)





6 FUTURE WORK

- Identify critical WCD rates at which fracture initiation and broaching occur
- How likely is this to happen in the Gulf of Mexico?
- Impact of different shut-in procedures ("soft" vs. "hard")
- Can wellbore architecture be improved to prevent fracture initiation and broaching during loss of well control?

7 ACKNOWLEDGEMENT

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