Fluid-Driven Fracture Initiation During Loss of Control Situations

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Abstract

If a kick is not detected and circulated properly out of the wellbore with heavier mud weight, it leads to blowouts. In this case, reservoir fluids gush out of the well uncontrollably without restriction leading to loss of control. This may lead to fractures initiating in the post-blowout capping stages, just below the casing shoe, propagating upwards creating a channel through which reservoir fluids can flow to the ocean floor. Being able to model these fracture failures will help understand wellbore integrity problems from loss of control situations and predict the possibility of broaching preventing many ecological disasters like the 1969 Santa Barbara oil spill from Union Oil's A-21 well. The hypothesis tested is that fracture initiation from a wellbore in a loss of control situation can be predicted through analysis of the near-wellbore stress field, with knowledge of the in-situ stress state and the properties of the formation and the borehole assembly. A 3D numerical model is employed to assess whether a fracture will initiate. This is done by considering the stressfield at the casing shoe; the point most vulnerable to tensile fracture failure downhole. In-situ stress state, wellbore pressure, casing shoe depth and the casing, cement, and formation's mechanical properties are independent variables that are shown to control fracture initiation; the dependent variable. A reservoir model is used to predict pressure build-up during capping procedures. A case study on Gulf of Mexico is presented with input wellbore pressure data generated using a worst case discharge model. Wellbore pressure drop during uncontrolled discharge from a well can cause casing collapse failures and subsequently pressure build-up in the post-blowout capping stage, may initiate fractures which can lead fluid leakage to the surface either through the cement or the interfaces with the casing and the formation. The region of the in-situ stress states where fracture initiation will occur is shown in dimensionless plots. This is useful for drilling and wellbore integrity teams. When targeting highly-pressured formations as in deepwater, wellbore architecture must be made with considerations of the wellbore pressures generated from loss of control situations like blowouts. Research reported in this publication was supported by an Early-Career Research Fellowship from the Gulf Research Program of the National Academies of Sciences, Engineering, and Medicine. The content is solely the responsibility of the authors and does not necessarily represent the official views of the Gulf Research Program of the National Academies of Sciences, Engineering, and Medicine.

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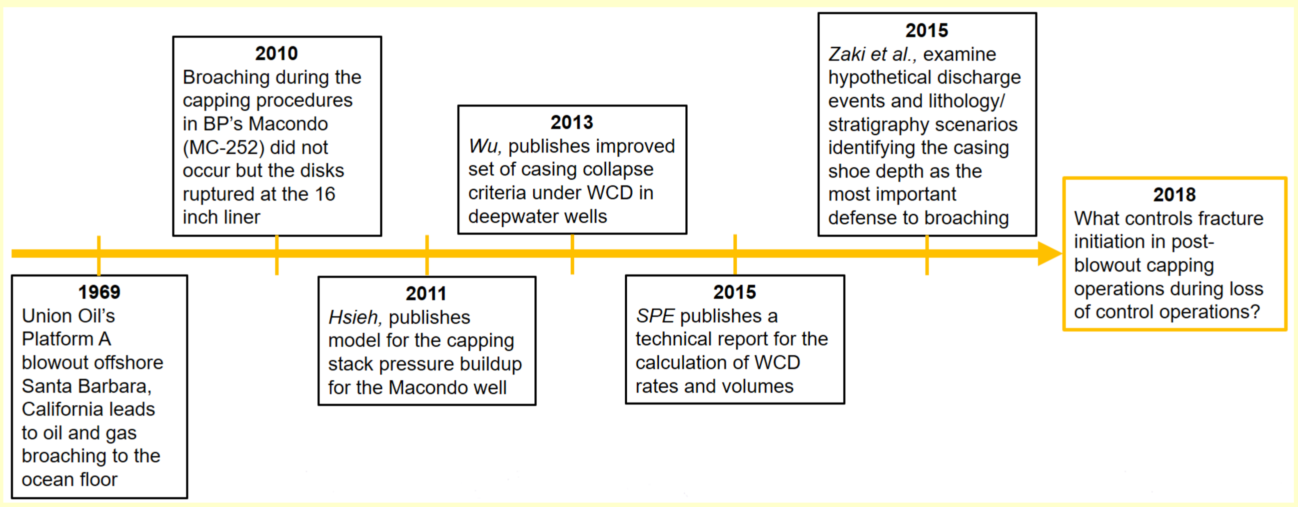
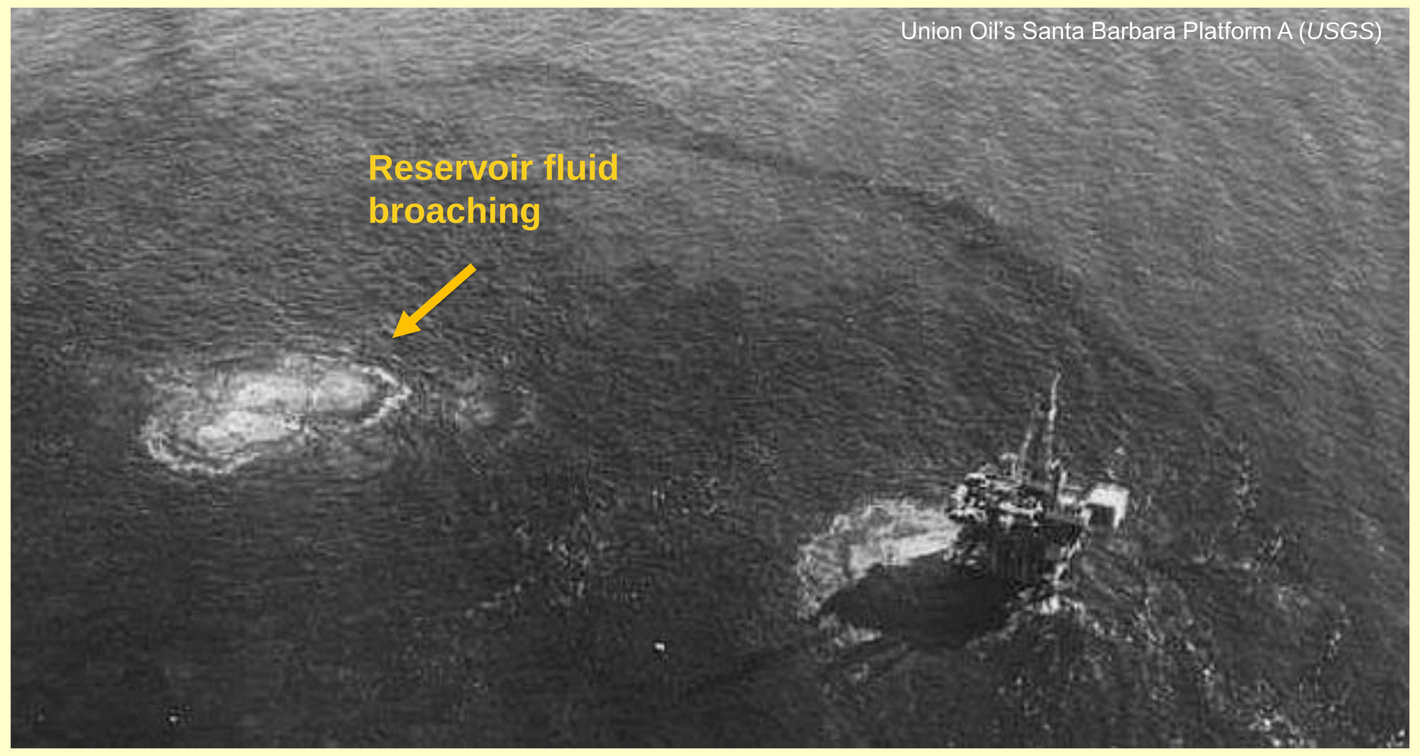
1 WORST CASE DISCHARGE (WCD)

- ❖ 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)



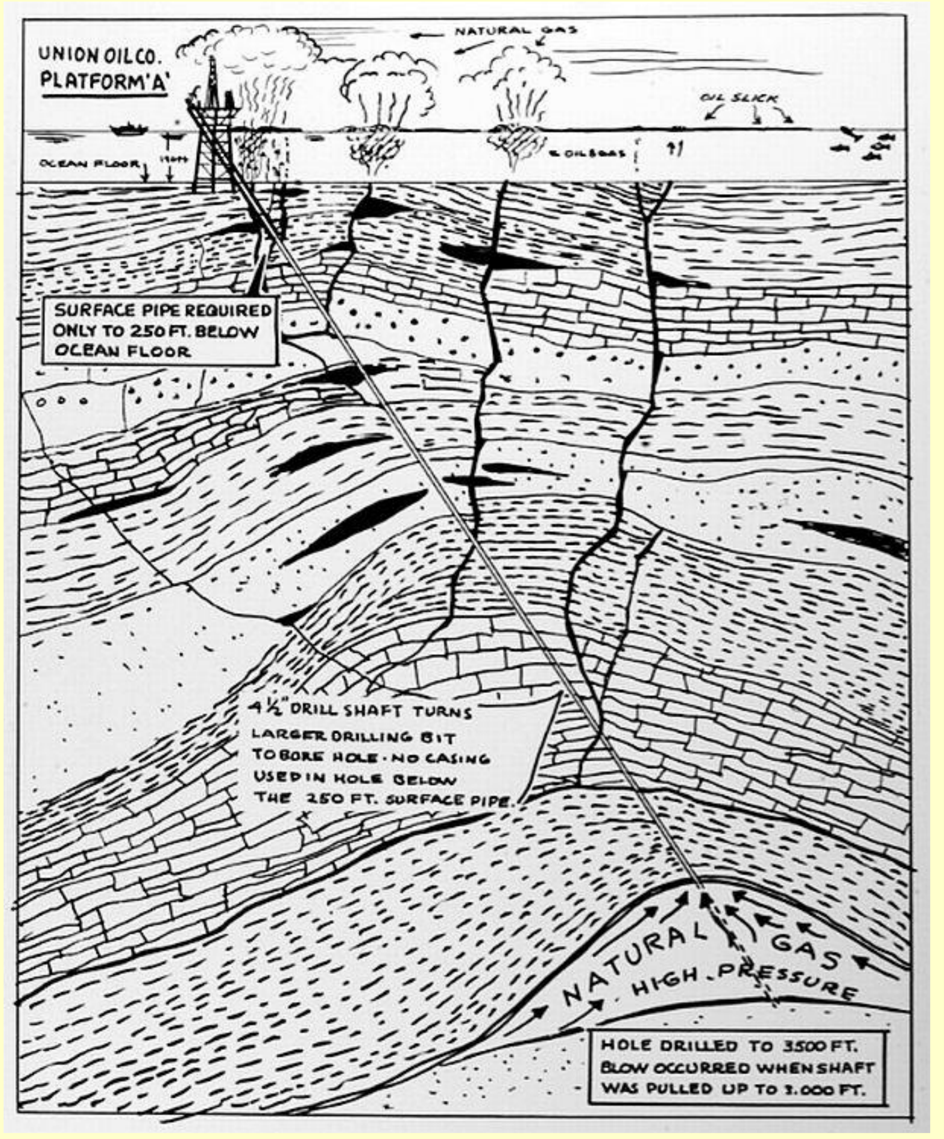
2 1969 SANTA BARBARA OIL SPILL

- ❖ 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

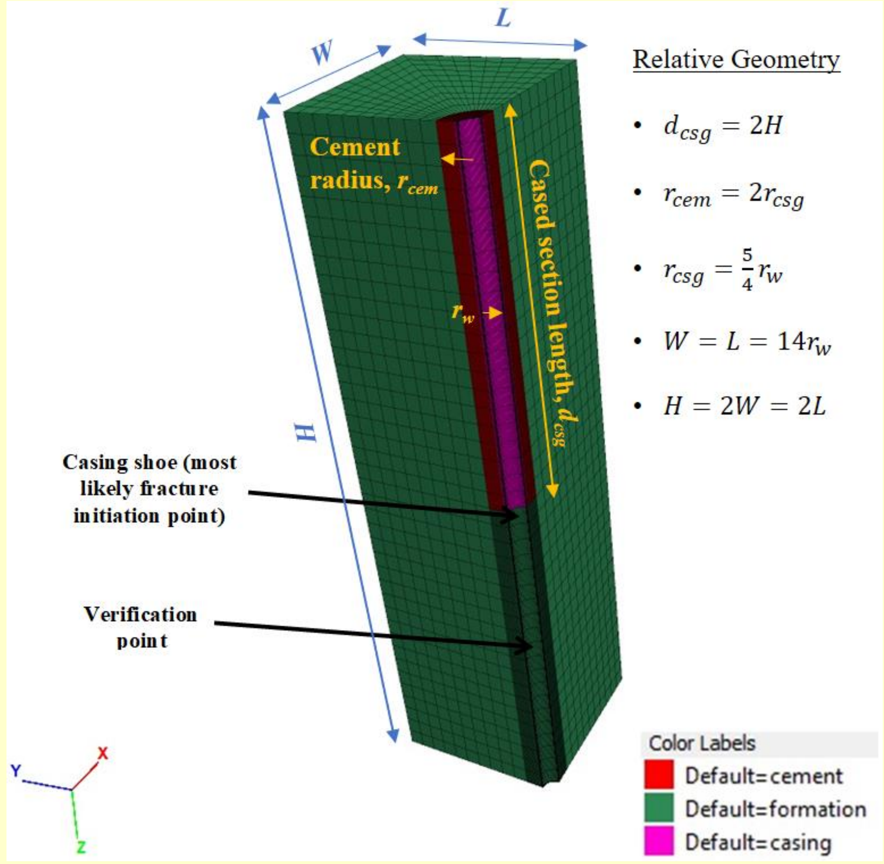
- ❖ During drilling kicks may lead to blowouts and uncontrolled discharge of reservoir fluids gushing from the wellbore.
- ❖ The wellbore pressure drop during discharge may cause casing collapse at several points
- ❖ Subsequent capping attempts can lead to fracture initiation below the casing shoe, or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

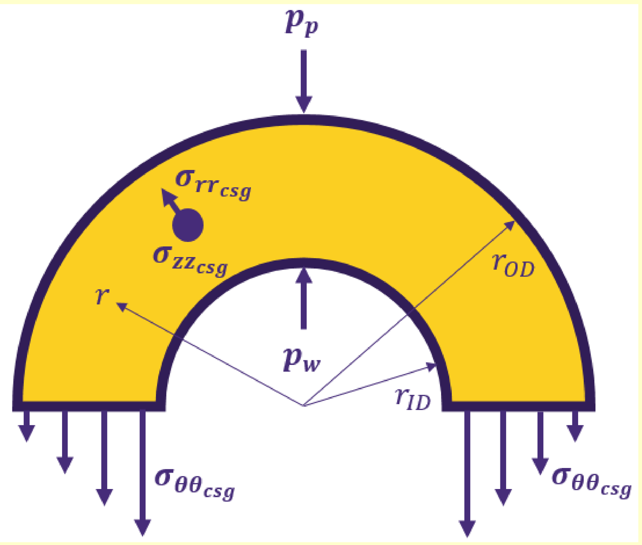


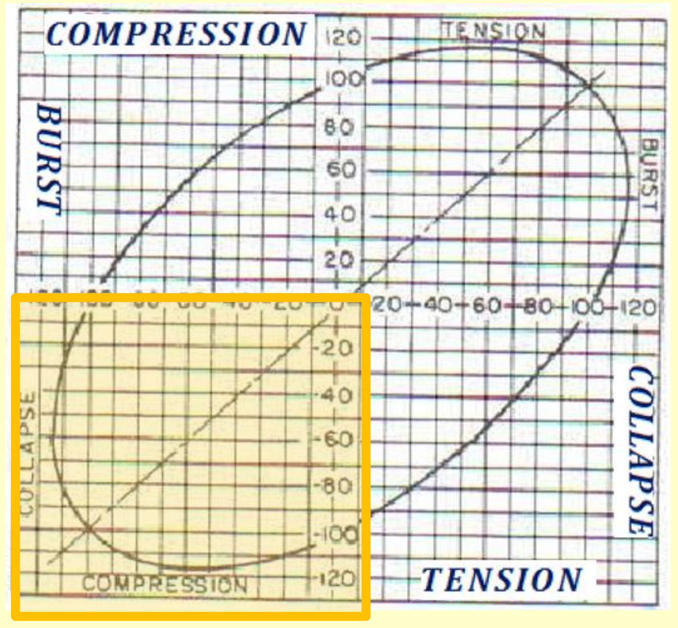
Dick Smith photo collection, UCSB, 1969-1971

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)



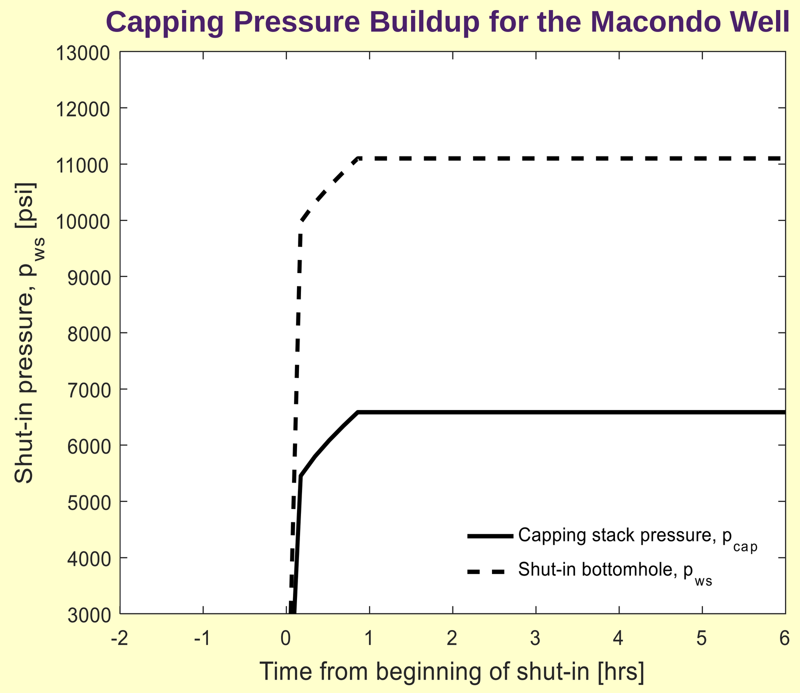




- ❖ Lamé equations for stresses inside casing

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

- ❖ Von Mises analysis to determine casing failure

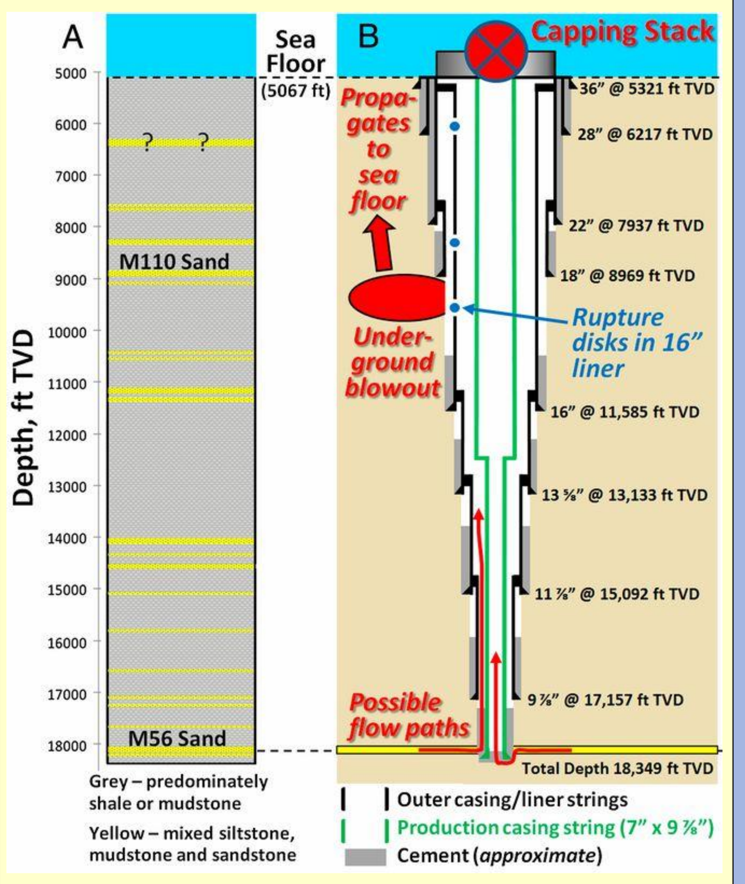


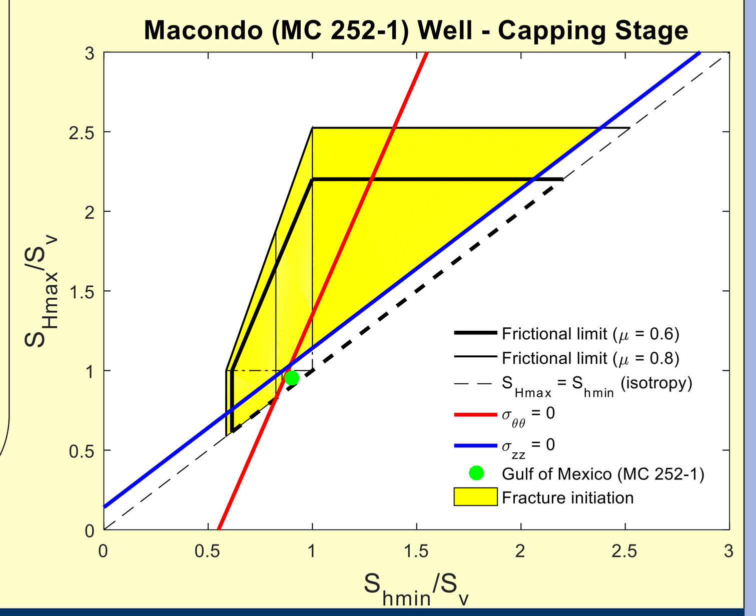
- ❖ MATLAB model for wellbore pressure build-up during "soft shut-in"
- ❖ Calculates the pressures at capping stack on sea floor and the bottomhole
- ❖ Compared with the actual capping pressure build-up observed at the BP's Macondo well → Excellent matching!

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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