09.04: How the Macondo pore pressure regression contributed to the Deepwater Horizon blowout

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ABSTRACT

We study pore pressure and stress at the Macondo well. Pore pressure approximately parallels the overburden stress to a depth of 17,640 ft subsea and thereafter decreases abruptly by 1,200 psi over 370 ft as the main sandstone reservoir (M56) is approached. We infer that lateral flow through the permeable sandstone controls the reservoir pressure, hence the pressure regression (Talk 8.03). We also observe a change in the mudstone effective stress vs. porosity relationship with depth. We attribute the shift to diagenesis of smectite to illite in the mudstone, and account for this process in our pore pressure prediction (Fig. 1). We show that the pore pressure regression was responsible for a reduction in fracture gradient as the main sandstone reservoir (M56) is approached (Fig. 2). This, in combination with the extreme pore pressures above, drastically narrowed the range of safe operational borehole pressures. These geologic factors led to drilling, casing, and cementing decisions that contributed to the Deepwater Horizon blowout.

CLICK ON IMAGE FOR LARGER VIEW

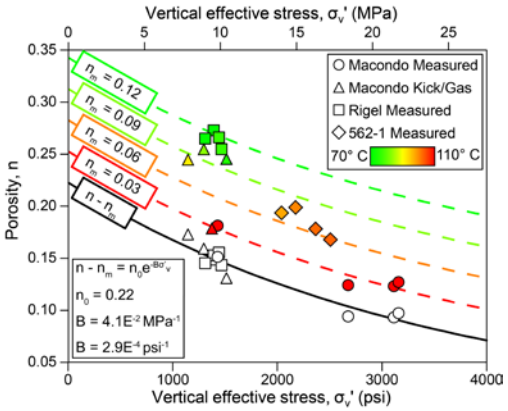

Fig 1: Mudstone porosity vs. effective stress after Lahann (2002). Color-coded symbols denote in-situ temperature for each mudstone porosity-effective stress calibration point.

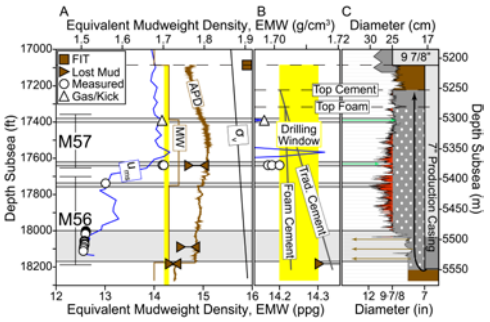

Fig 2: A) Pressure and stress gradient vs. depth expressed as an equivalent mud weight (EMW). B) Pressure and stress gradient vs. depth during temporary abandonment. C) Wellbore cross-section during temporary abandonment.

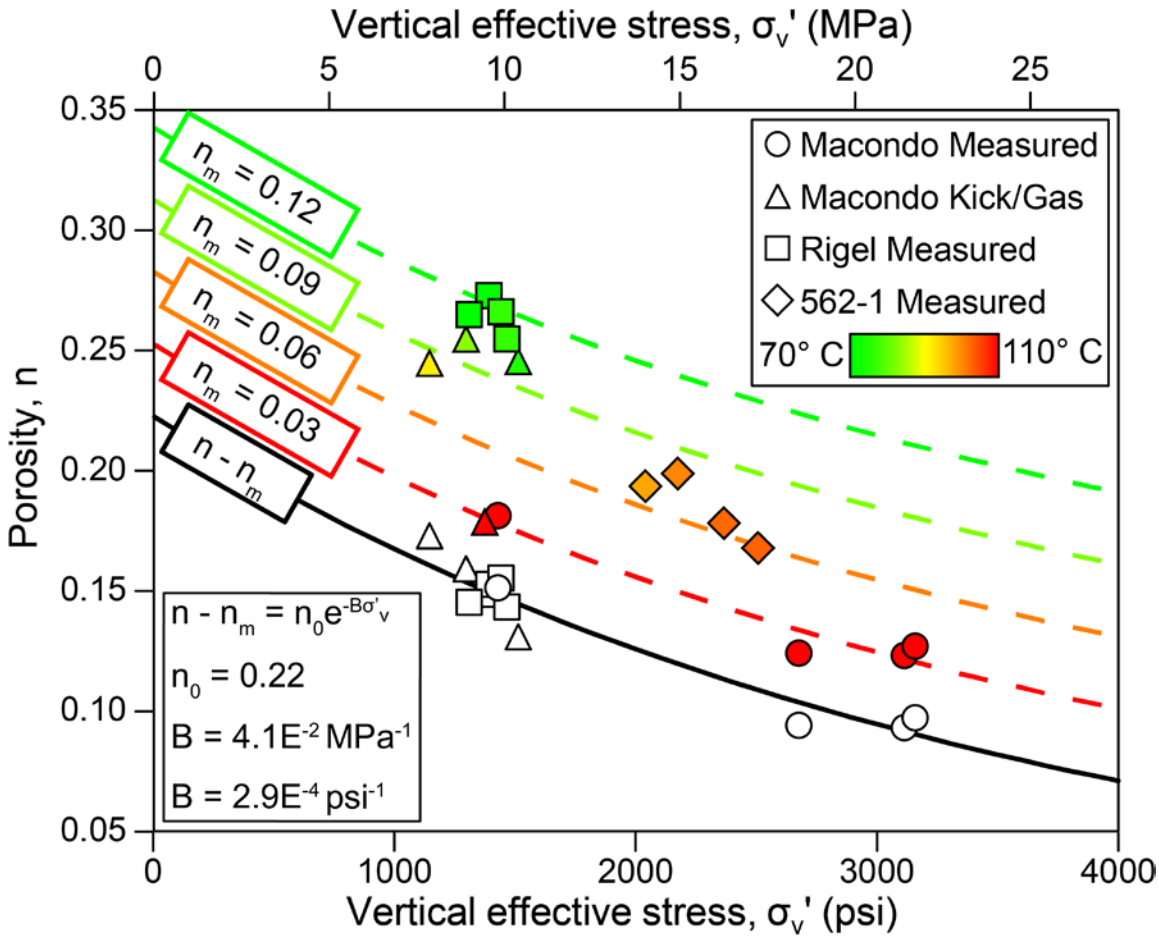

Fig. 1: Mudstone porosity vs. effective stress. Color-coded symbols denote in-situ temperature for each mudstone porosity-effective stress calibration point (MDT, GeoTap, kick/gas pressure). The points are corrected for clay-bound water porosity (open symbols) and then are used to calibrate the black line. Dashed lines show the porosity-effective stress relationships for different temperatures (color coded) and clay-bound water porosities. Measurements from the M56 reservoir (σ'_v >2500 psi) are corrected for hydrocarbon buoyancy. Porosity is estimated from velocity.

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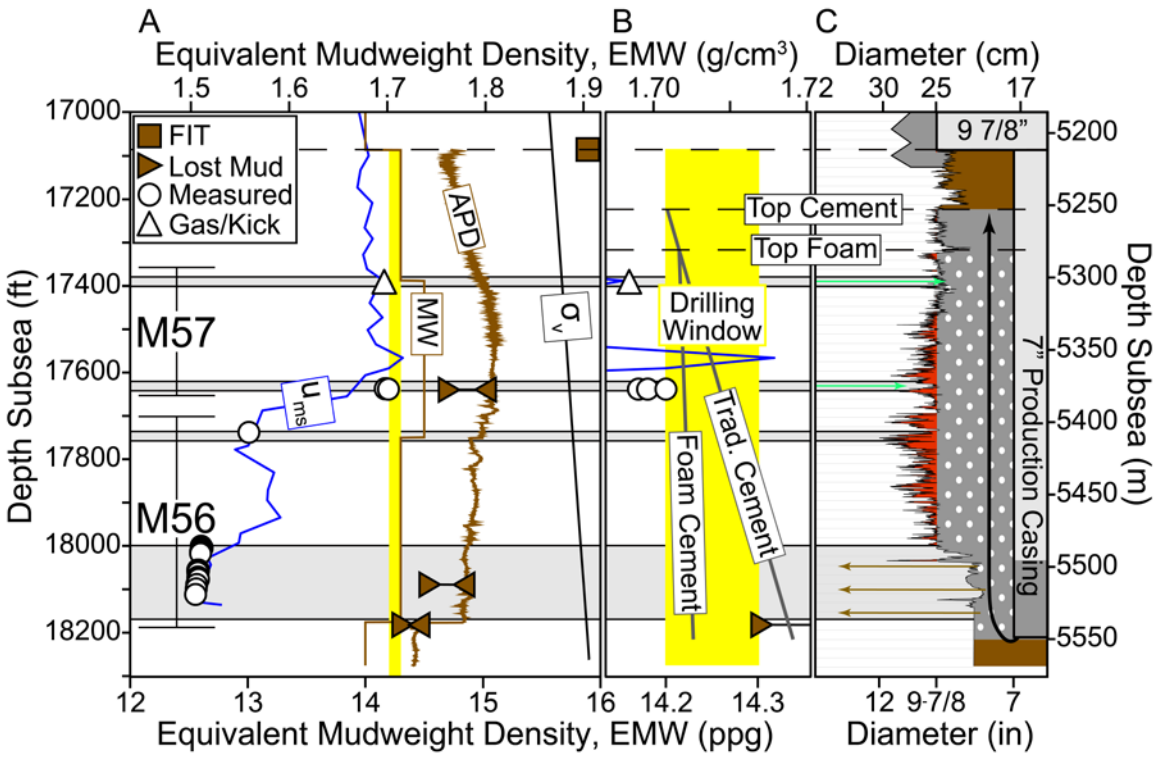

`**Fig. 2**: A) Pressure and stress gradient vs. depth expressed as an equivalent mud weight (EMW). Lost mud events record the lower and upper bounds of the fracture gradient (brown triangles); the formation integrity test (FIT, brown square) records a lower bound of the fracture gradient. The blue line records the estimated mudstone pore pressure, u_{ms}. The APD is the annular pressure while drilling as recorded on the drill string. The MW records the static pressure from drilling mud weight measured at surface conditions. To prevent influx of M57 pore fluids (C, green arrows), the static borehole pressure had to be kept above 14.20 ppg (1.702 g/cm^3) EMW. However, to avoid fracturing the M56 (C, brown arrows), the dynamic pressure had to be kept below 14.3-14.4 ppg (1.714-1.726 g/cm^3) EMW. The zone in yellow shows the range of pressures that had to be maintained (the drilling window). B) Pressure and stress gradient vs. depth during temporary abandonment. The two gray lines represent the static pressure that would be induced by foamed cement (left, 14.5 ppg or 1.738 g/cm^3) vs. a traditional cement (right, 16.74 ppg or 2.006 g/cm^3). C) Wellbore cross-section during temporary abandonment. Cement is pumped through the bottom of the casing and up the annulus. White circles differentiate the foamed cement from the traditional cement cap above. Red shows caliper measurements greater than the width of the under-reamer.

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