

Deepwater Shallow Water Flow (SWF): Causes and Evasion*

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Search and Discovery Article #41809 (2016)**

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Abstract

SWF represents a costly drilling challenges in deepwater. This study shows the impact of depth below the mud line (BML) vs. the subsea mud-line depth (WD) on this phenomenon. It calculates the mud-up required to evade SWF occurrences at different WD / BML depths.

The backbone of this study is establishing the differential pressure between the sand vs. the shale beds. This is due to the fact that most of the SWF's take place while penetrating the shale–sand boundaries. Case histories from the Gulf of Mexico, where the upper Pleistocene depositional fan was and is still active, are utilized.

During compaction, sand's formation water rapidly influxes upward whereas dewatering of shale is slow. The differential pressure (ΔP) value ranges from 630 psi (1.2 ppg) to 50 psi (0.2 ppg) at variable depths. All ΔP 's show highest values between 1500 and 2500 ft BML, which is where most SWF takes place. Moreover, ΔP noticeably increases near the ML at greater WD, and it can be the reason for the occasional conductor and well head sinking in the extra WD.

Sand-shale hydrodynamic pressure modeling and high-resolution shallow seismic before drilling can mitigate the potentially problematic zones. Choosing correct mud-up values (ΔP) at depth is essential to combat SWF and conversely loss of circulation.

This pilot method can also be successfully applicable in other similar young, deepwater settings worldwide; e.g., the Nile, Niger, and Amazon deltas, as well as south Asian areas.

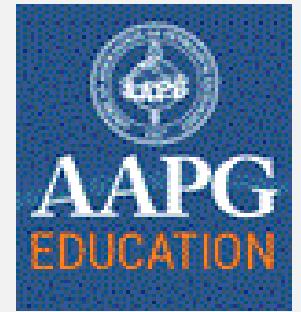
Selected References

- Dutta, N.C., 2002, Geopressure prediction using seismic data: Current status and the road ahead: *Geophysics*, v.67/6, p. 2012–2041.
- Fertl, W.H., 1976, Abnormal Formation Pressures: New York, Elsevier Scientific Publishing Co., 382 p.
- Leftwich, J.T., Jr., 1993, The development of zones of undercompacted shale relative to abnormal subsurface pressures in sedimentary basins: Ph.D. dissertation, The Pennsylvania State University.
- Leftwich, J.T., Jr., and T. Engelder, 1994, The characteristics of geopressure profiles in the Gulf of Mexico basin, *in* Basin Compartments and Seals: AAPG Memoir 61, p. 119-129.
- Mallick, S., and N.C. Dutta ,2002, Shallow water flow prediction using prestack waveform inversion of conventional 3D seismic data and rock modeling: *The Leading Edge*,v. 21/7, p. 675-680.
- Orange, D.L., D. Saffer, P. Jeanjean, Z. Al-Khafah, G. Humphrey, and G. Riley, 2003, Measurements and modeling of the shallow pore pressure regime at the Sigsbee Escarpment: Successful prediction of overpressure and ground-truthing with borehole measurements: *The Leading Edge*, v. 22, p. 906-913.
- Shaker, S.S., 2015, A new perspective on shallow water flow (SWF) prediction and the prevention of sinking well-heads in deepwater: Search and Discovery Article #41614 (2015). Website accessed May 30, 2016,
http://www.searchanddiscovery.com/documents/2015/41614shaker/ndx_shaker.pdf.
- Shaker, S.S., 2016, Causes and deterrent of SWF in deep water of the Mississippi prodelta areas: *The Leading Edge*, v, 35/4, p. 330-335.
- Terzaghi, K., and R.B. Peck, 1948, Soil Mechanics in Engineering Practice, 1st edition: John Wiley & Sons, New York.

Terzaghi, K., and R.B. Peck, 1967, Soil Mechanics in Engineering Practice, 2nd edition: John Wiley & Sons, New York, 729p.

TGS, 2014, Shallow hazards and prospects in high resolution (advertisement): AAPG Explorer March, 2014, p. 32. Website accessed May 30, 2016, <http://www.aapg.org/publications/news/explorer/2014/03mar>.

Winker, C.D., and J.R. Booth, 2000, Sedimentary dynamics of the salt-dominated continental slope, Gulf of Mexico: integration of observations from the seafloor, near surface, and deep subsurface: GCSSEPM Foundation 20th Annual Research Conference Deep-Water Reservoirs of the World, December 3–6, p. 1059–1086.



Deepwater Shallow Water Flow (SWF): Causes and Evasion

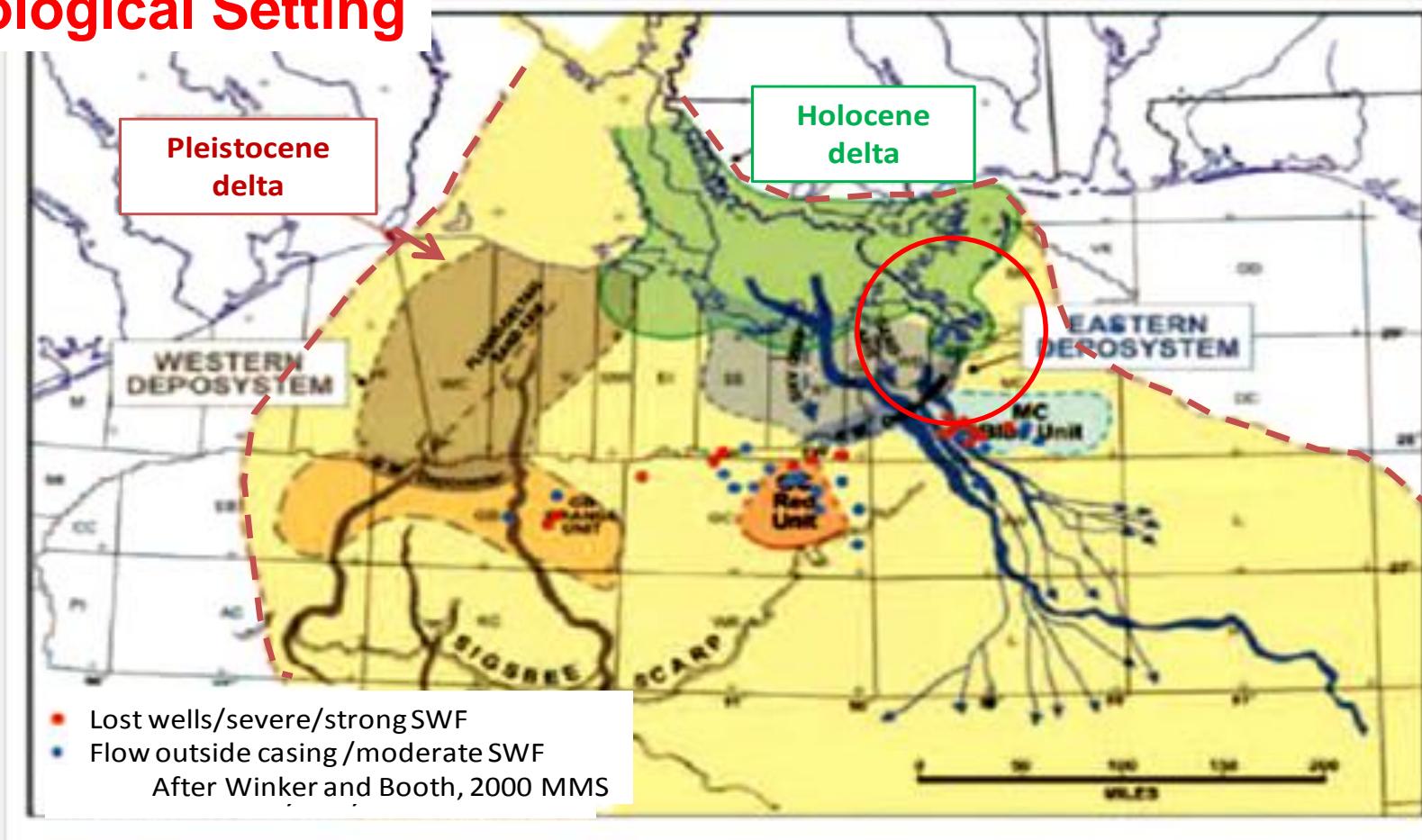
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G. A. S.
*Geopressure Analysis
Services*

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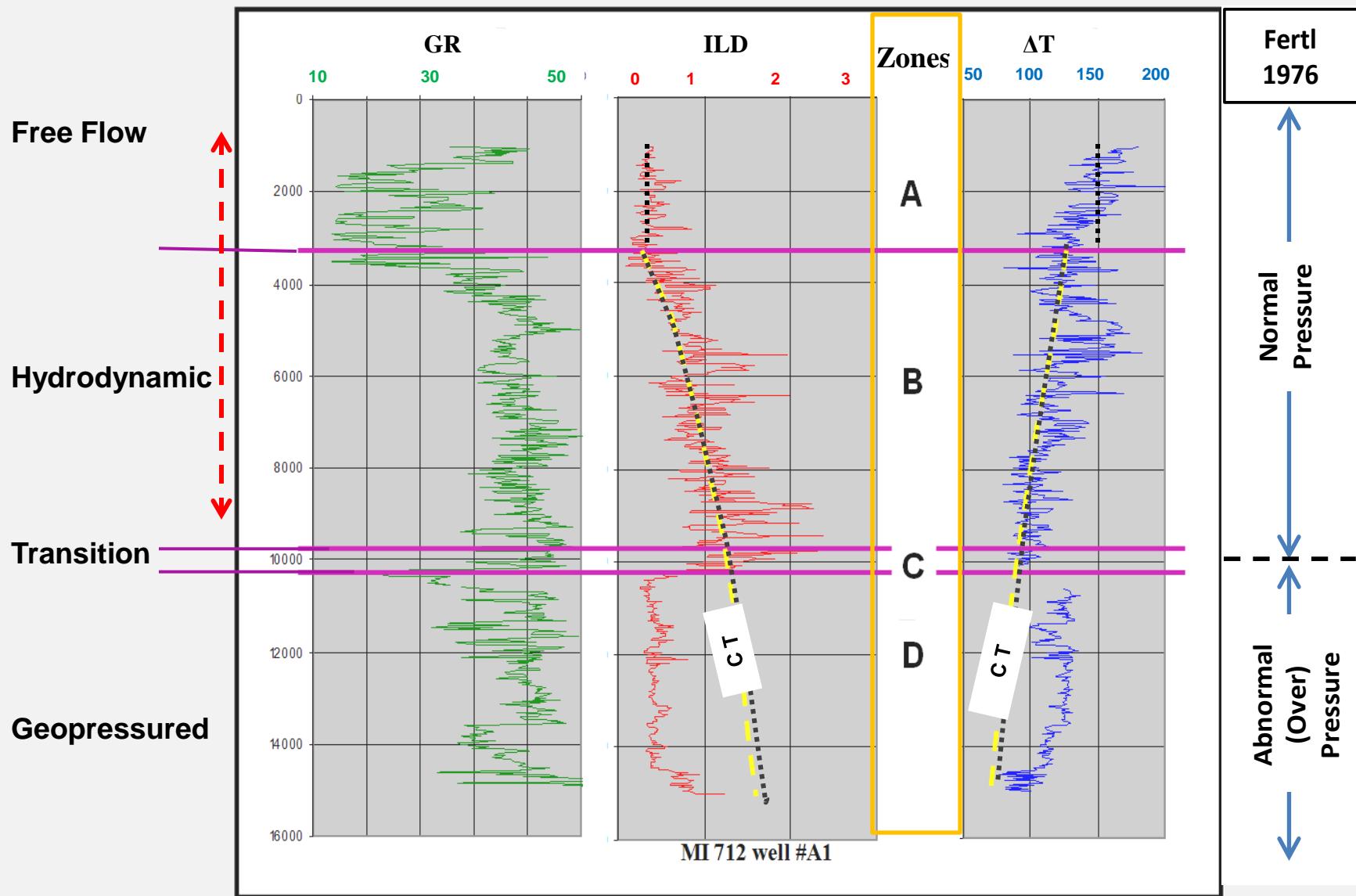
Geological Setting



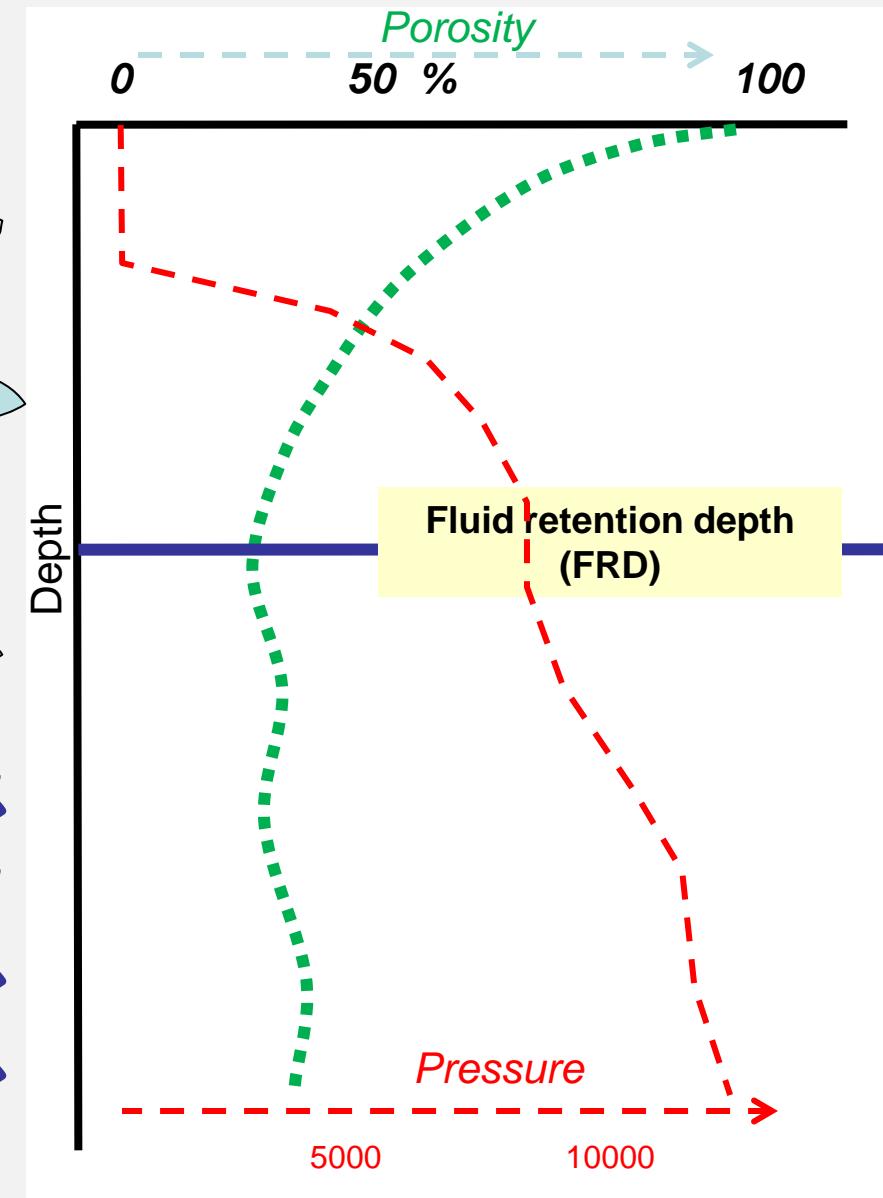
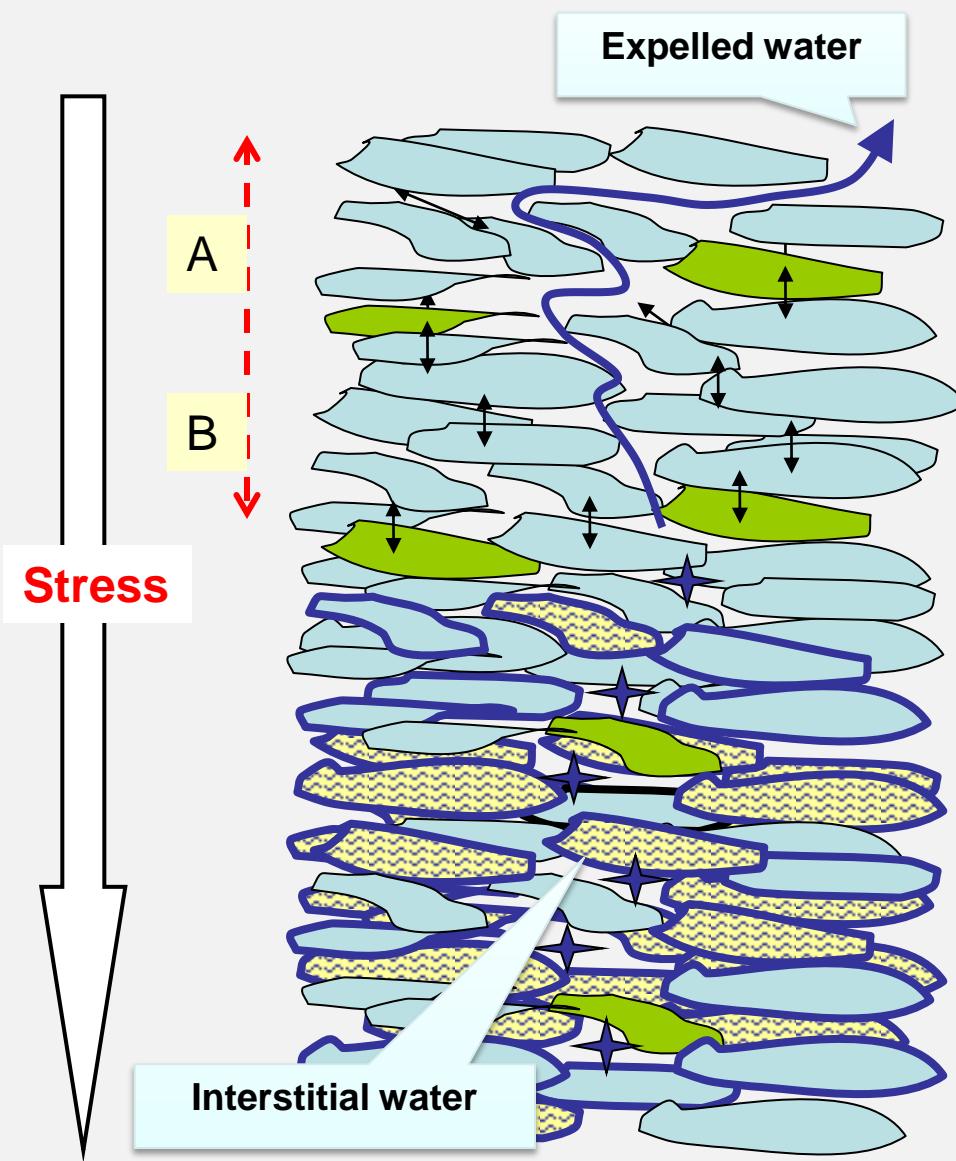
Up Pleistocene

Generic Subsurface pore pressure zones

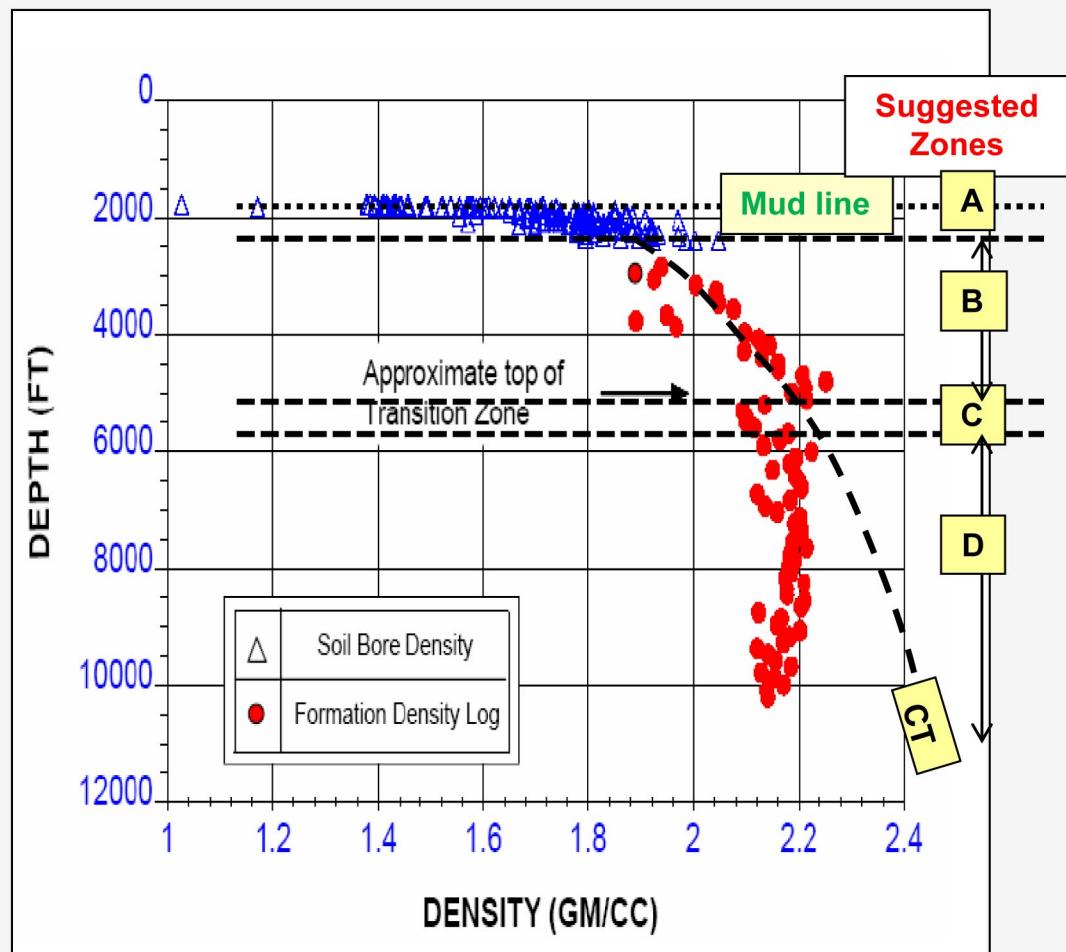
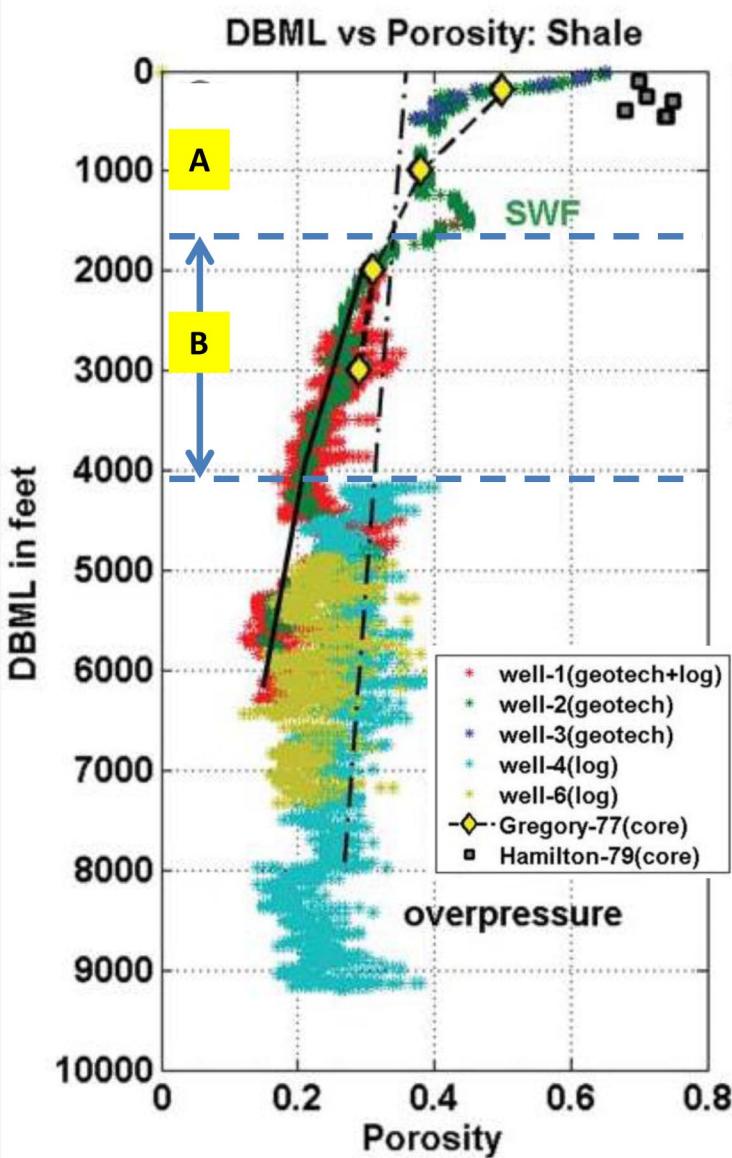
Terzaghi 1948
Leftwich 1994



Sediments Compaction and Dehydration



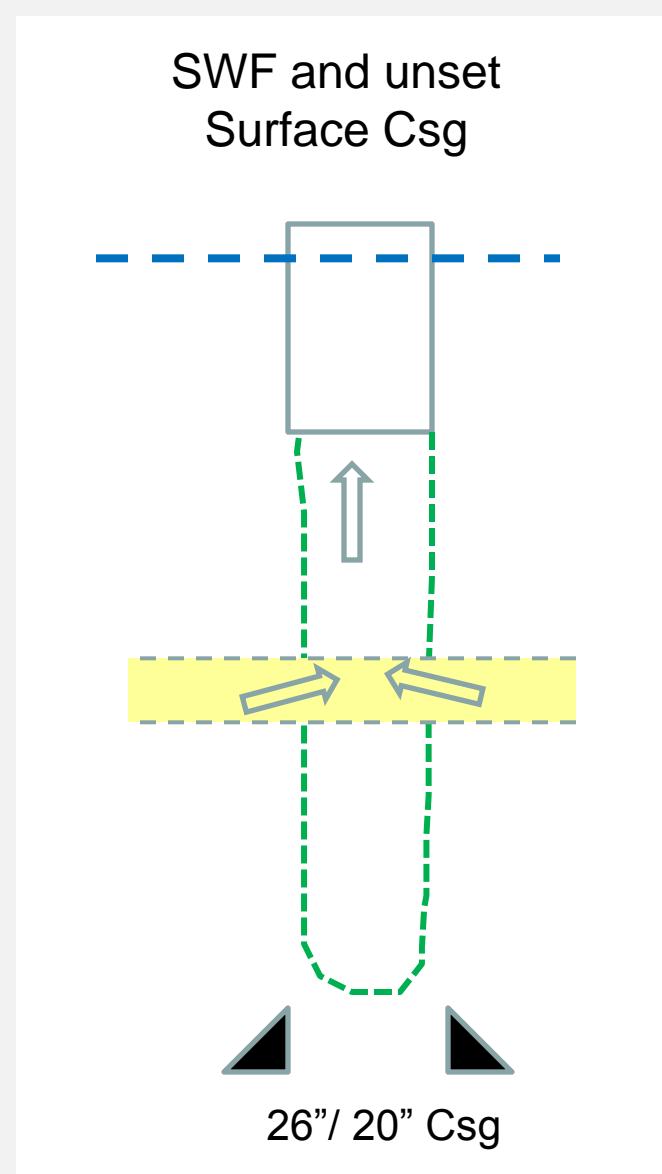
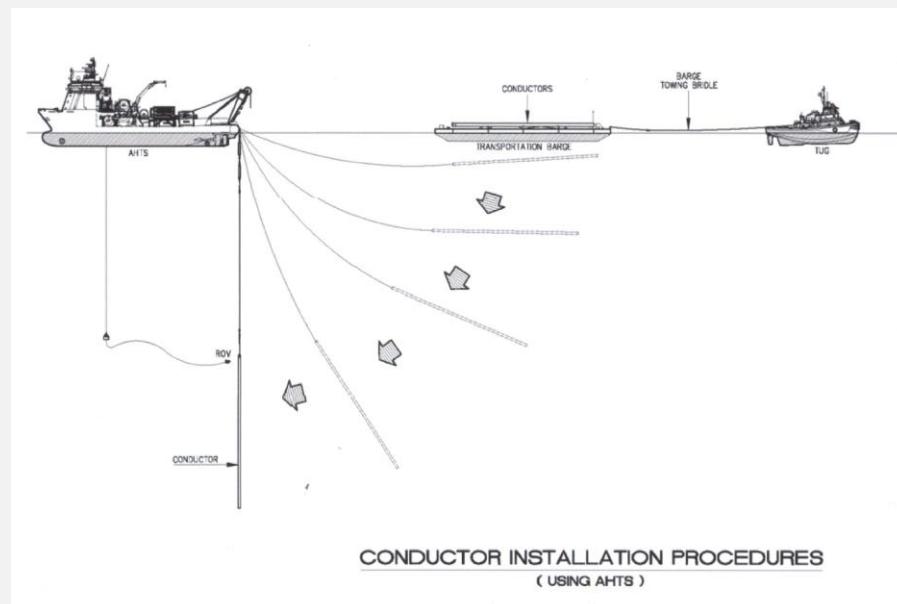
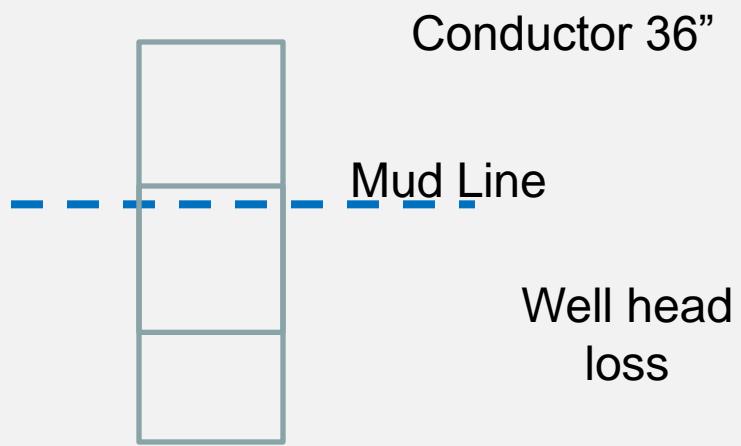
Deepwater pore pressure zones vs. ϕ and ρ



Modified after Texas A & M 2005

Modified after Dutta et al., TLE 2009

Operation challenges at shallow depth in deepwater



Drilling troubles due to SWF

- SWF sands occur in water depths of more than 400m

- They are found at depths of 250- 1000m below the mud-line

- Overpressures are usually caused by rapid sedimentation ?

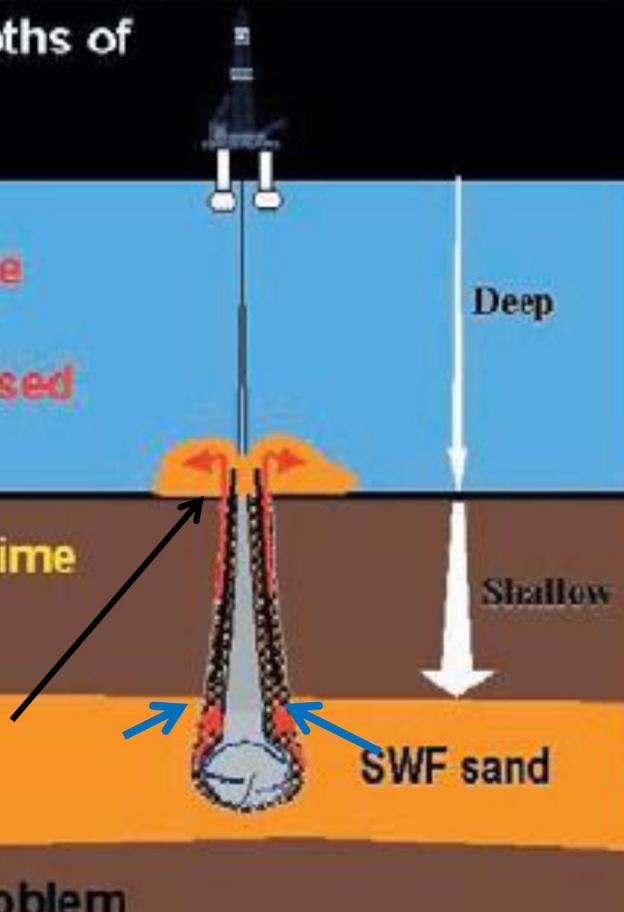
- Flow typically increases with time

Prevent setting Surface CSG

- Sediments pile up at well head

Abandonment of Well location

- Estimated costs of the SWF problem
> \$200M in GOM



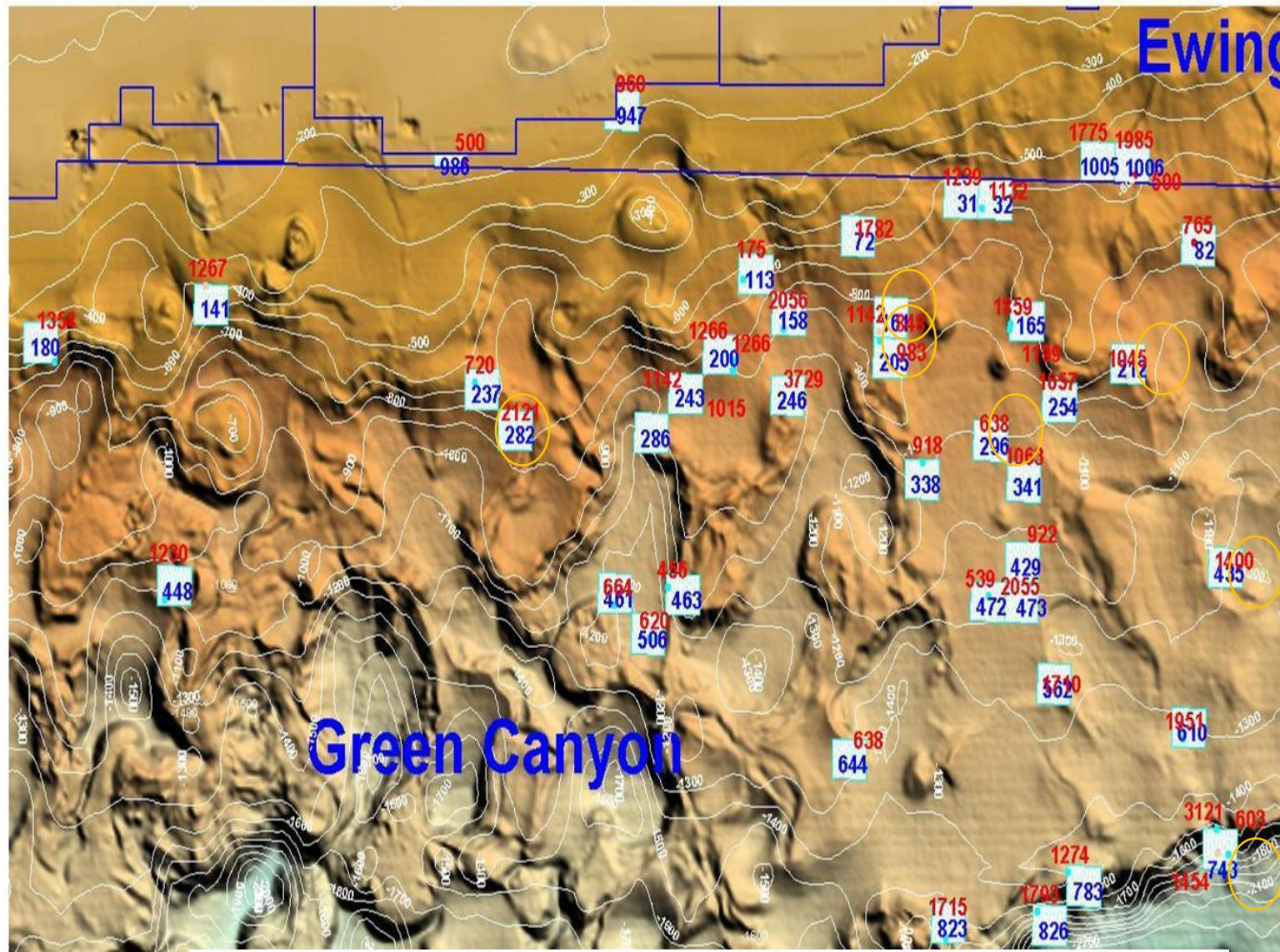
Shallow water flow problem encountered in deepwater drilling.

Modified after Mallick and Dutta ,2002, TLE

Sea floor topography ?



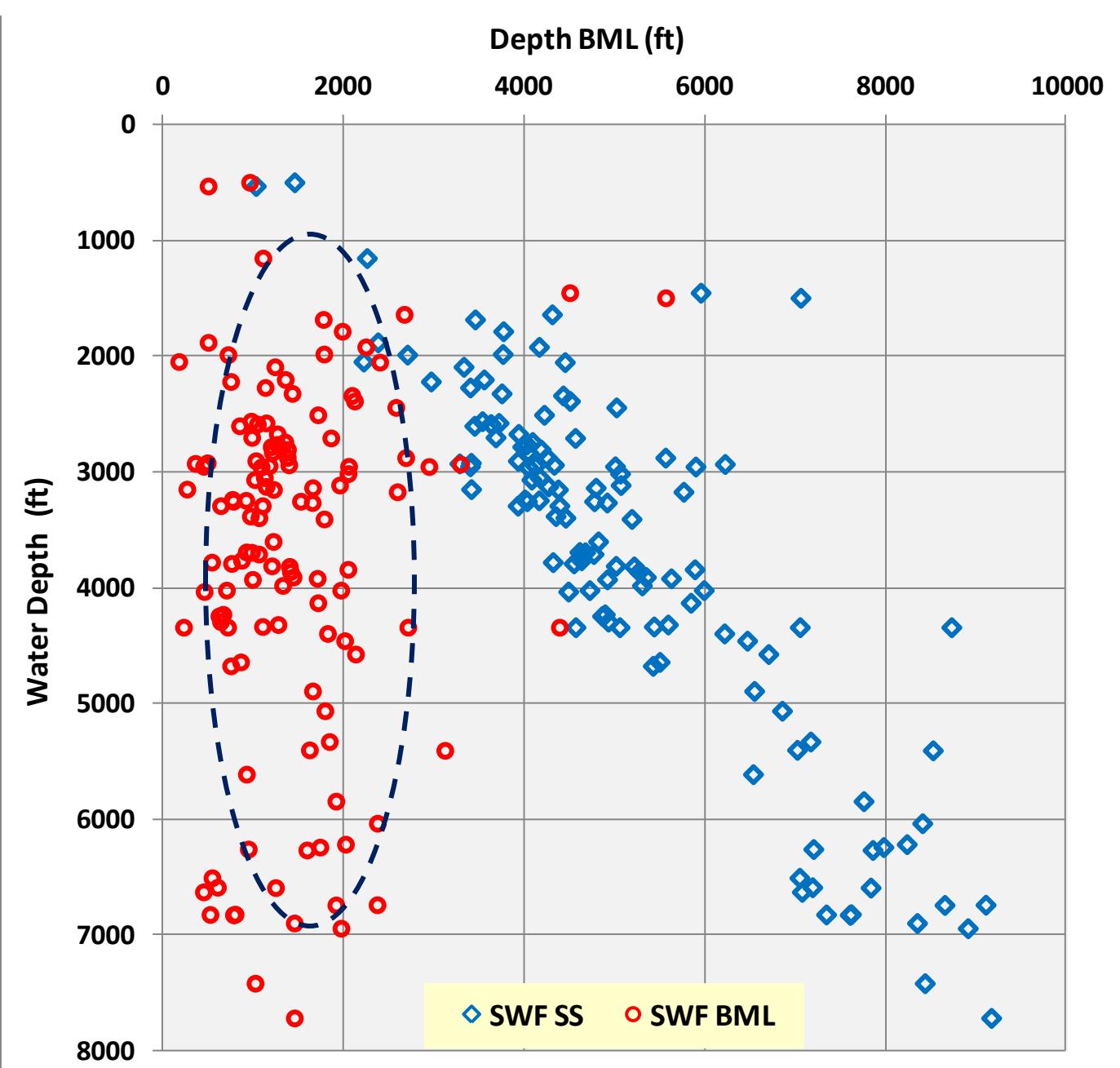
U. S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Region



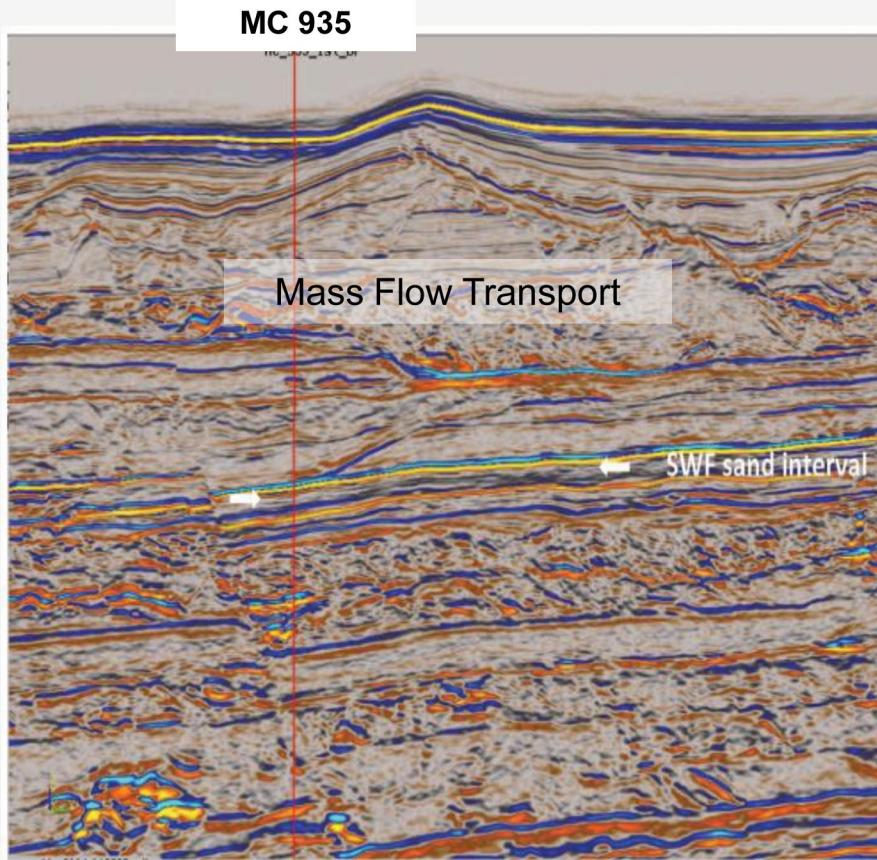
Blue is block number

Red is depth BML of SWF

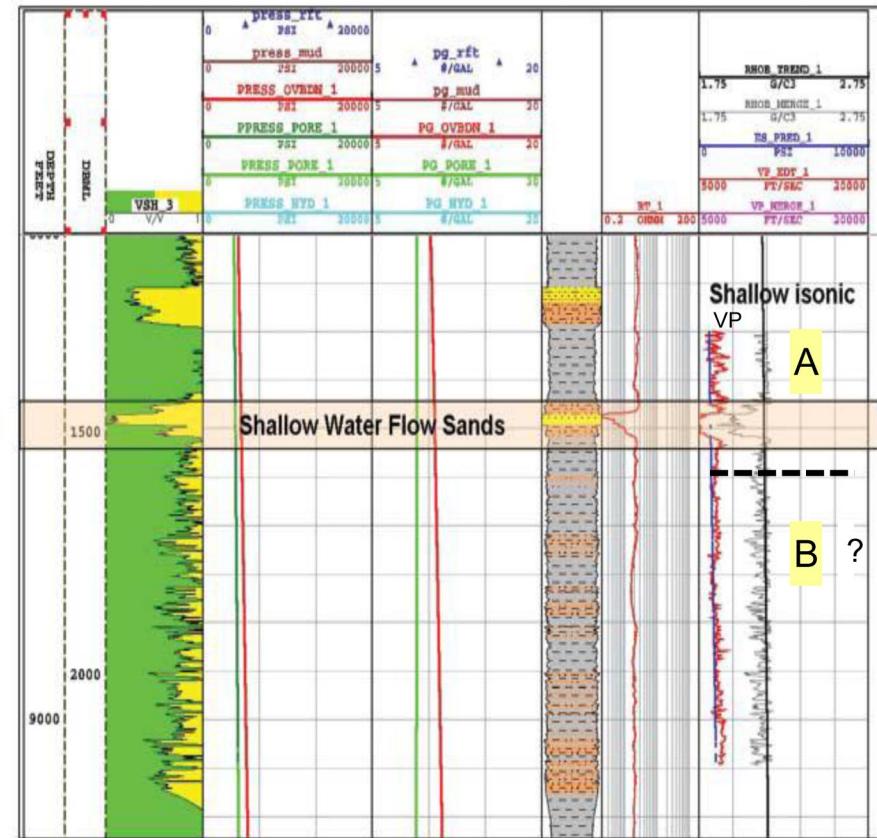
SWF and WD vs. BML



Most of the SWF takes place penetrating the shale – sand interface

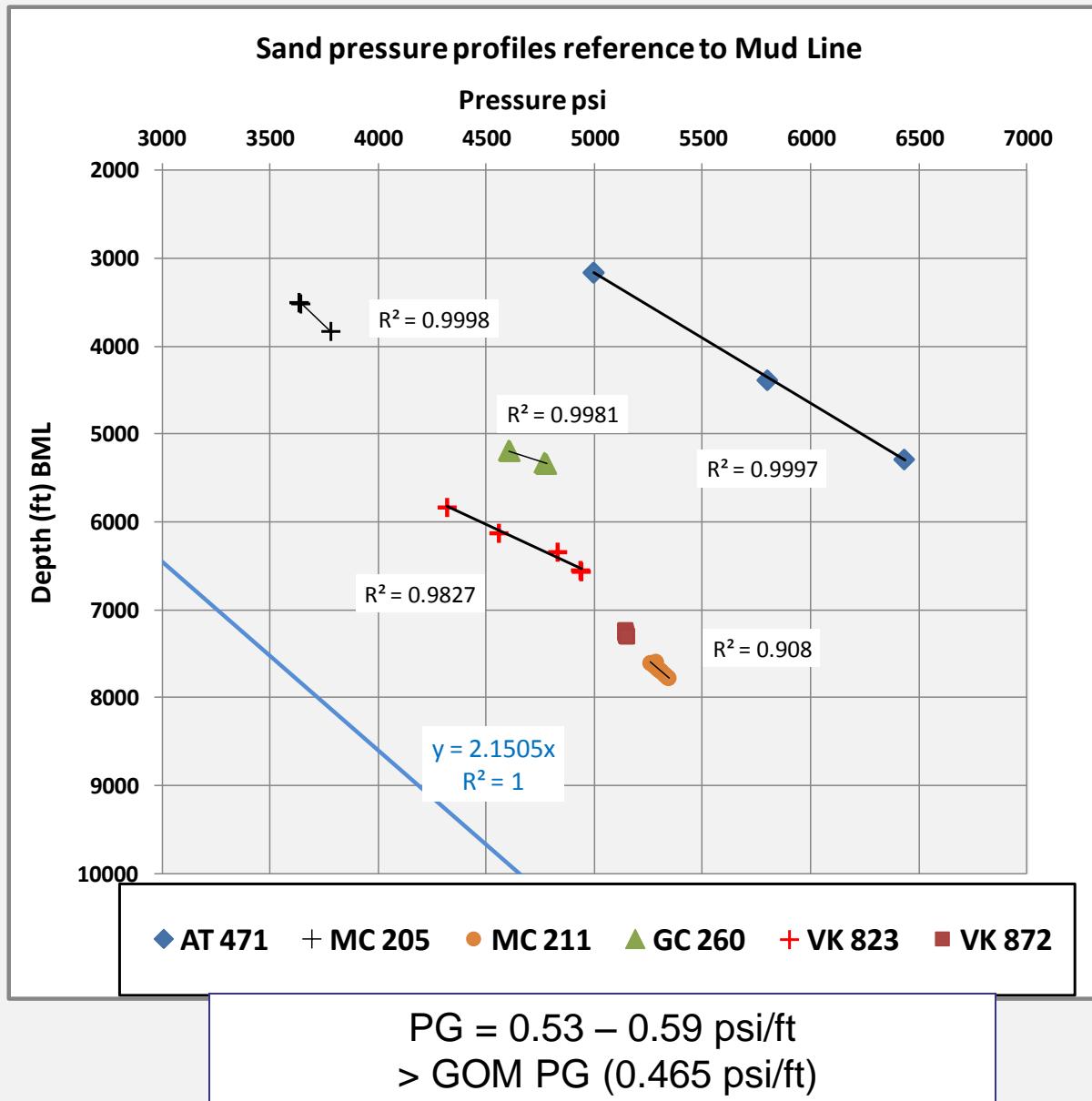


After Dutta et al., 2010

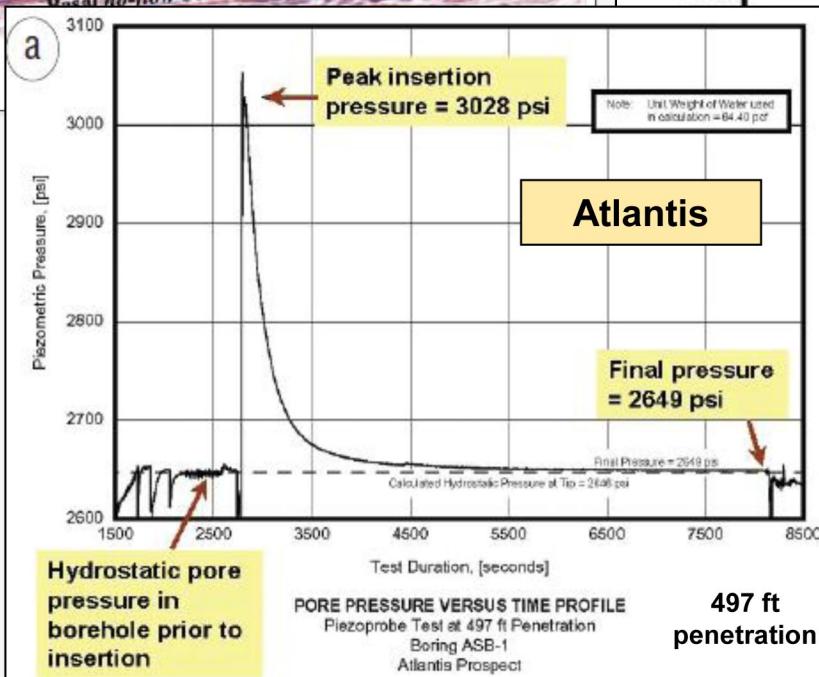
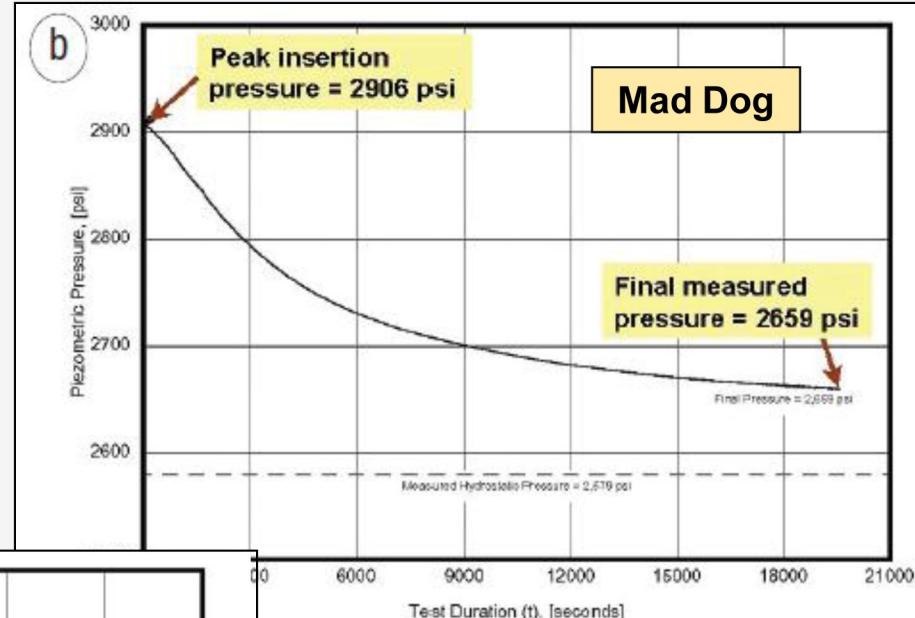
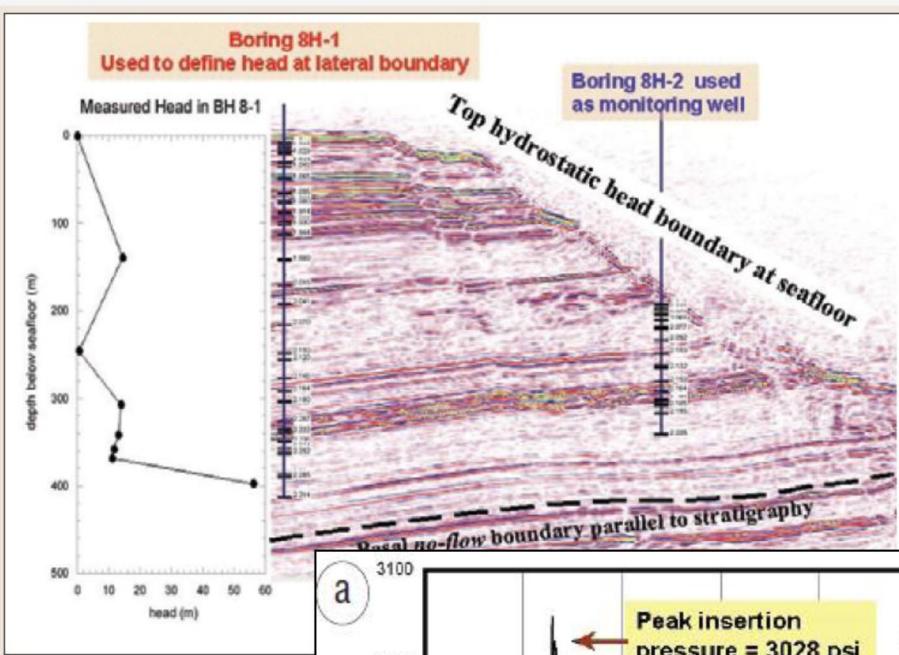


Modified after Dutta et al., 2009

SAND Pressure (BML) from RFT's and MDT's (zone B)

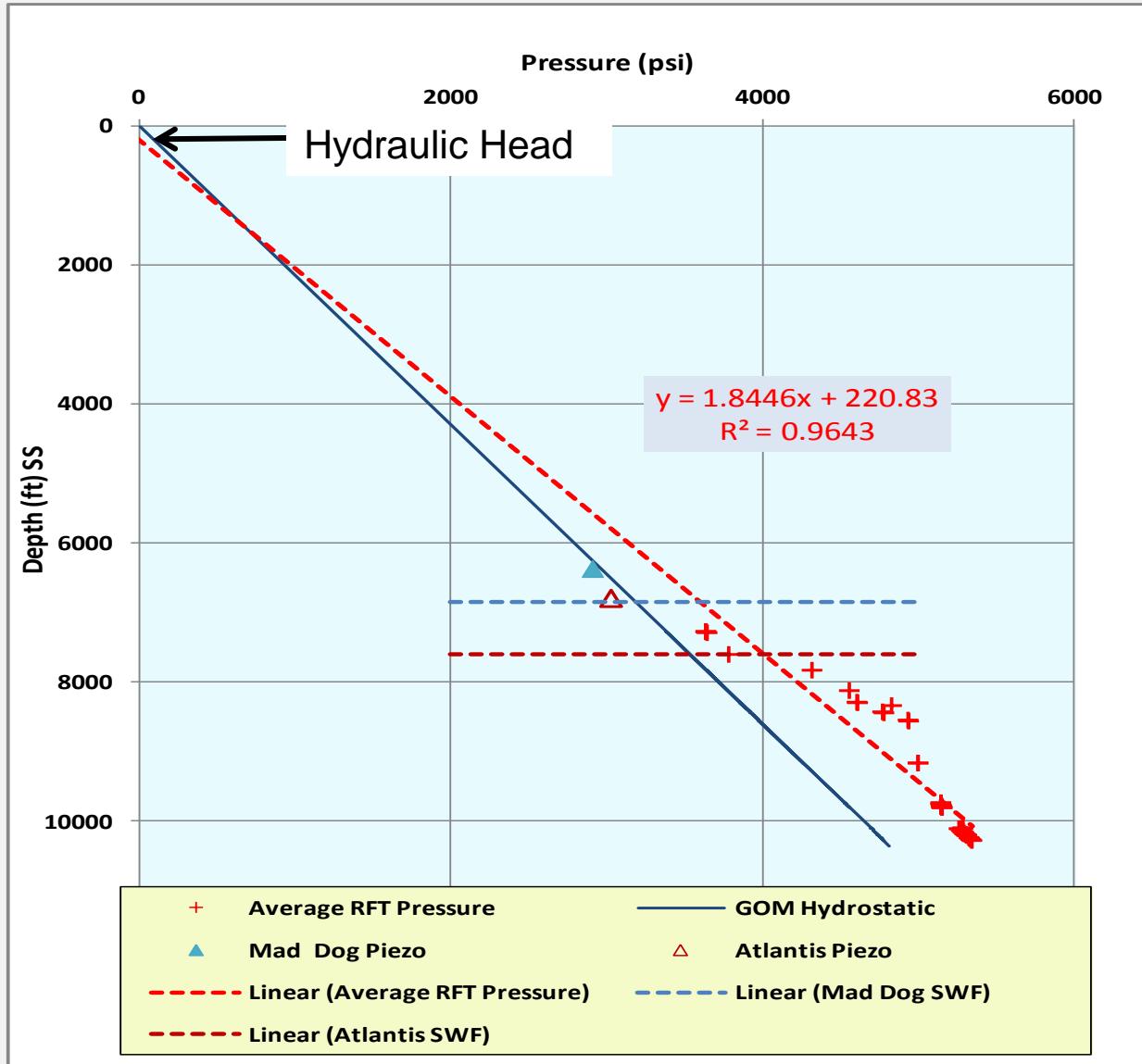


Pressure from Piezoprobe tests in Mad Dog and Atlantis.



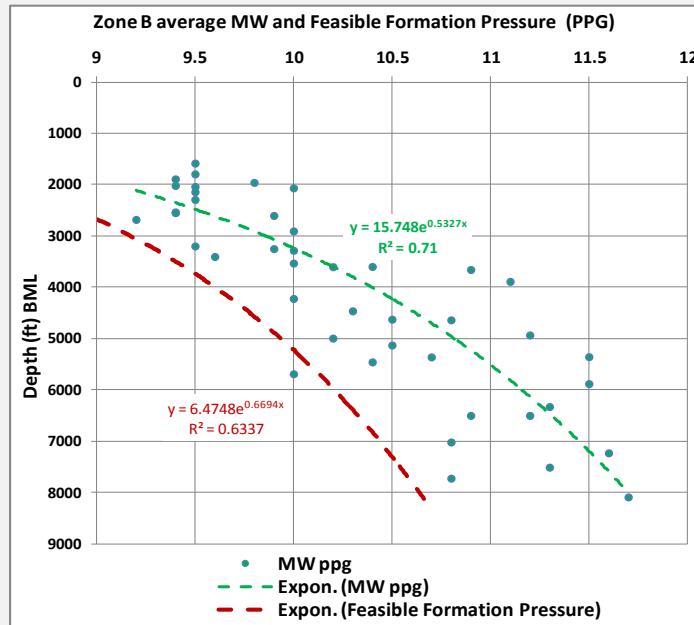
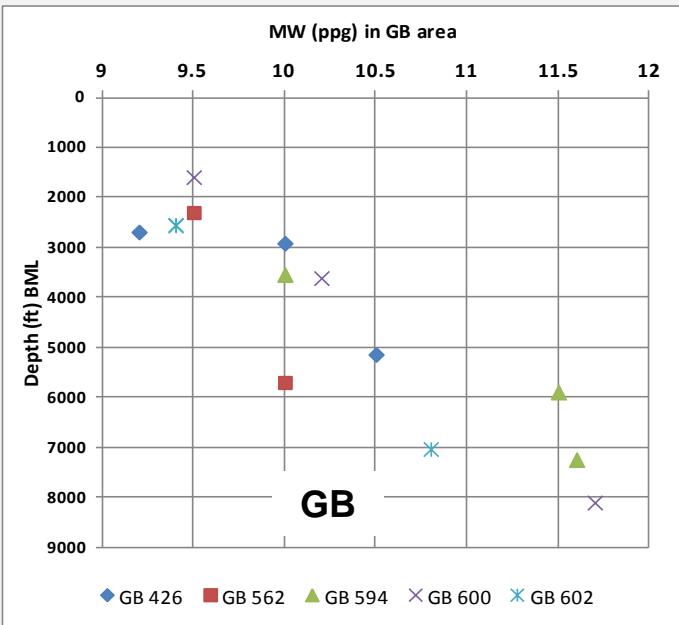
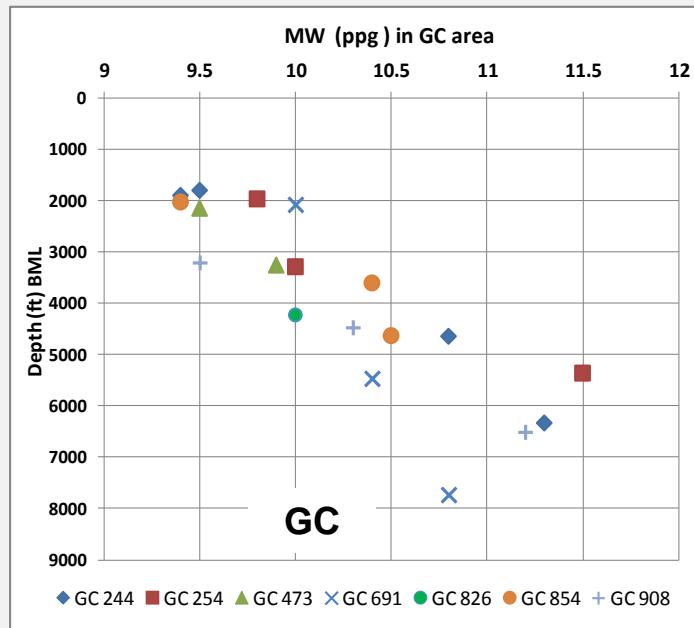
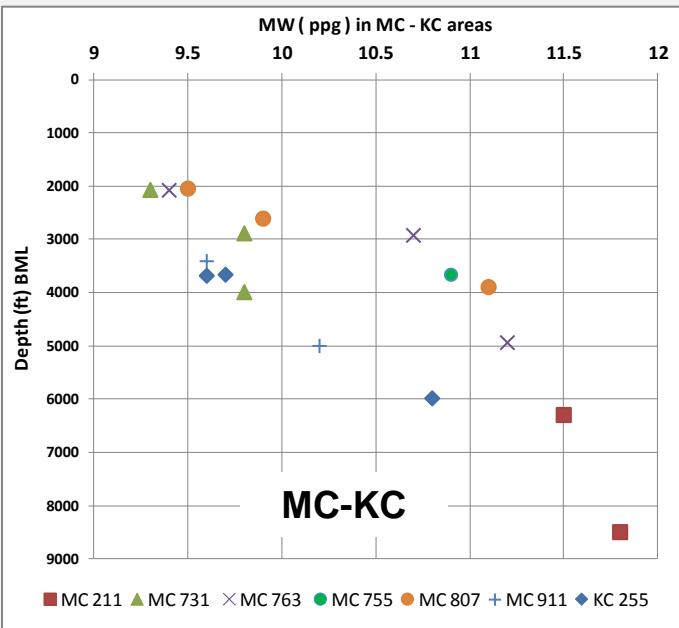
After Orange et al., TLE 2003

SAND Pressure (SS) Average gradient

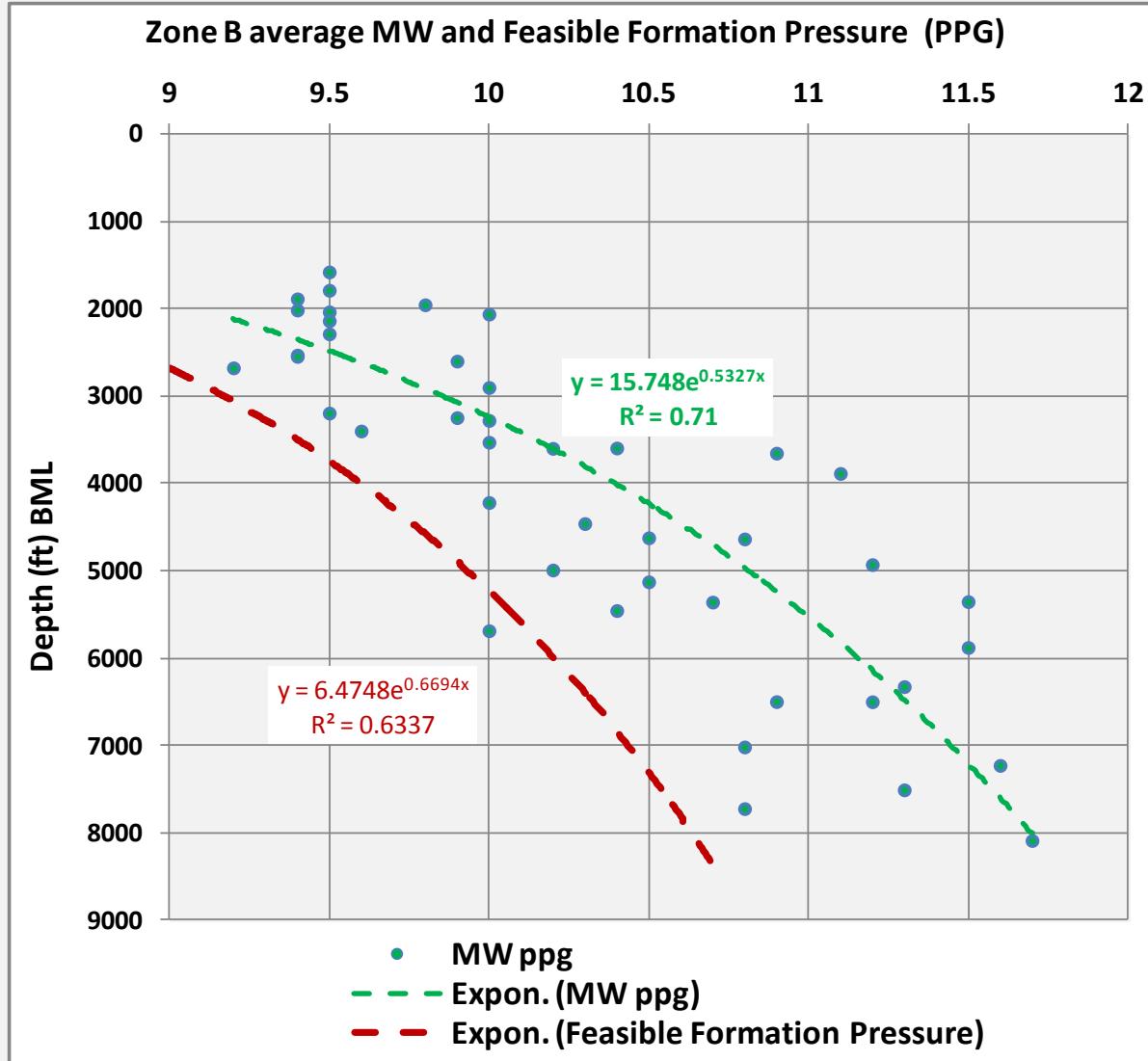


$$\text{Pressure (psi)} = \text{depth (SS)} * 0.54 - 120$$

Drilling Mud Pressure (ppg) in the Compaction zone B



Feasible Formation Pressure Calculation (ppg)



$$\text{Av. MW (ppg)} = [2 \ln \text{depth (BML)}] - 6.12$$
$$\text{FF Pressure (ppg)} = [1.4 \ln \text{depth (BML)}] - 2.6$$

Calculations of Sand P - FFP (ΔP) and safe MW at 5000' WD

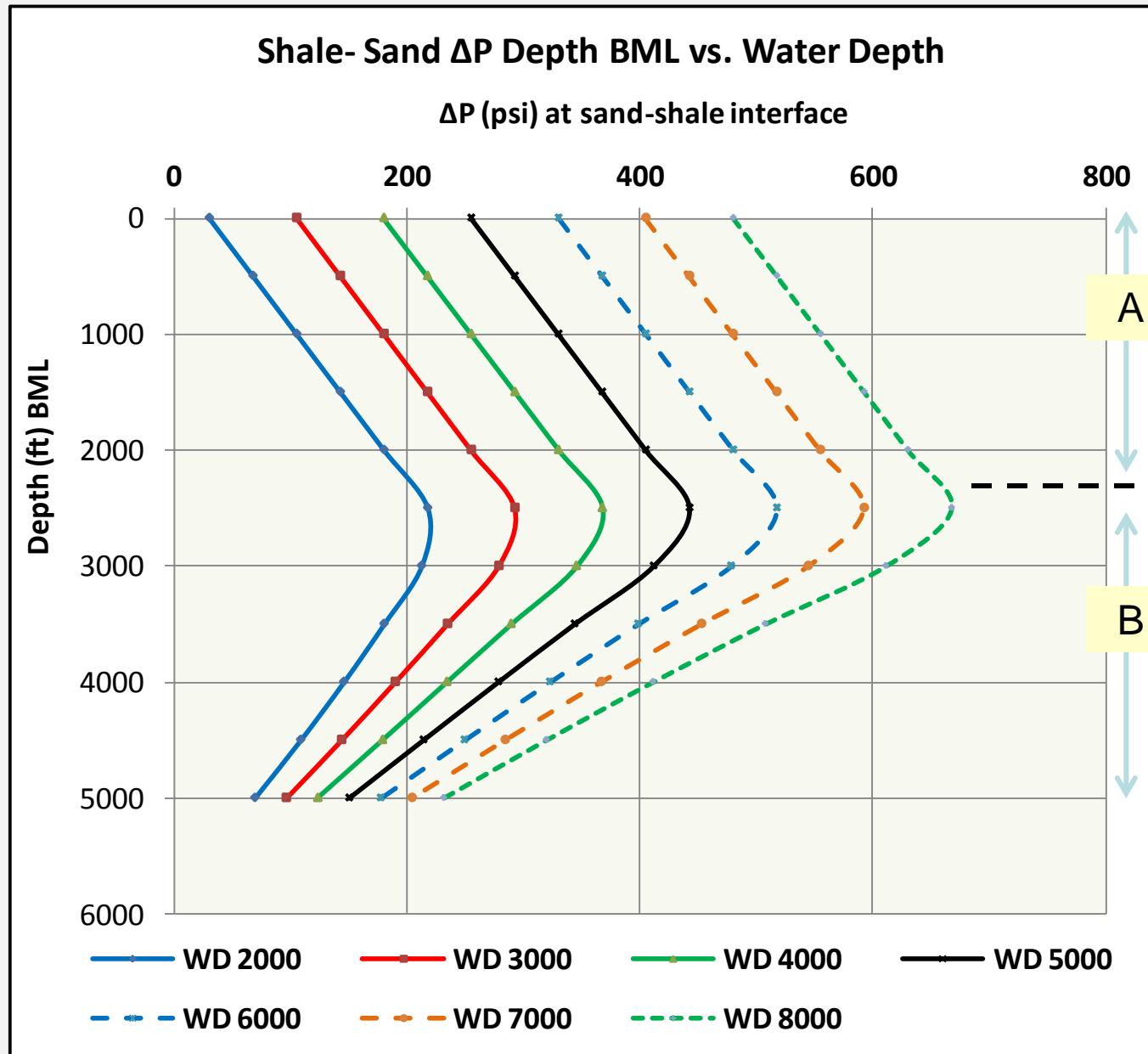
WD ft	TD SS ft	TD BML	Sand PP psi	Sand PP ppg	FFP ppg	ΔP ppg	ΔP psi	Average MW	Min Safe Mud	PP Zones
5000	5300	300	2742	9.99	8.97	1.01	277.50	9.50	10.51	A
5000	5500	500	2850	10.00	8.97	1.03	292.50	9.50	10.53	A
5000	6000	1000	3120	10.04	8.97	1.06	330.00	9.50	10.56	A
5000	6500	1500	3390	10.07	8.97	1.09	367.50	9.50	10.59	A
5000	7000	2000	3660	10.09	8.97	1.12	405.00	9.50	10.62	A
5000	7500	2500	3930	10.11	8.97	1.14	442.50	9.53	10.67	A
5000	8000	3000	4200	10.13	9.14	0.99	411.61	9.87	10.86	B
5000	8500	3500	4470	10.15	9.37	0.78	343.68	10.16	10.94	B
5000	9000	4000	4740	10.16	9.57	0.60	278.18	10.41	11.01	B
5000	9500	4500	5010	10.18	9.74	0.43	213.91	10.63	11.07	B
5000	10000	5000	5280	10.19	9.90	0.29	150.15	10.83	11.12	B

$$\text{Sand Pressure (psi)} = \text{depth (SS)} * 0.54 - 120$$

$$\text{FF Pressure (ppg)} = [1.4 \ln \text{depth (BML)}] - 2.6$$

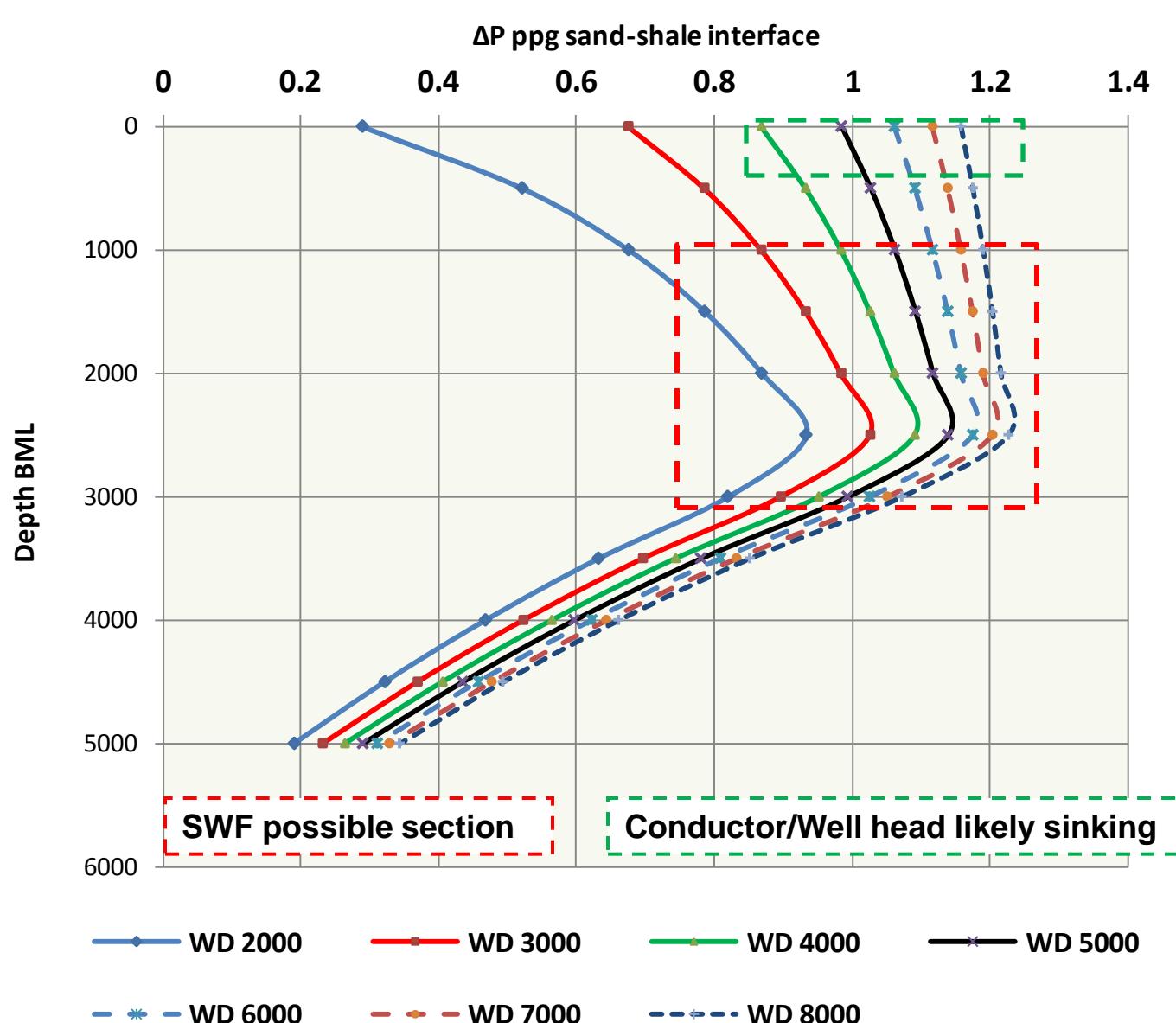
$$\text{Av. MW (ppg)} = [2 \ln \text{depth (BML)}] - 6.12$$

ΔP in psi



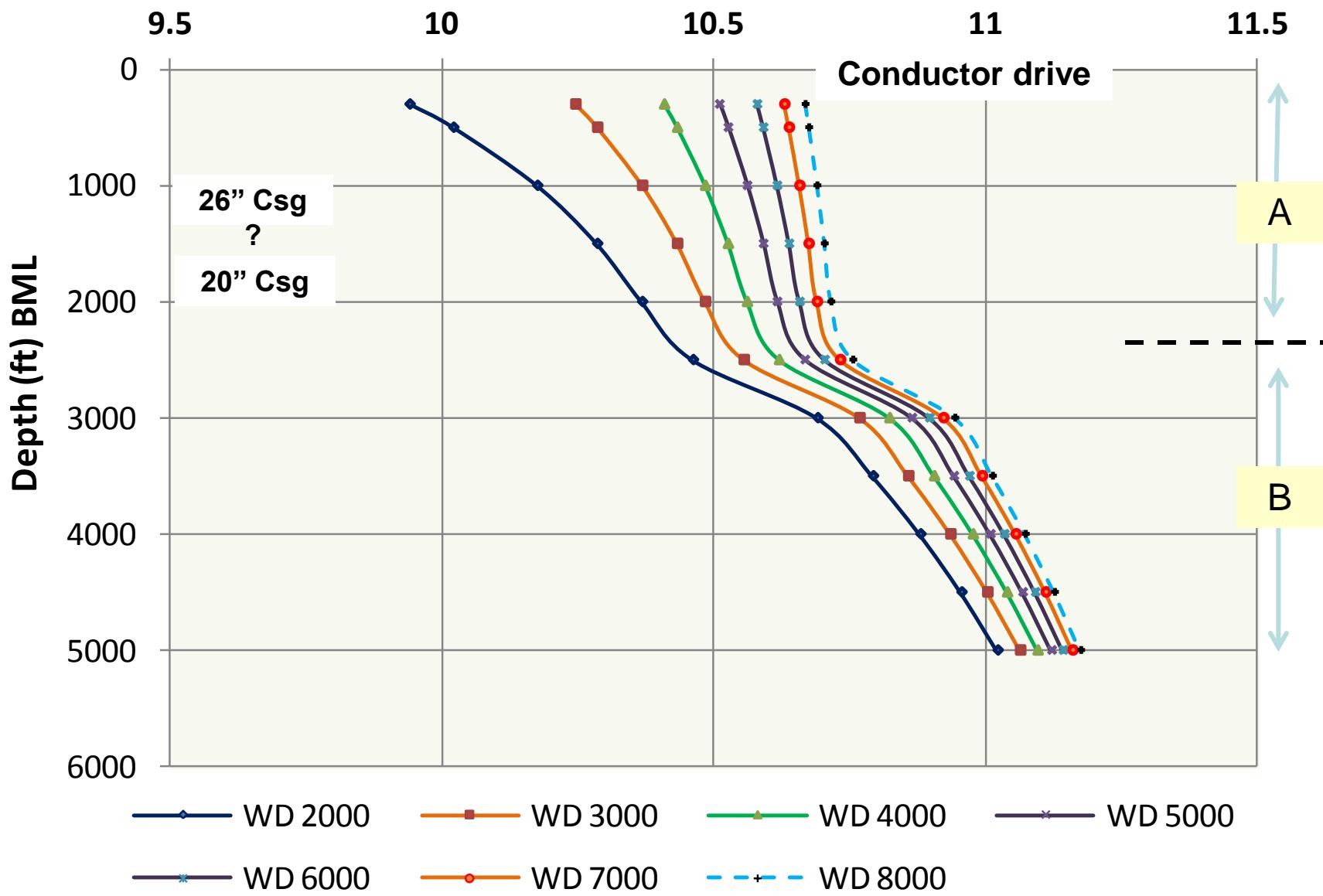
ΔP in ppg mwe

Sand - Shale ΔP Depth BML vs. Water Depth

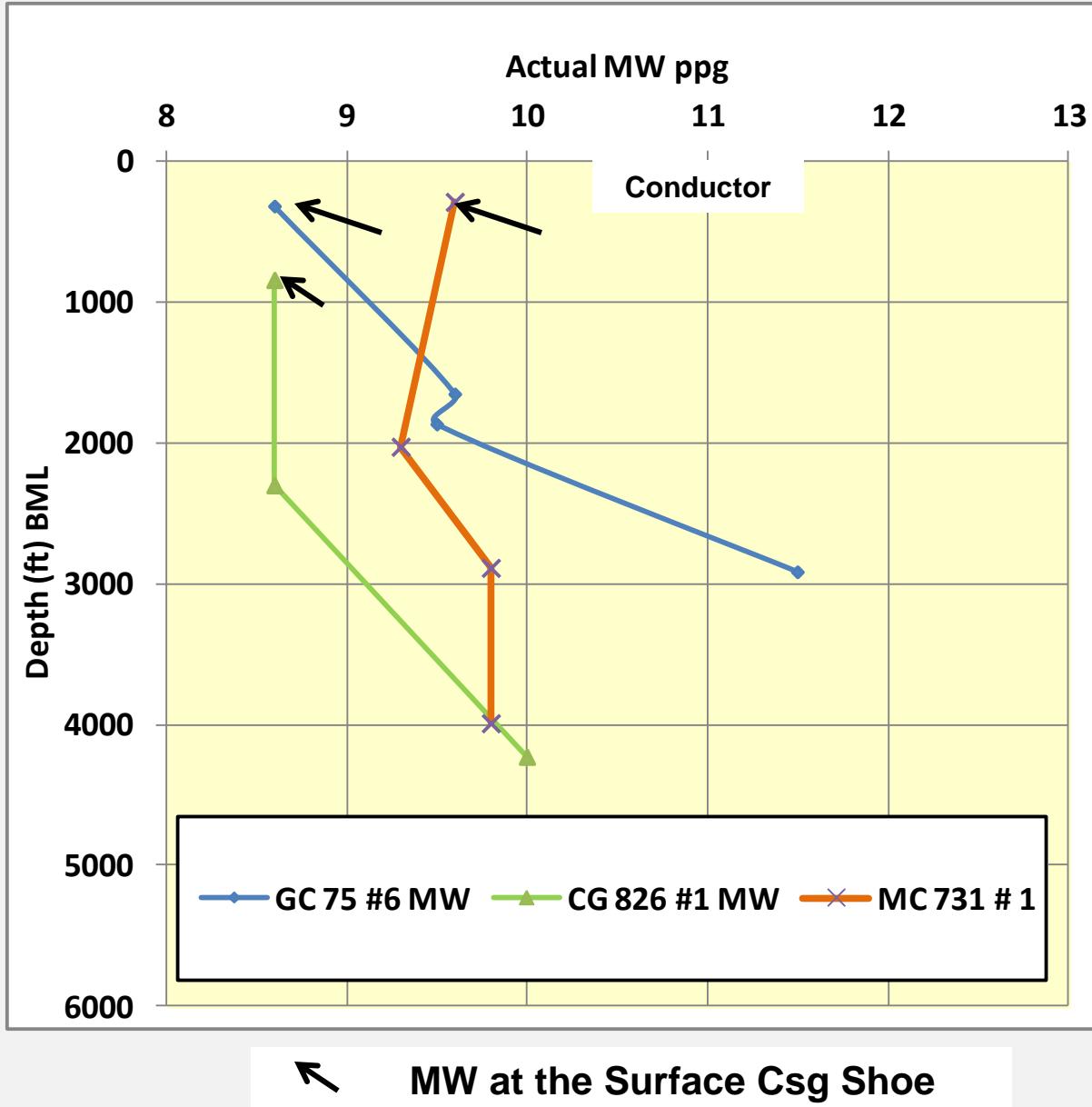


Safe MW in ppg

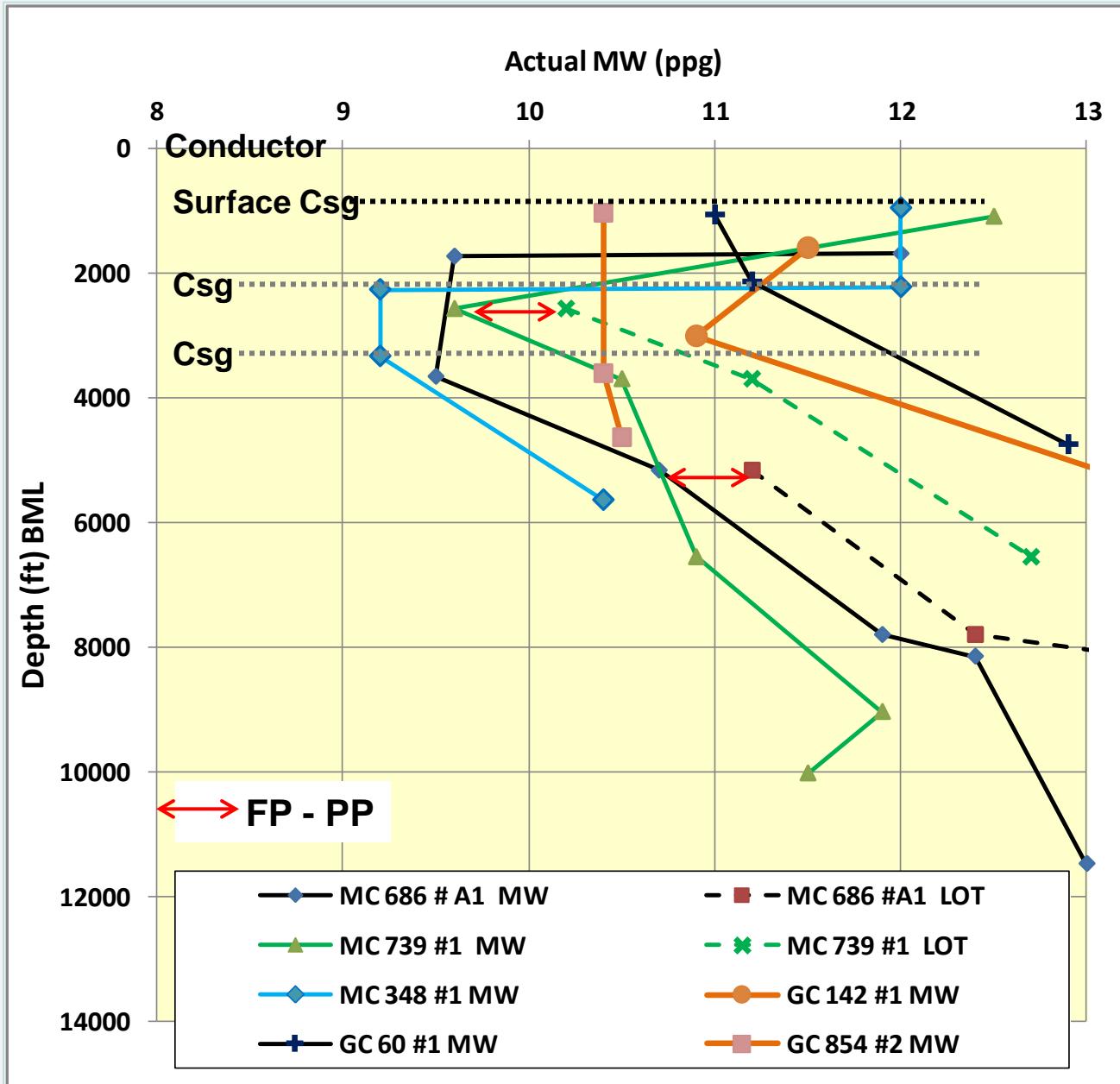
Safe MW ppg



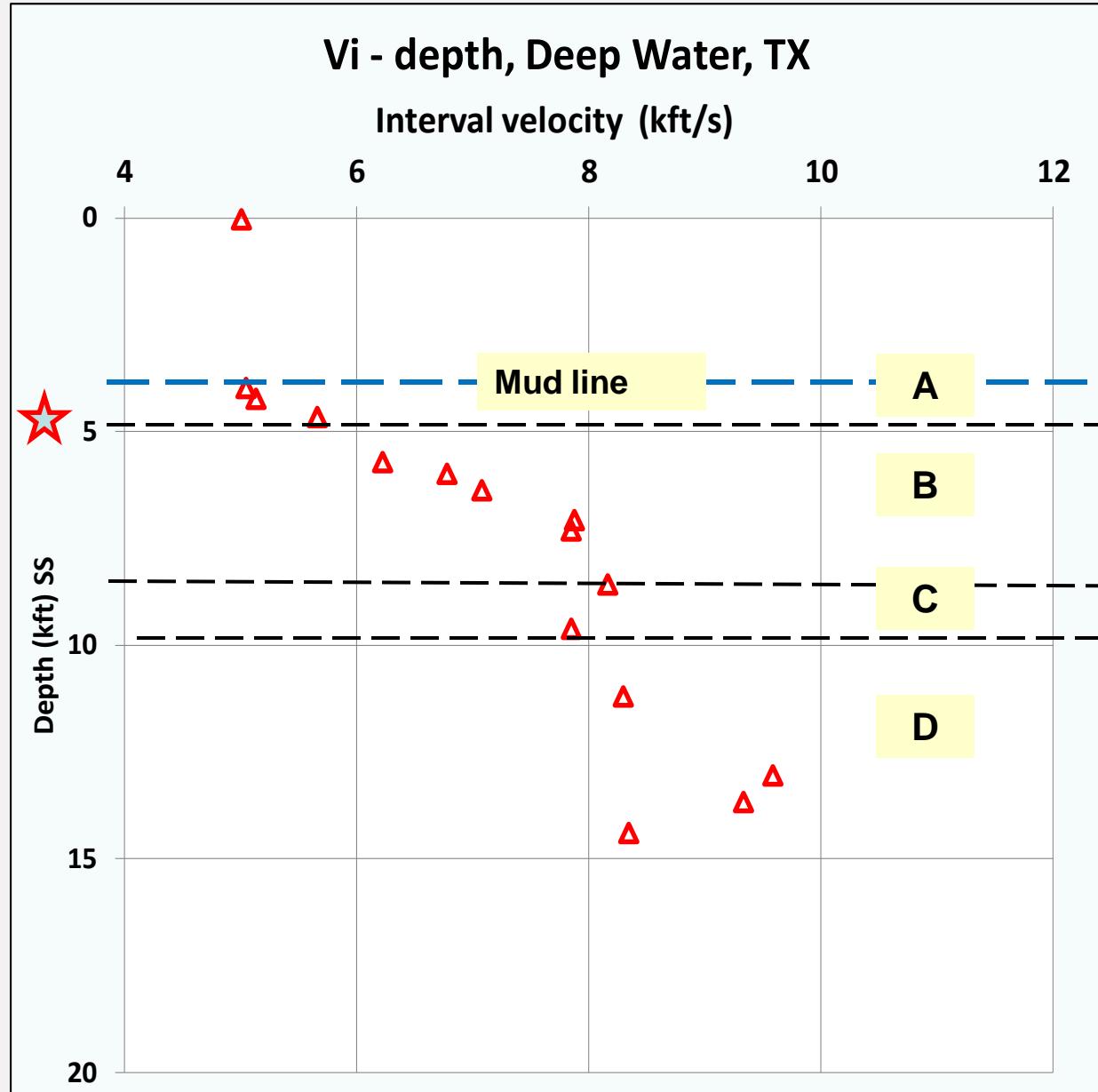
Case histories of wells WITH SWF



Case histories of wells WITHOUT SWF

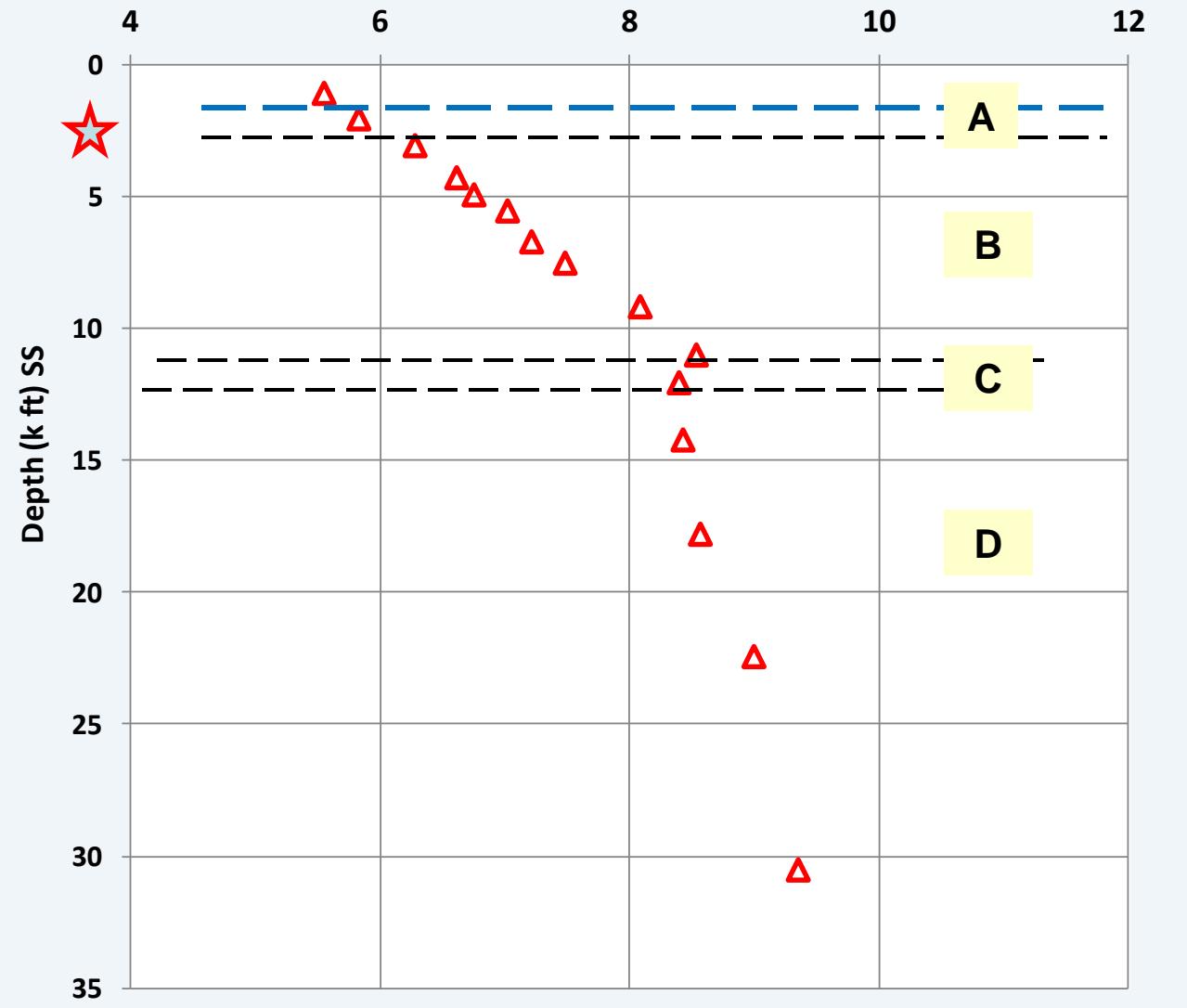


Seismic velocity can defines potential SWF Depths



Vi - depth, outer shelf, LA

Interval velocity (kft /s)



Summary and Recommendations

1. The possible Main cause of SWF is the pressure differential between sand and shale at zones A - B.
2. Recommended **Safe MW** to drill from the conductor (36") base to the surface CSG seat is calculated vs. WD.
3. Pre-drilling Vi profile can help in defining possible SWF depth
4. Accurate velocity modeling for the shallow section (higher frequency) is recommended.
5. Hydraulic hammering instead of jetting is recommended to install Conductor.

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- AADE 2016 committee
- Jason Maxey and Rusty Connell

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