Rock physics modeling and analysis of 4D time shifts – Visund Sør

Per Avseth, ROSE Meeting, 24/4-2012

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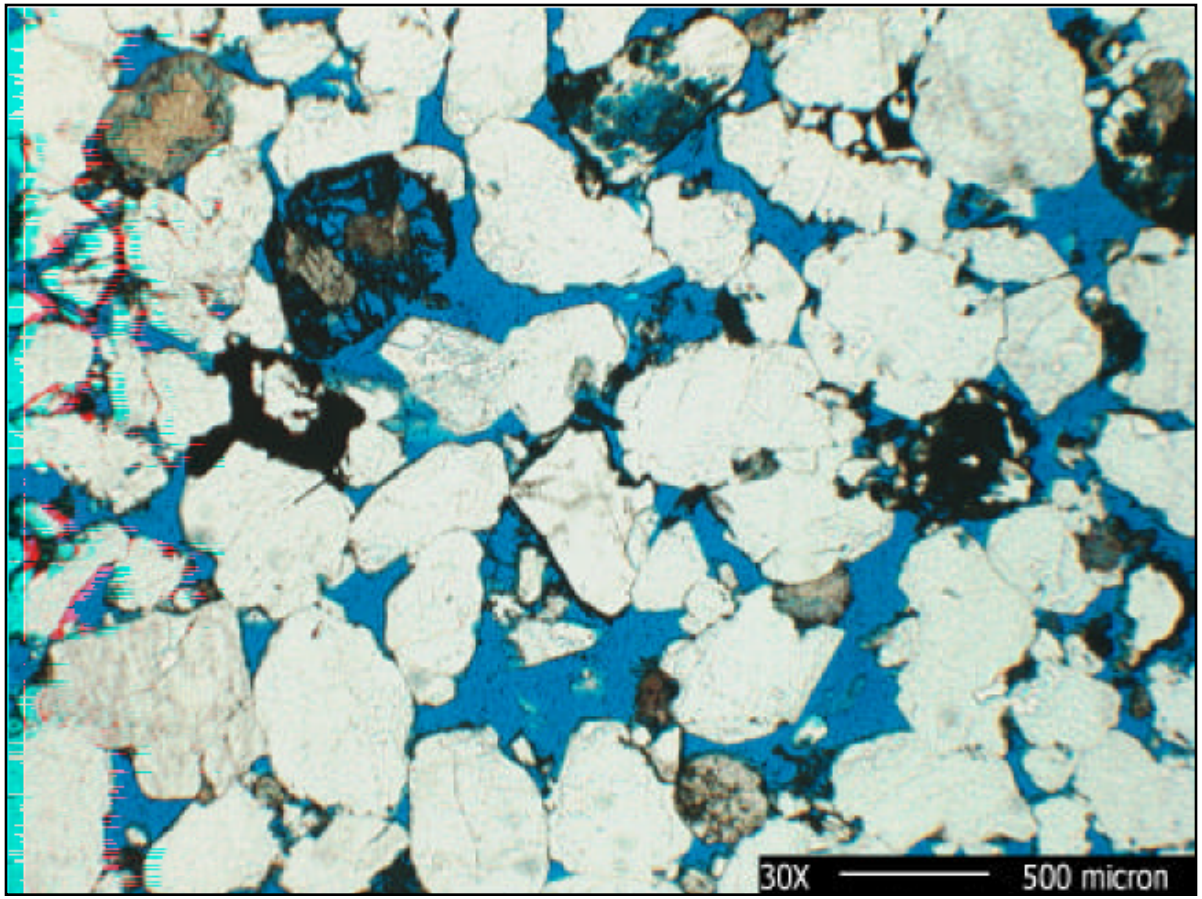
Odin
PETROLEUM AS

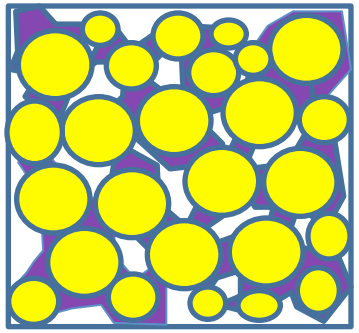
Statoil

Pacthy cement

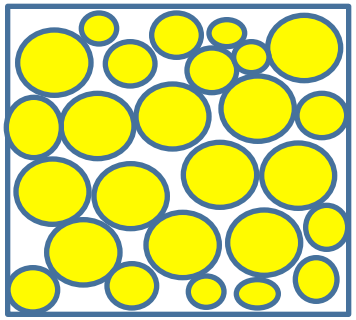
This sand shows tremendous heterogeneity in grain/pore sizes and shapes. Some grain contacts are sutured; some appear to be clay-cemented; some appear to be loose. *We should expect pressure dependence, at least from the fraction of contacts that are deformable.*



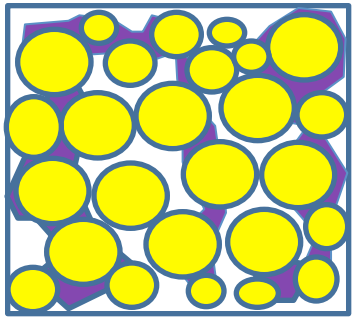
Patchy cemented sst model, 2-step HS modeling:
1) MUHS at High-por end-member,
2)MLHS from high-por to mineral point.



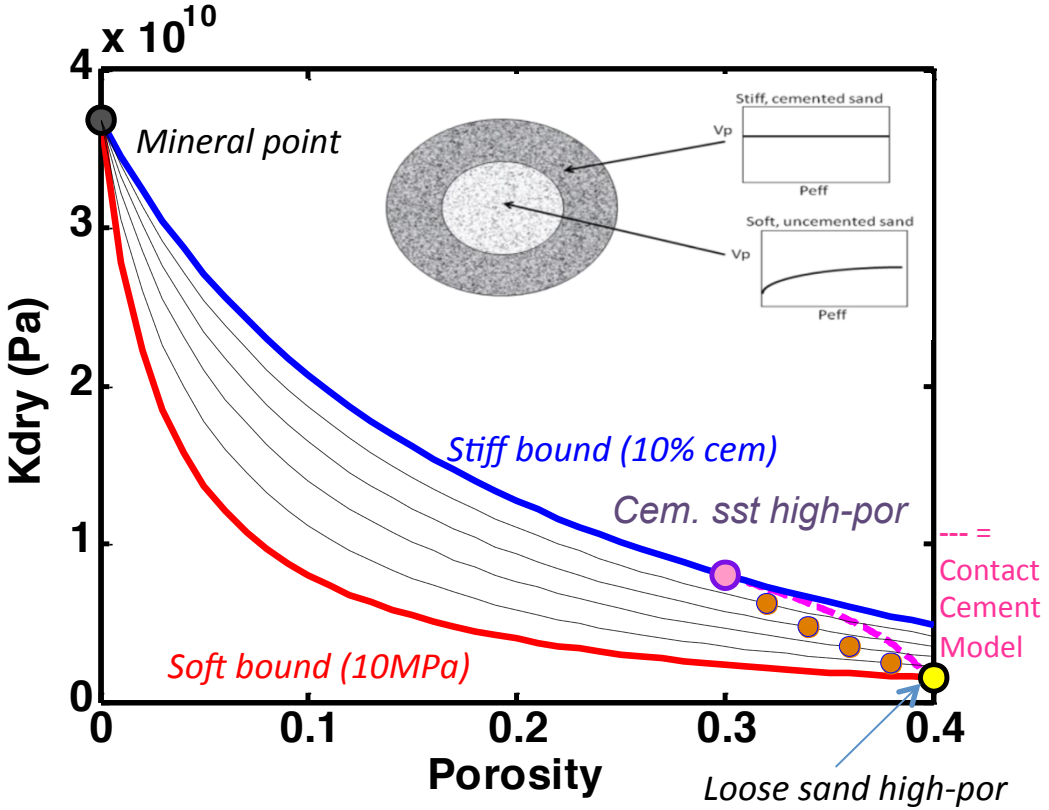
Cemented sst
(10% cement)
Por=Porc-Vcem
No pressure sens.



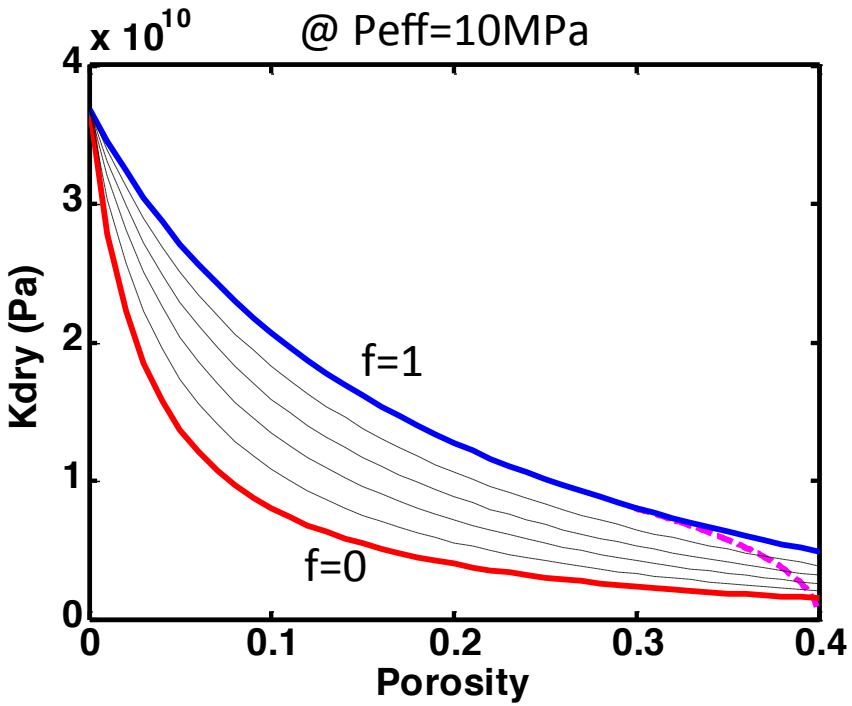
Uncons. sand
(0% cement)
Por=Porc
Pressure via HM

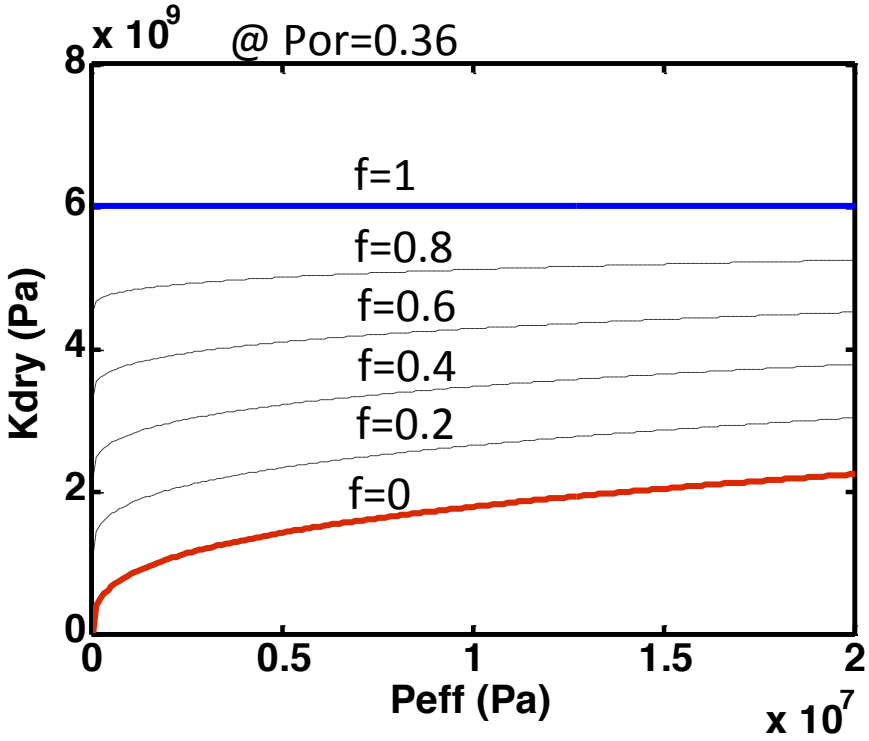


Patchy cemented sst (connected patches)
(f % cemented rock, 1-f % unc.sand)
Por=f x (Porc-Vcem) + (1-f) x Porc
Pressure via HM for unc. sand fraction

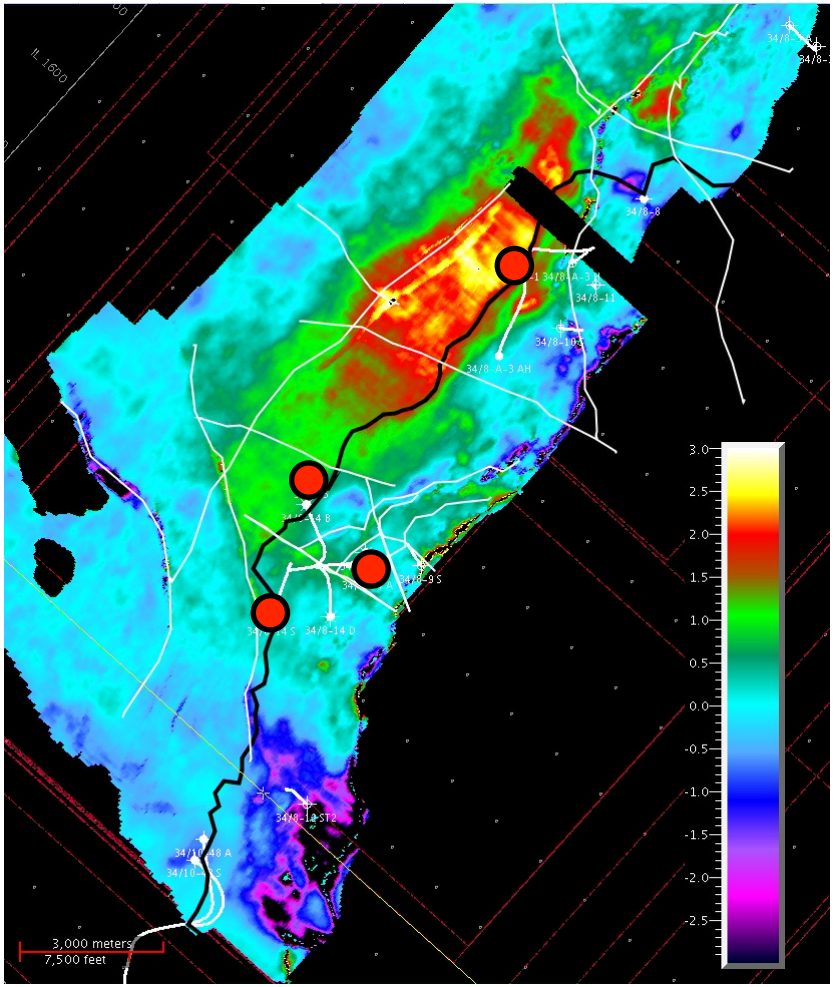


HS-upper modeling for varying volume fractions (f=0:0.2:1)



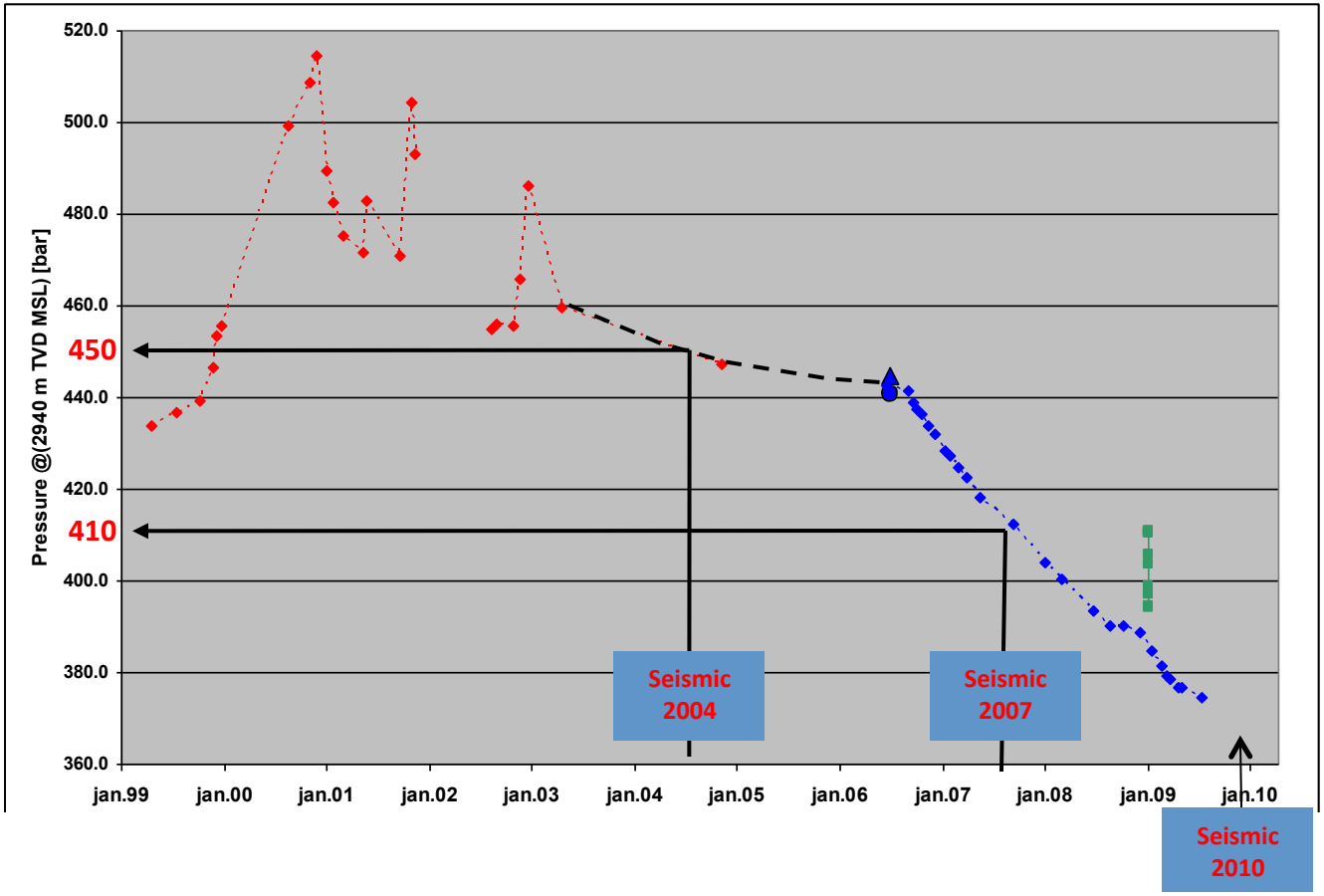


Observed timeshifts at Base Brent, 2004-2010

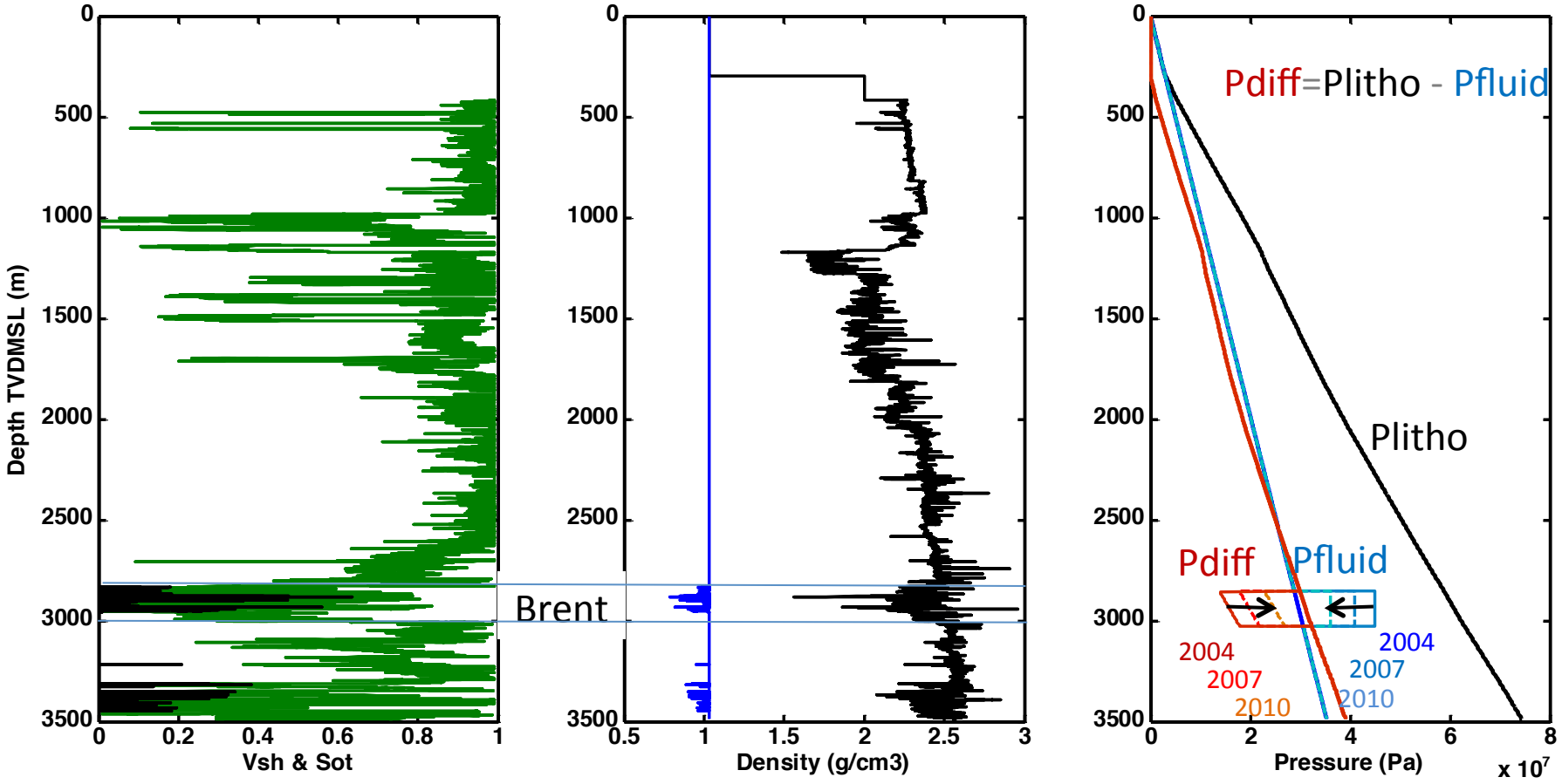


Well	Time shift Statoil 04-10 (ms)
34/8-1	2.25
34/8-5	0.8
34/8-14-A	0.4
34/8-14-S	0.25

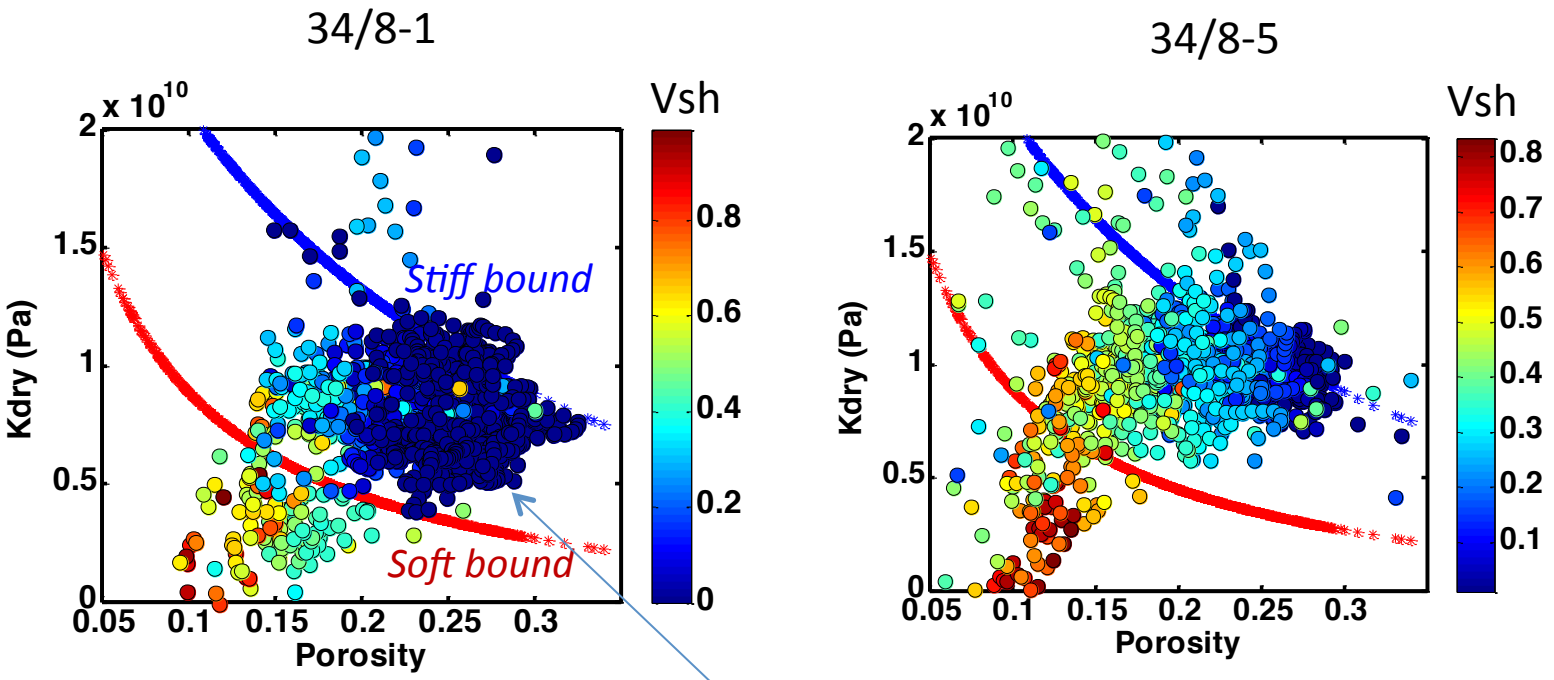
Reservoir pressure development around well 34/8-1



Pressure modeling

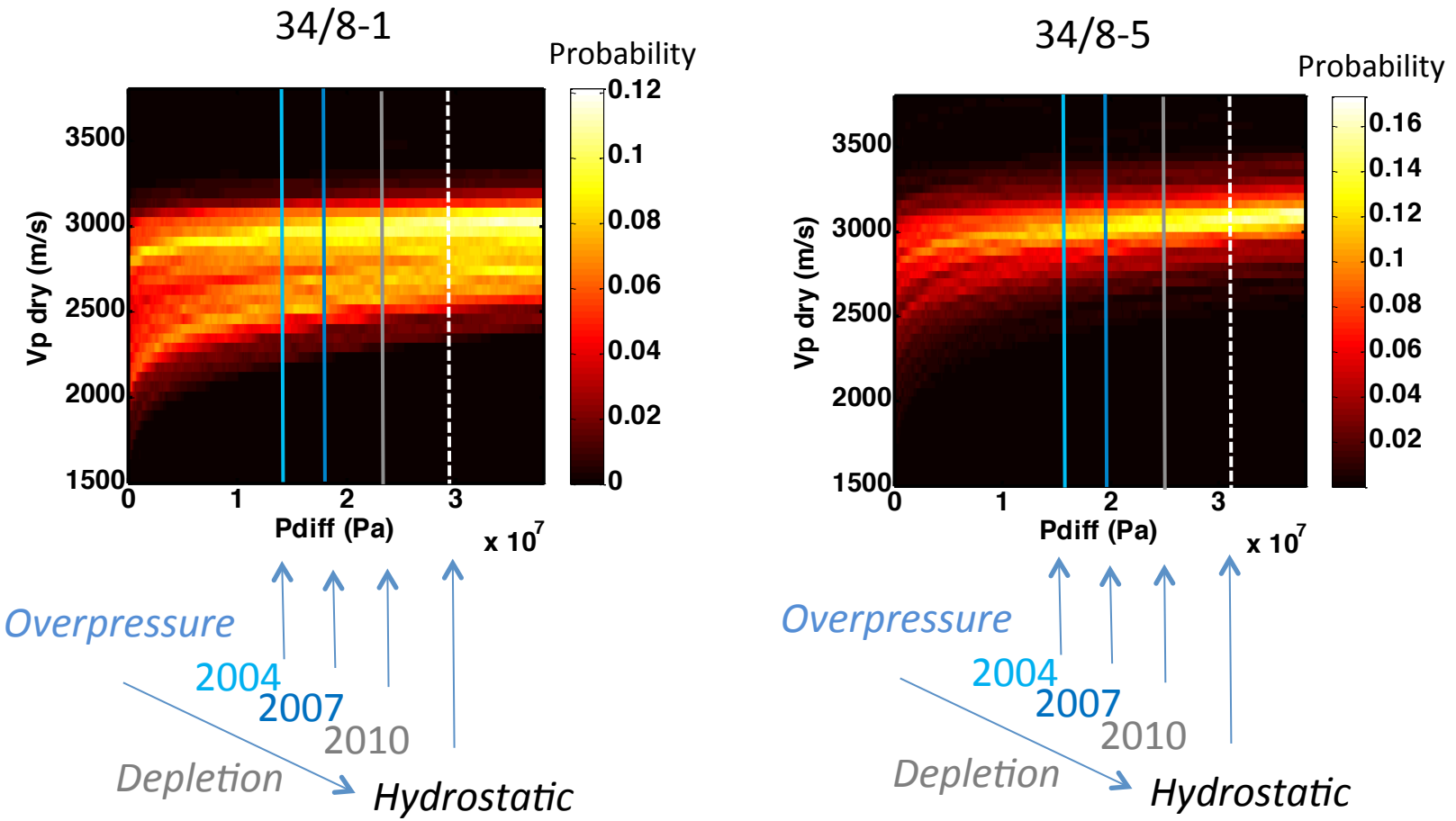


Rock physics crossplots:
Porosity versus Kdry



Note the softer sandstones present in 34/8-1. Data points falling on (or below) the soft bound will have pressure sensitivity according to Hertz-Mindlin contact theory, whereas data points falling on (or above) the stiff bound have no pressure sensitivity, c.f. Dvorkin-Nur model. Data points falling in between have pressure sensitivity given by a weight function.

Stress-curves (probabilistic for Brent interval)



Note that there are 2 ”populations” of data revealed in the stess-curves of 34/8-1; one relative soft (Vp_dry=2000 @Pdiff=0) and one relative stiff (Vp_dry=2800 @Pdiff=0)

Time shift attributes

Time strain:

$$\frac{\Delta TWT}{TWT_{base}} = \frac{\Delta Z}{Z_{base}} - \frac{\Delta V_P}{V_{P,base}}$$

0

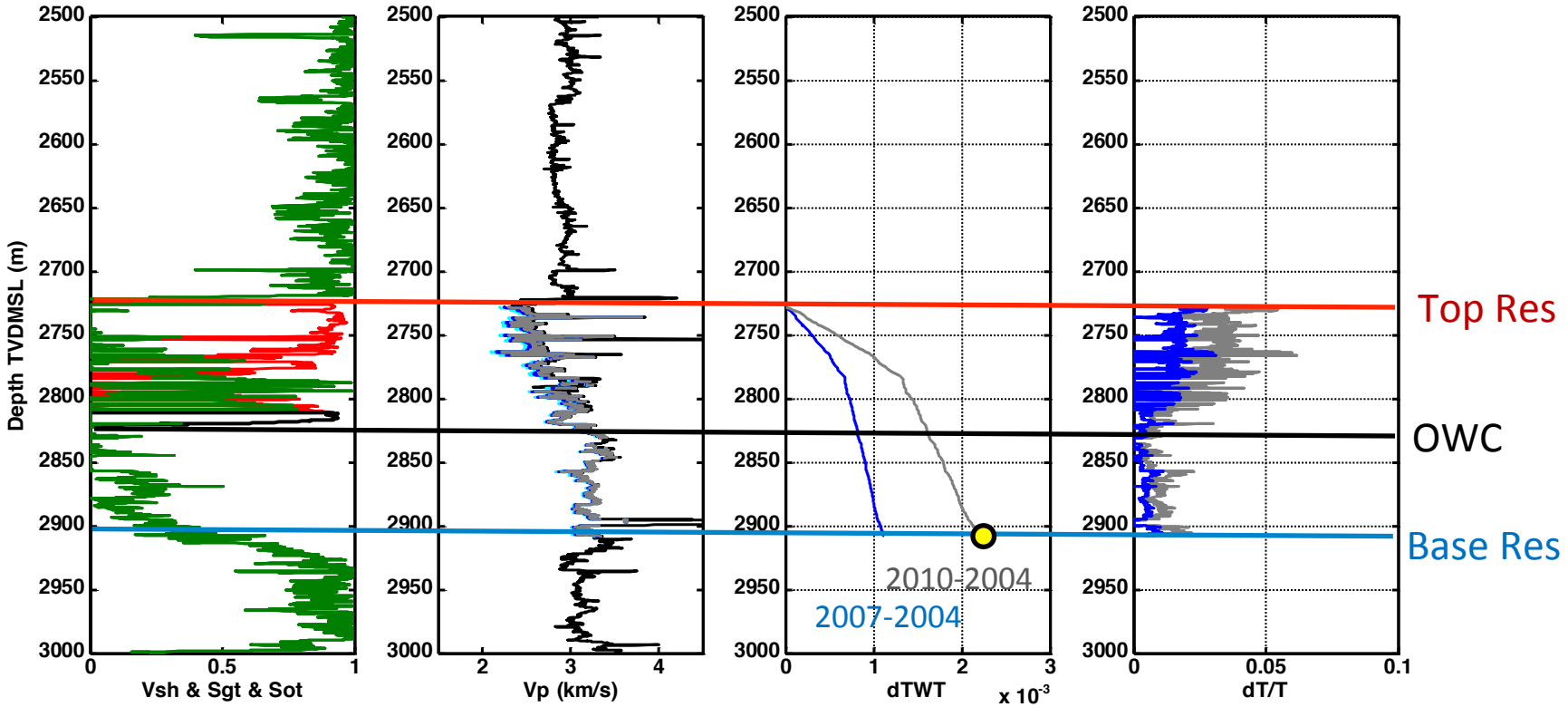
Time shift:

$$\Delta TWT(z) = 2\int_{Z,top}^{Z,bottom}\left[\frac{1}{V_{P,monitor}(z)} - \frac{1}{V_{P,base}(z)}\right]dz$$

Time shift derivative

$$d(\Delta TWT)/dt = \frac{2\Delta Z \cdot \left[\frac{1}{V_{p,monitor}(z)} - \frac{1}{V_{P,base}(z)}\right]}{\frac{2\Delta Z}{V_{p,base}(z)}} = -\frac{\Delta V_P}{V_P}$$

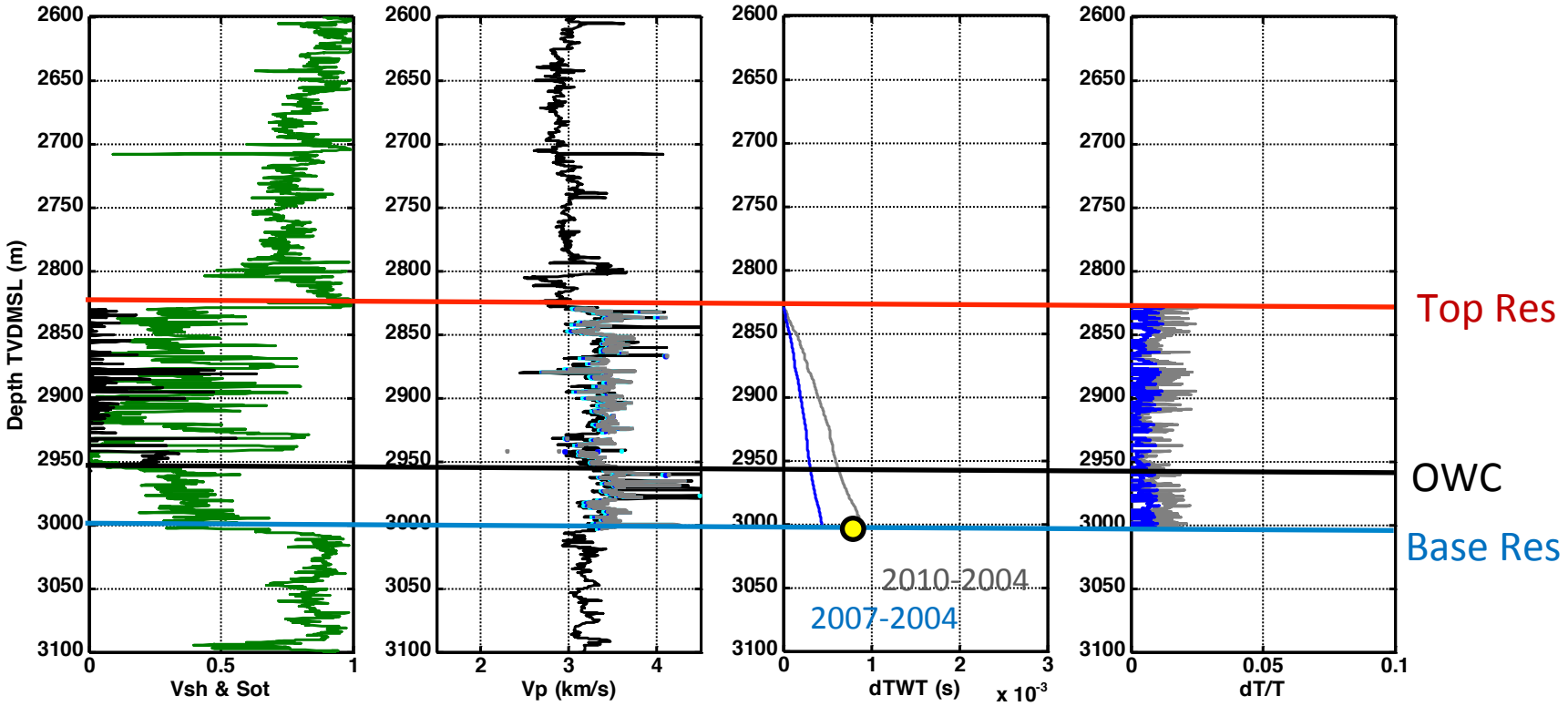
Time shift estimates; 34/8-1



= Observed timeshift 2004-2010 = 2.25 ms

= Modelled timeshift 2004-2010 = 2.2 ms

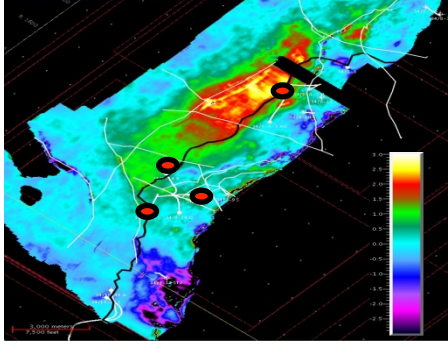
Time shift estimates; 34/8-5

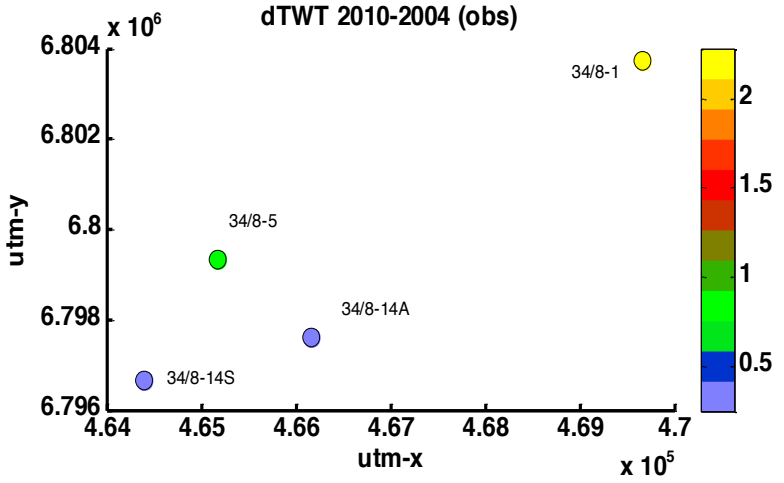


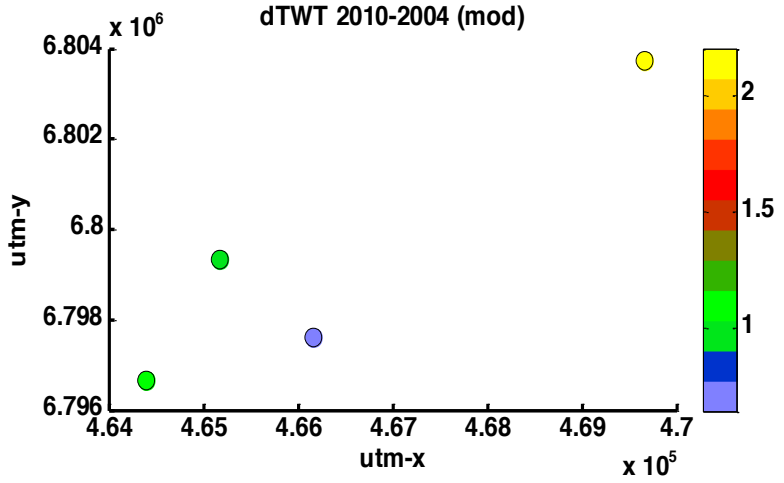
= Observed timeshift 2004-2010 = 0.8 ms

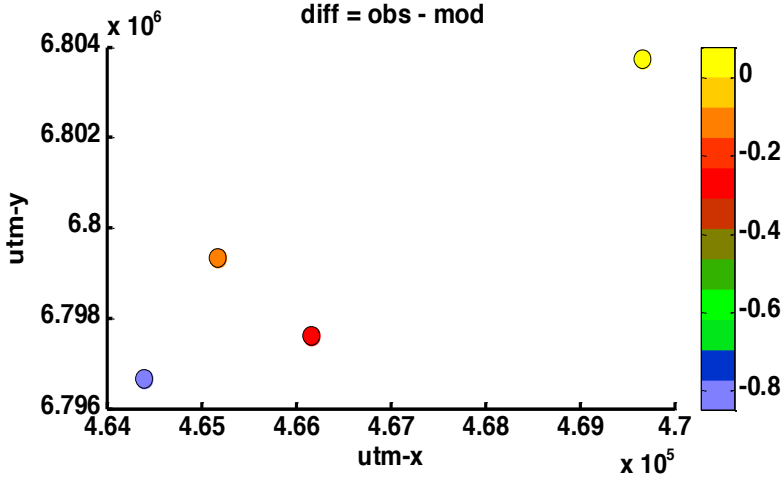
= Modelled timeshift 2004-2010 = 0.9 ms

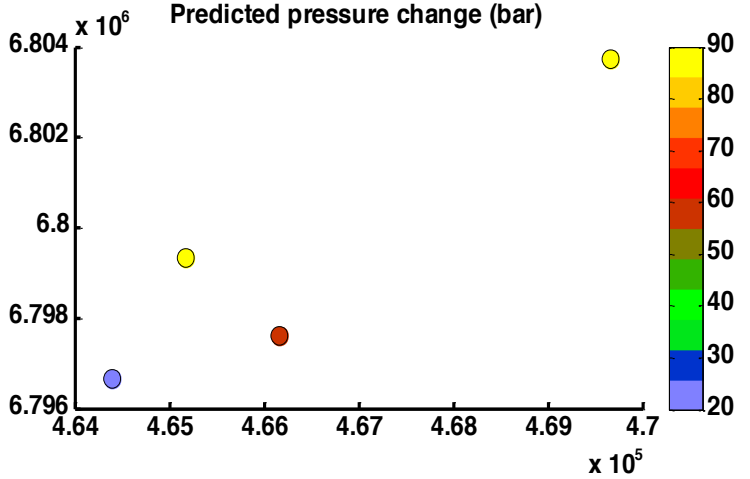
Observations versus predictions (map view)











Conclusions

- We have presented an approach to model stress sensitivity in patchy cemented reservoir sandstones, and demonstrated how to use this model to estimate time shifts and time shift derivatives using well log data as input.

- We have predicted time shifts between 2004-2010 using the ”patchy cement model” and get very good match with observed timeshifts at Base Brent for wells 34/8-1 and 34/8-5.

- The larger stress sensitivity in well 34/8-1 is due to 3 reasons:

  i) presence of looser reservoir sandstone in Tarbert Fm

  ii) shallower burial and associated lower in situ effective stress

  iii) presence of thick gas coloumn (gas sands have larger stress sensitivity than brine sands)

- We have estimated pressure changes from time shift attributes using the patchy cement model. The results indicate that barriers are causing less efficient depletion in the south (wells 14S and 14A).

Acknowledgements

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