STRESS DISTRIBUTION IN THE FOOTWALL OF AN ACTIVE NORMAL FAULT

by

Tim Harper and Tim Pritchard

A GENERAL PROBLEM

- How can we describe stress distribution in the sediments in and above oil and gas fields for input to well design (e.g. wellbore stability analyses)?

- Current practice typically relies available on wellbore measurements (leak-off tests and wellbore breakouts) averaged to produce a 1D stress distribution (stress varies only with depth).

LIMITATIONS OF RELYING ON WELLBORE MEASUREMENTS

- No predictive model of stress distribution to guide interpretation
- Uncertainty associated with:
  - quality and availability (including distance from region of interest) of w/b measurements
  - ambiguities of w/b tests (e.g. mud as frac fluid, well deviation) and interpretation

DOLPHIN WELLBORE MEASUREMENTS

- Leak-off tests in production wells almost all in deviated sections
- Appraisal well LOTs in hanging wall
- Otherwise some 4-arm caliper data, including a few re-runs
- Drilling records

What other information could be used to predict stress distribution?

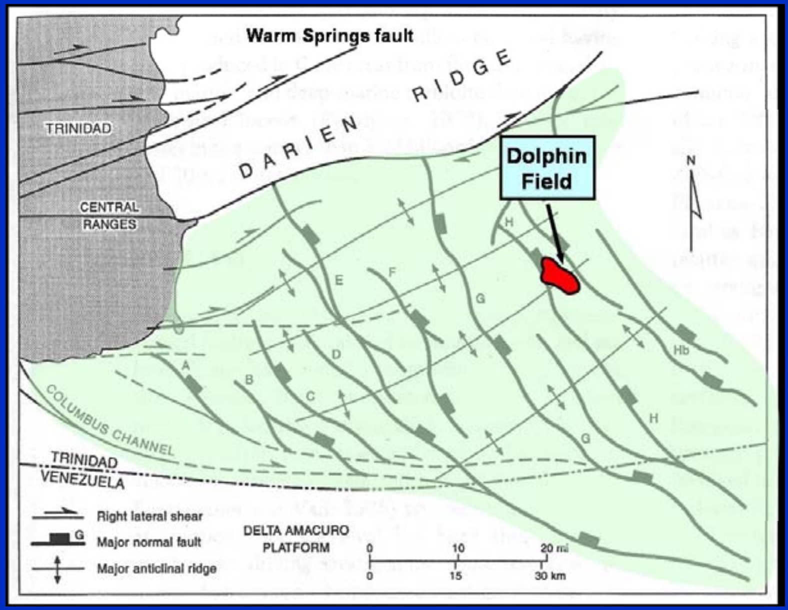
- Whether for exploration, appraisal or development, there is always a body of geoscientific data (seismic sections, structure contour maps, conceptual models of geologic history etc etc)

- If the geological history can be modelled, one or more predictions of the stress distribution can be compared with the available wellbore measurements

- This procedure has been applied to the Dolphin field, using FLAC to predict stress distribution in the footwall

THE DOLPHIN FIELD

An active tectonic environment involving the boundary of the Caribbean and S. American plates to the North and high rate active normal faulting



The Dolphin gas field is located in the footwall of an active normal fault above a shale diapir.

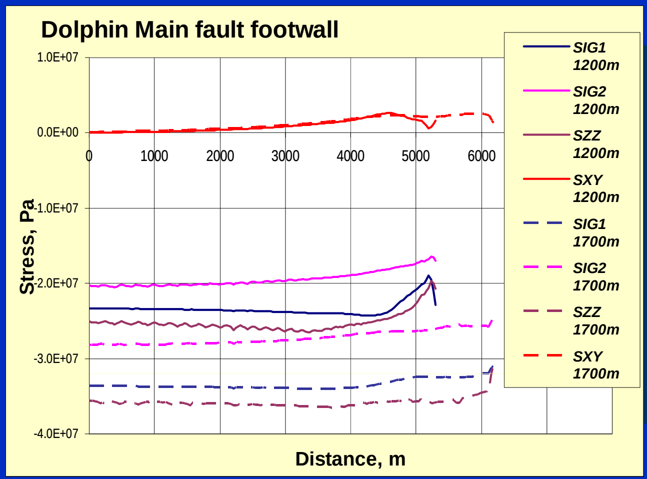
Numerical model

- FLAC used to model post-A Sand slip
- Preceded by numerous preliminary models:
  - to bound material properties (e.g the shale diapir which had not been drilled)
  - to identify boundary conditions
  - to identify the mechanism responsible for the formation of the antiformal hydrocarbon trap

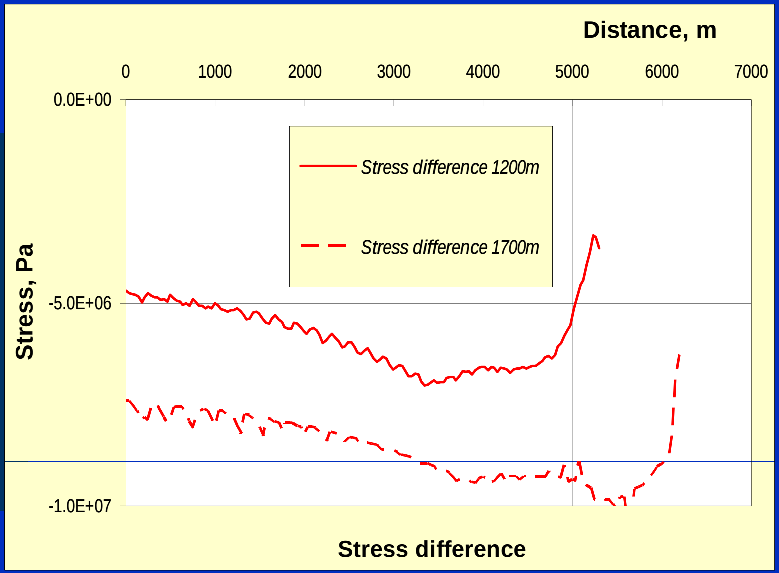
N.B. FLAC was used to discriminate between competing conceptual and speculative geological models before defining the final model for prediction of stress distribution in the footwall

Sediment mechanical properties estimated from petrophysical logs; pore pressures from RFT and analyses of seismic records

MODEL RESULTS

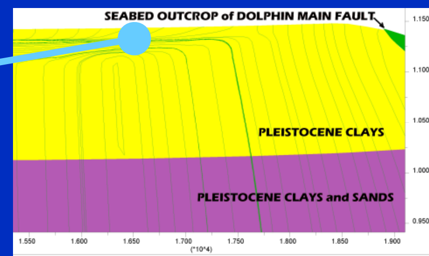


Line profiles of normal stress, SXY & stress difference 1300m & 1700m below sea bed (fault on RHS)



TESTING THE PREDICTED STRESS DISTRIBUTION: 1) 5 Leak-off tests

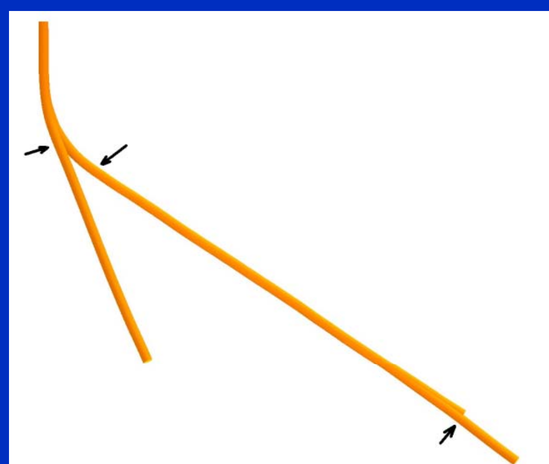
2 LOTs in vertical/subvertical near-surface locations



LOT values exceeding overburden consistent with local thrust fault environment

3 LOTs in plane of model

ENE WNW



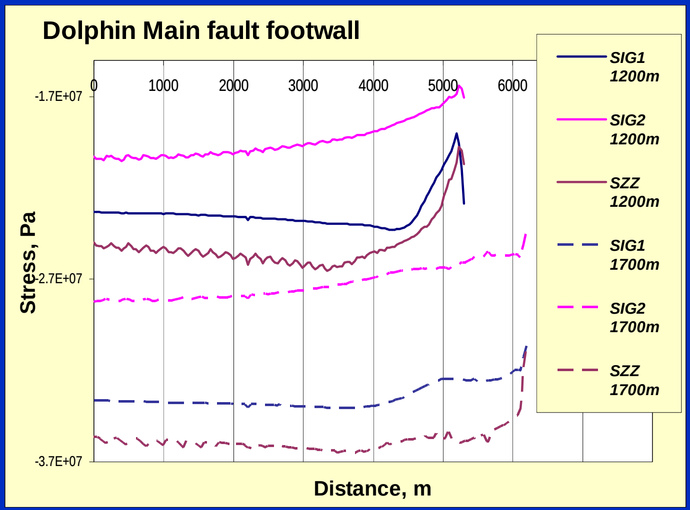
Deviation (deg)	% diff LOT vs model
26	9.8
55	10.4
56	14.2

LOT results represent only an upper bound. They are 10-15% greater than model. Not obvious whether model or LOT's correct.

TESTING THE PREDICTED STRESS DISTRIBUTION: 2) Caliper logs

- Caliper logs proved key to understanding the mechanisms of wellbore instability in these low permeability sediments
  - Squeeze/tight hole (undrained)
  - Breakout (after drainage)

FLAC output aided interpretation of instability mechanisms. Preferential tendency for undergauge wellbores along axis parallel to Dolphin Main fault.



TESTING THE PREDICTED STRESS DISTRIBUTION: Conclusions

- Wellbore measurements are sparse and not straightforward to interpret. This constrains the extent to which the model output can be tested/validated.

- Model results are derived from data which are almost entirely independent of the wellbore measurements.

- Wellbore measurements neither inconsistent with FLAC output nor precisely supportive. To the extent allowed by the wellbore data, the FLAC results agree with the wellbore measurements*. It is not clear whether LOT interpretations or FLAC most closely represent in situ conditions.

* (except wrt the extent of the bending stresses induced by uplift – only ~40% throw modelled).

TECTONIC ENVIRONMENT

- Overall a strike slip fault environment: SZZ (150^0-330^0) > $S_{subvertical}$ > $S_{subhorizontal}$ (060^0-240^0)
- Active normal faulting driven by sediment influx driving unstable fault. No regional extension 060^0-240^0 normal to Dolphin Main fault.
- Local thrust environment under the production platform generated by bending associated with footwall uplift

MAIN CONCLUSION

The Dolphin field provides a demonstration that an evaluation of stress distribution, required for normal oil/gas field engineering purposes, can be greatly enhanced by modelling stress genesis based on independent (geoscientific) information. This allows us to overcome the normally invalid assumption that stress varies only with depth implied by conventional stress evaluations based on wellbore measurements alone.

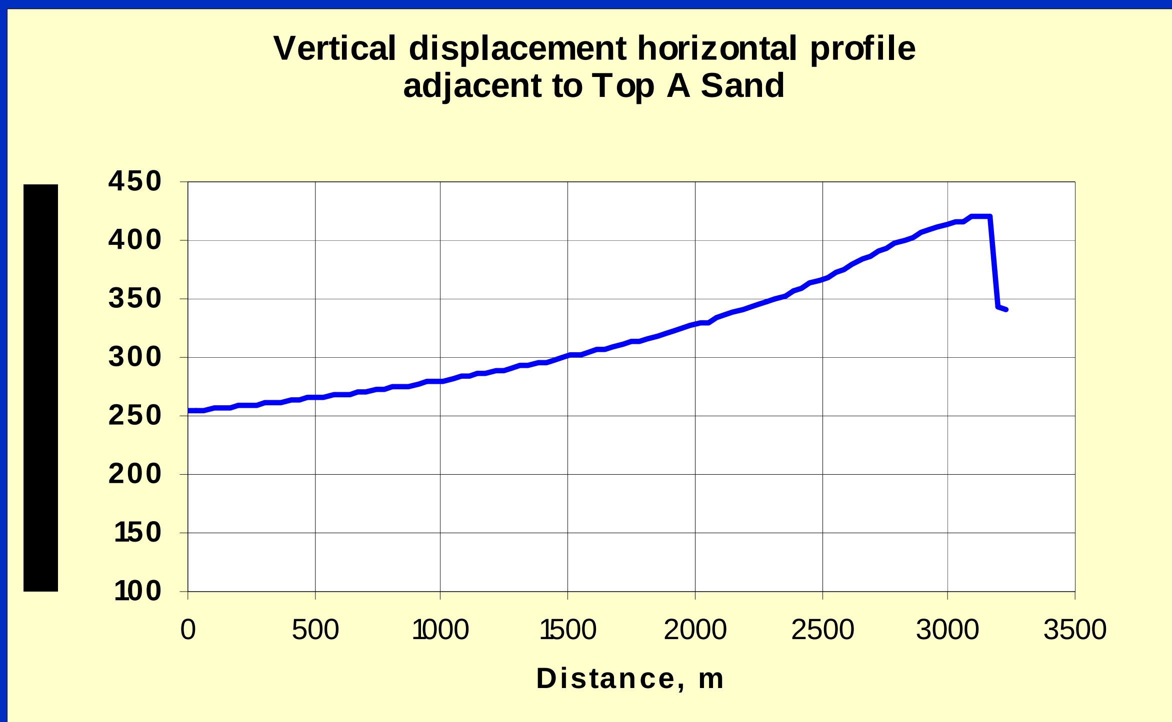
Acknowledgements

BG T&T and partners

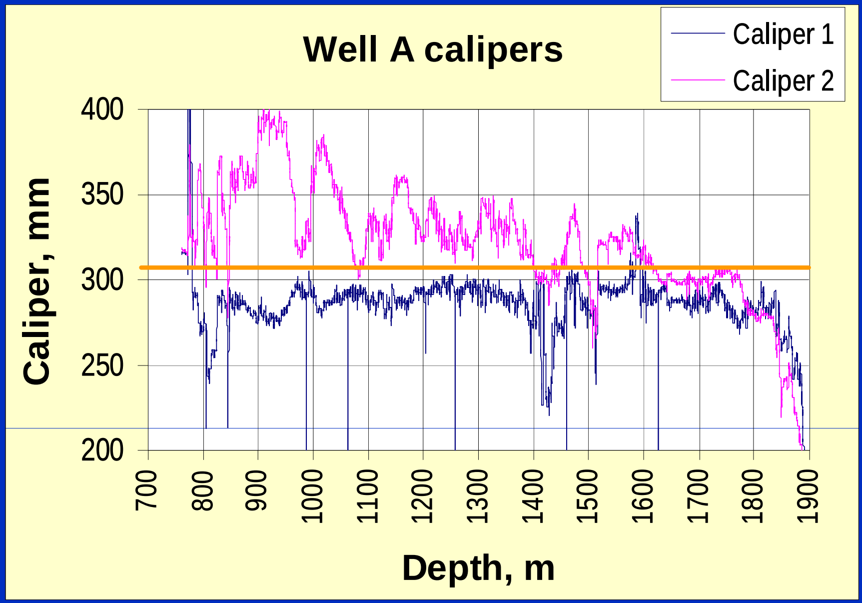
Footwall uplift

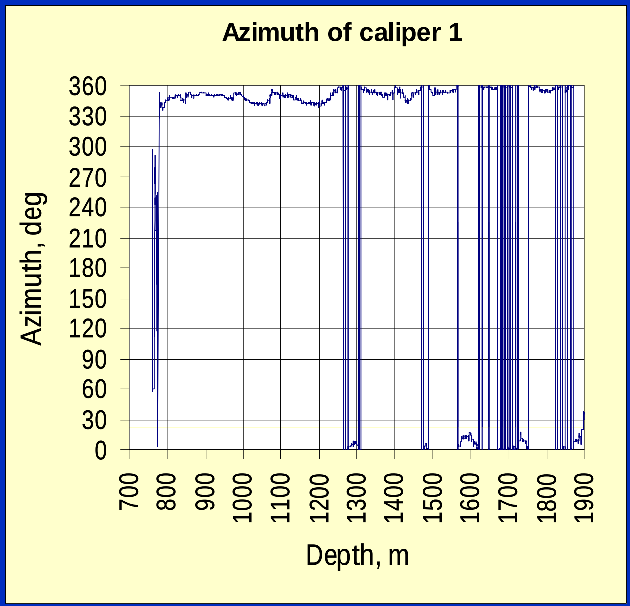
WSW

ENE

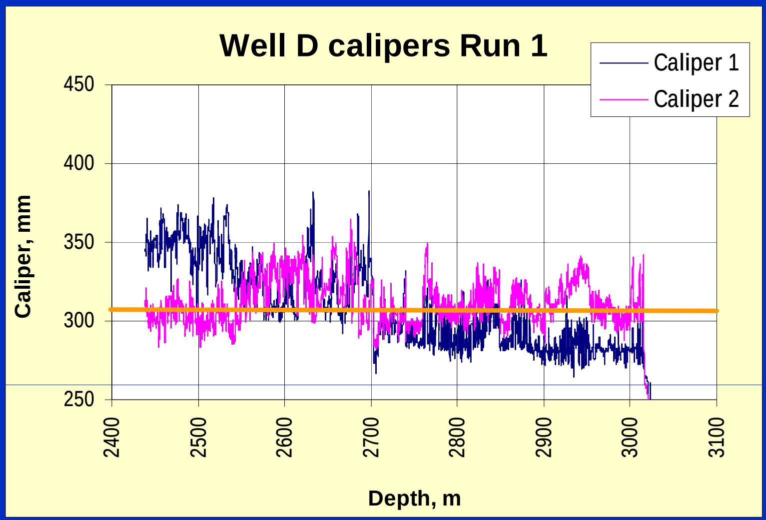


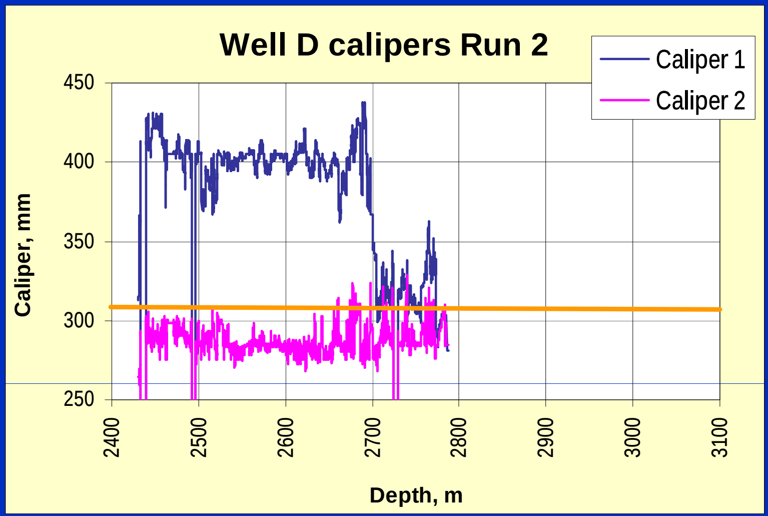
Undergauge normal to 150^0-330^0





Wellbore geometry vs time





1. Undergauge (squeeze)
2. Breakout after an elapsed time