Pore Pressure Profiles in Deep Water Environments: Case Studies from Around the World*

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Abstract

Deep water sandstone reservoirs are commonly observed to be isolated within shale-dominated sequences. Pore pressure profiles through such sequences are based on both direct measurements in the reservoirs, and estimation based on porosity and shale properties in the non-reservoir section. Profiles from clastic sequences of deep marine shales with associated, thin reservoirs, reveal an overburden/lithostatic parallel increase of pressure beneath a fluid retention depth (near top overpressure). The depth to the fluid retention depth is largely controlled by clay content. Many deep water shales have high clay content, explaining the shallow onset of overpressure, which adds the additional drilling hazard of shallow water flows in this environment. Thick reservoir sections reveal local hydrostatic-parallel profiles creating variable transition zones into adjacent shales. At temperatures greater than about 100^{o}C, however, there is a tendency for pressure profiles to converge with the overburden/lithostat, creating narrower drilling margins and more likelihood of seal breach. Lithostatic parallel profiles can be used locally for pore pressure prediction, provided that reservoirs are not able to drain laterally or vertically to the surface, and remain at temperatures less than about 100^{o}C. Care must also be taken where the reservoir has a large structural relief, as lateral transfer may enhance crestal pressures. Pressures in many deep water reservoirs can be used to assess risk failure, particularly for stratigraphic traps. Examples will be used from Nile Delta, Gulf of Mexico, SE Asia and West African basins.

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- Encased/Restricted, High Relief and Laterally Extensive reservoirs

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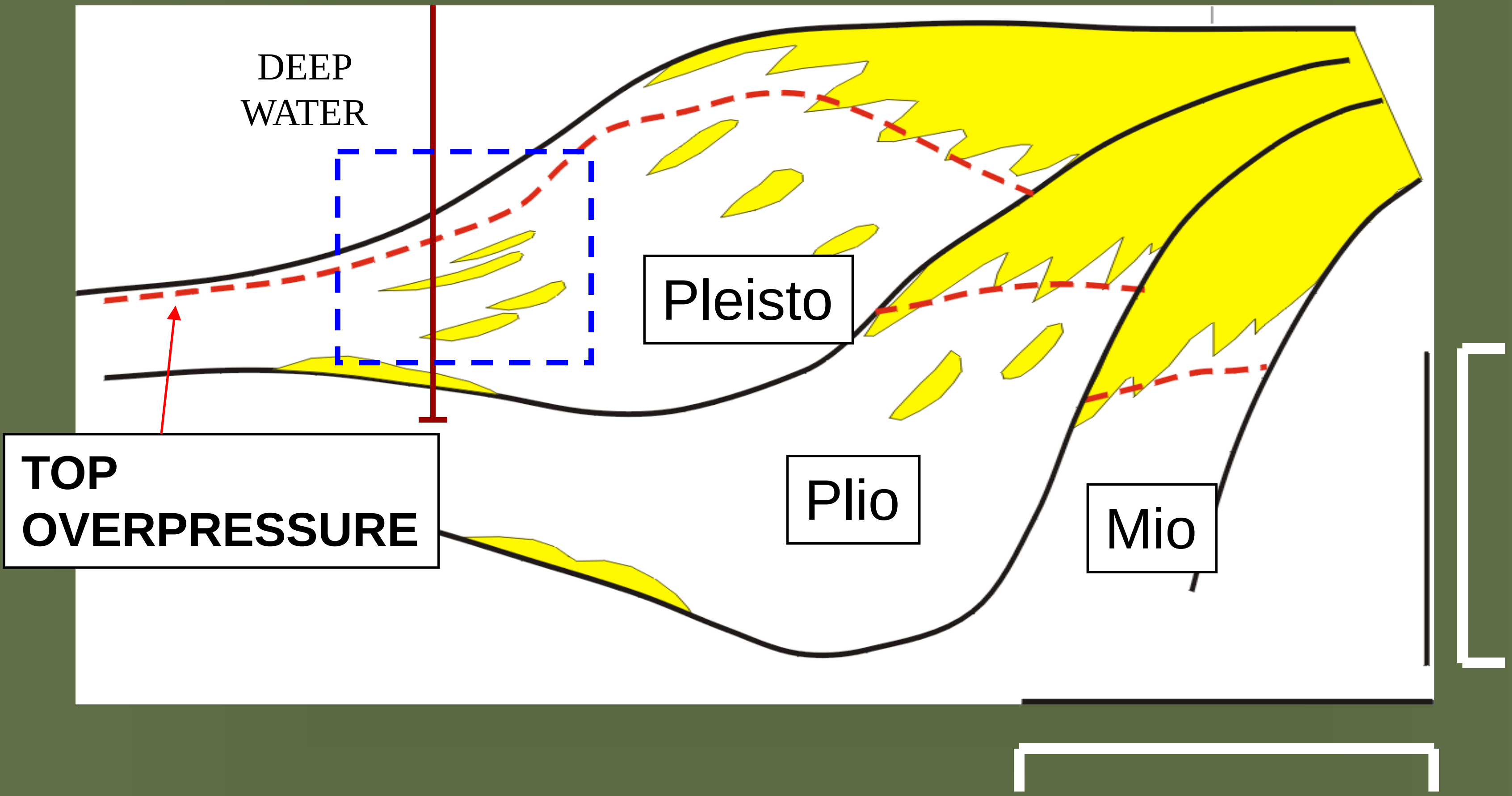
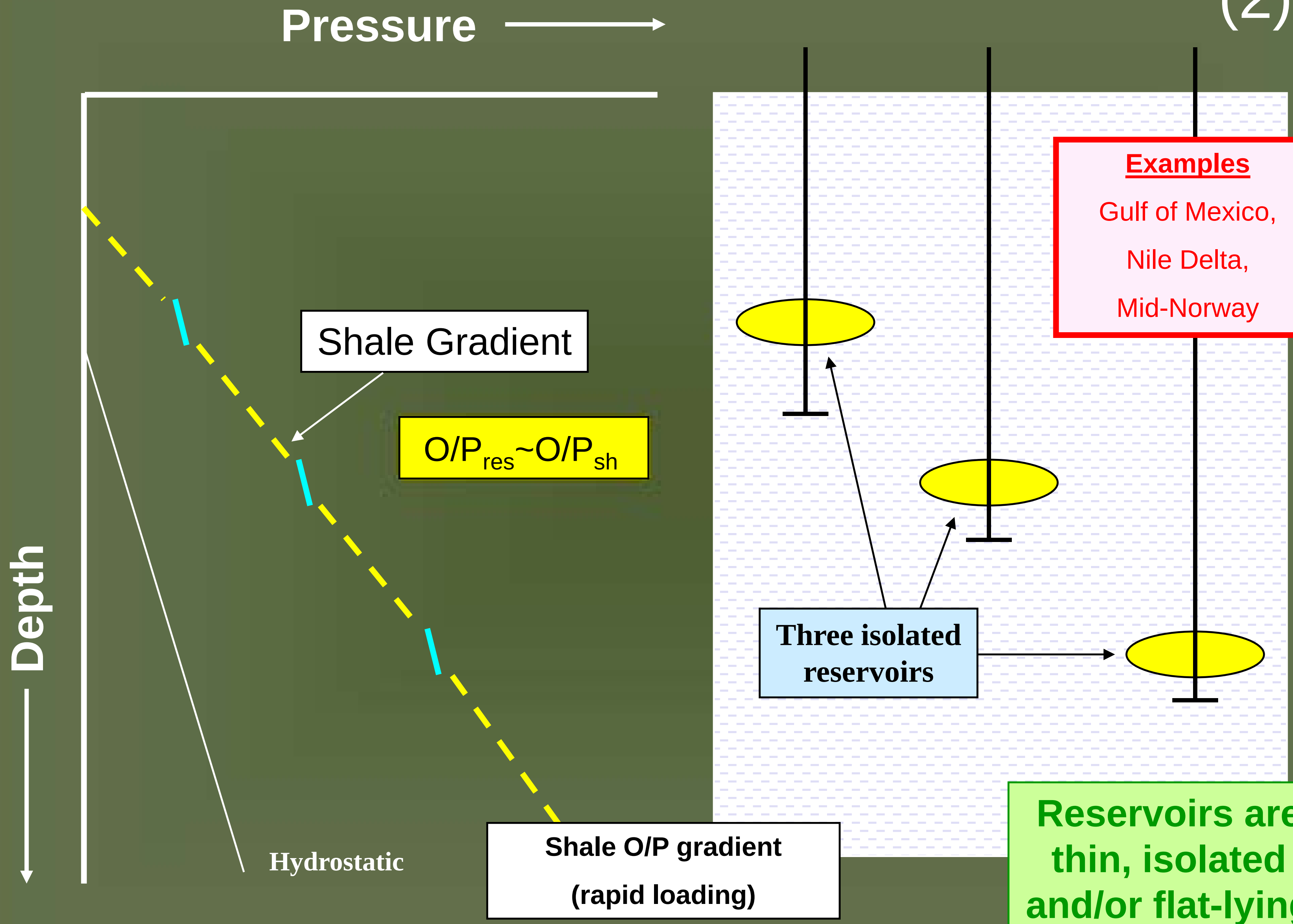
OCEAN MARGIN

COASTLINE



100 km

Shallow water flow, gas hydrate and slope stability problems



Pressure

Depth

Shale Gradient

$O/P_{res} \sim O/P_{sh}$

Hydrostatic

Shale O/P gradient

(rapid loading)

Three isolated reservoirs

Examples

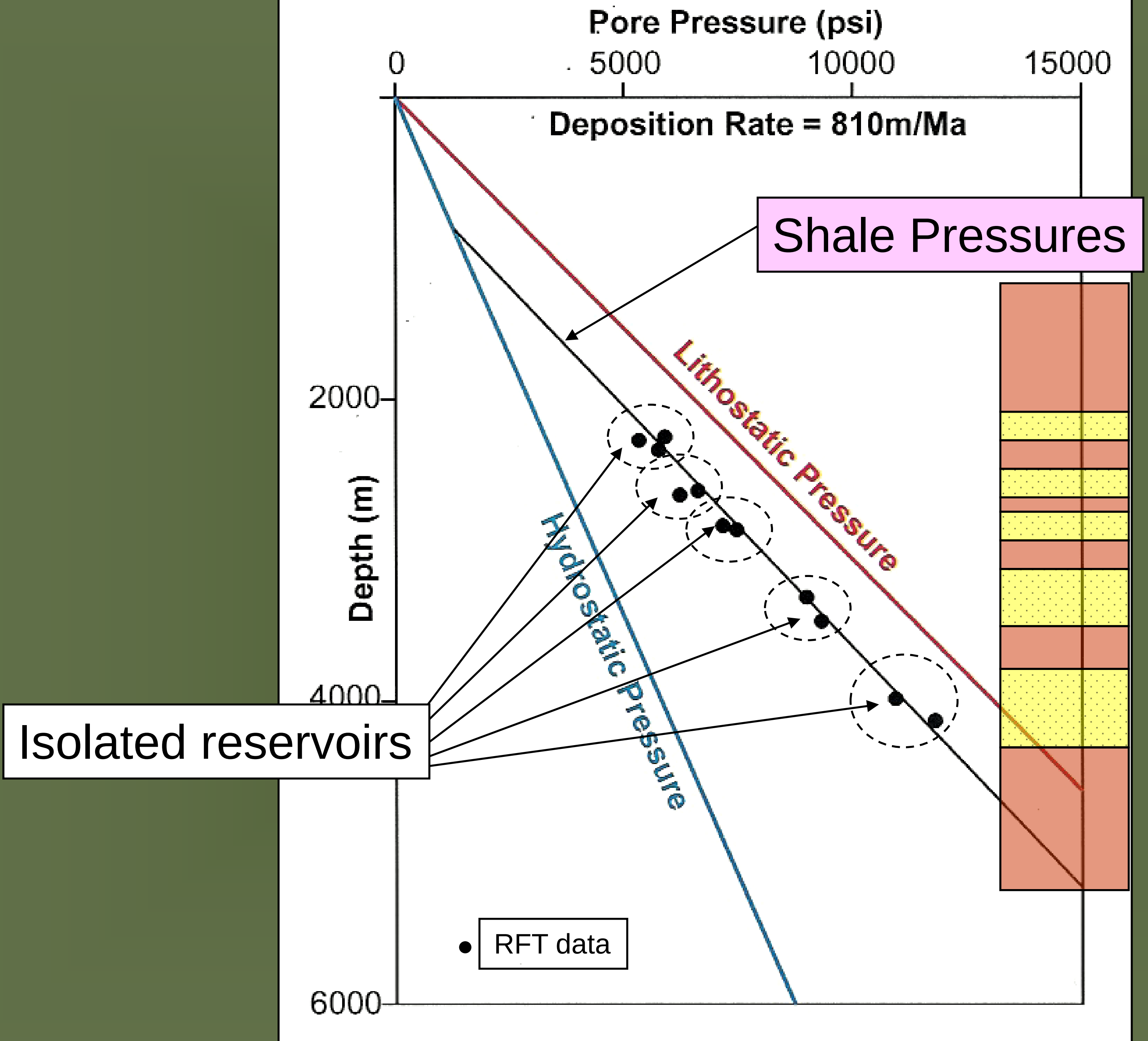
Gulf of Mexico,

Nile Delta,

Mid-Norway

Reservoirs are thin, isolated and/or flat-lying

(2)



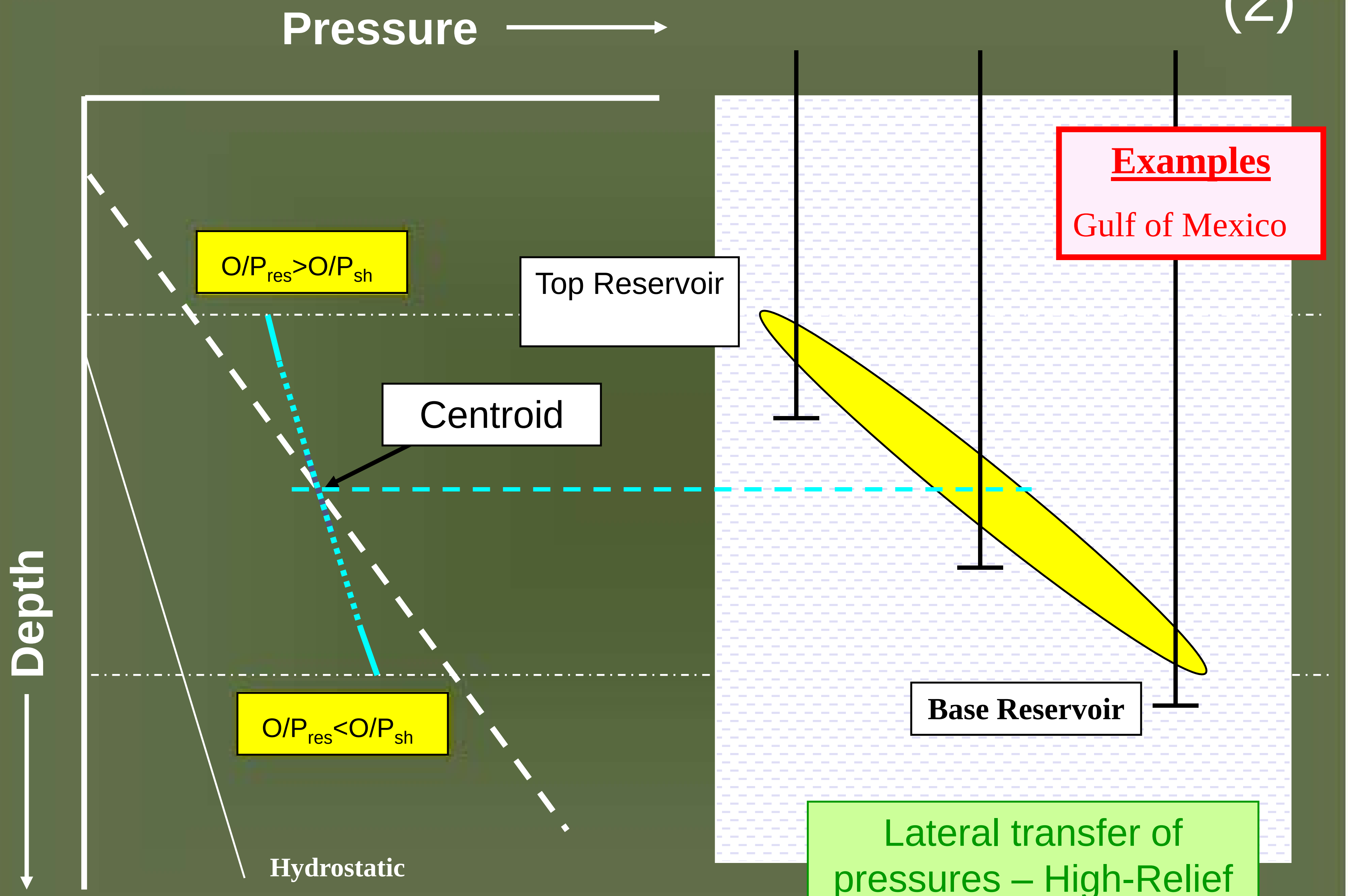
Shale Pressures

Isolated reservoirs

Nile Delta, Egypt, from Mann & Mackenzie (1990)

(2)

Lateral transfer of pressures – High-Relief Reservoirs



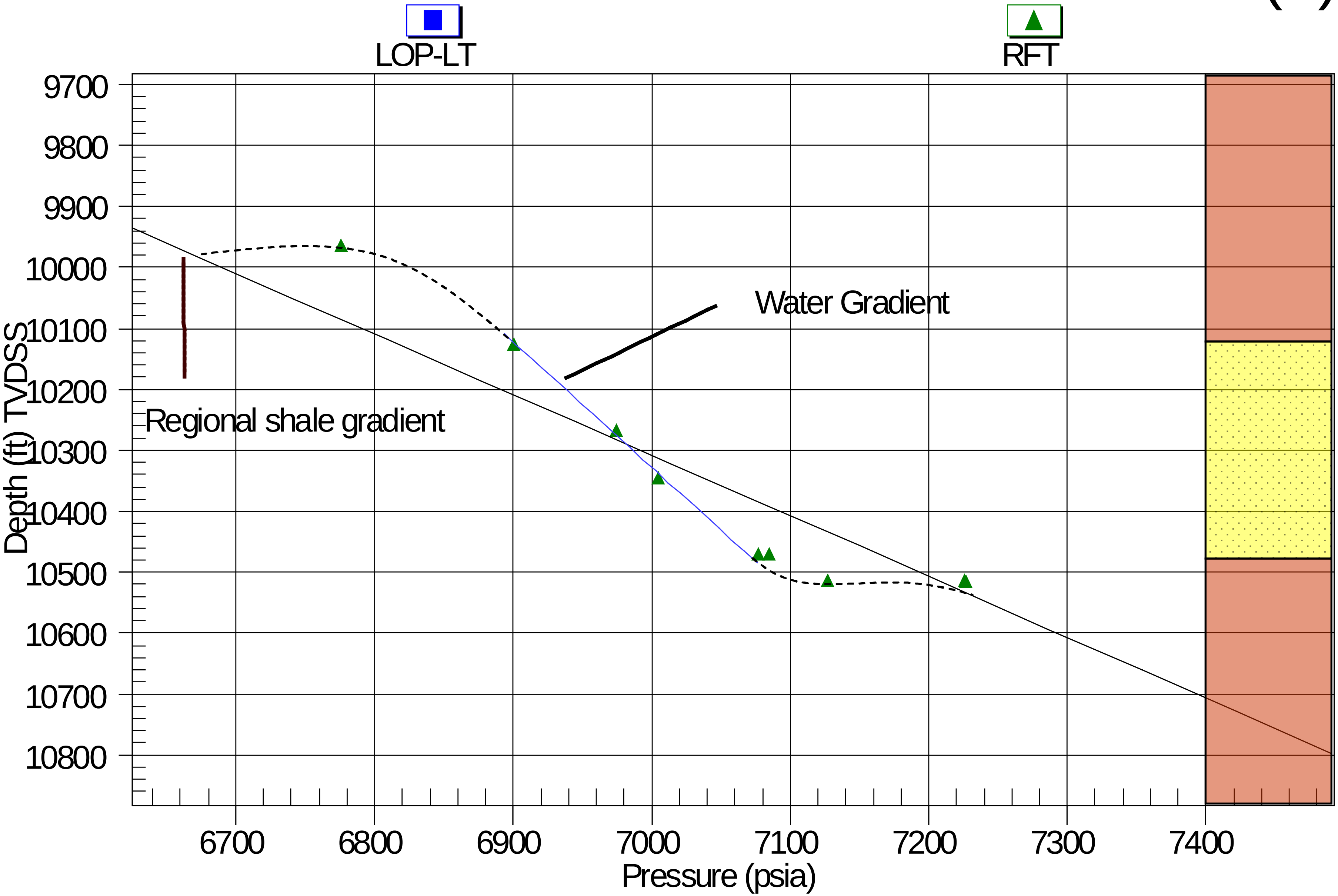
Examples

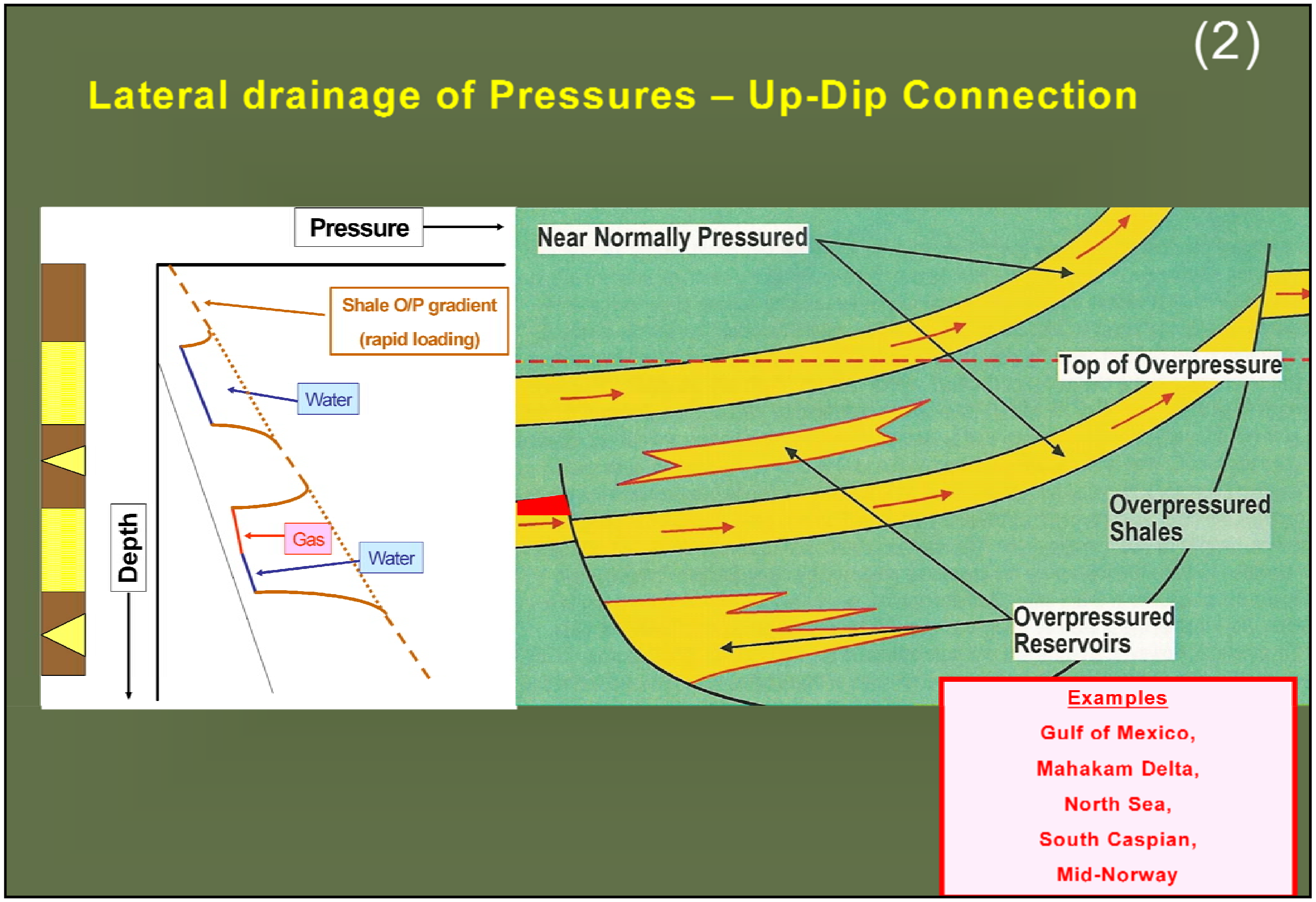
Gulf of Mexico

Gulf of Mexico MC 755/2 Lateral Transfer Effect

(2)

PressureView 3   GeoPressure Technology Ltd





(2)

Lateral drainage of Pressures – Up-Dip Connection

Examples

Gulf of Mexico,

Mahakam Delta,

North Sea,

South Caspian,

Mid-Norway

(1) Here is a section through a sequence of laterally connected and isolated sand bodies visualised on a P-D plot and a section through the subsurface.

(2) Sands can be either laterally continuous; e.g., shallow marine (more likely to be connected to shallower levels or sea bed via faults or continuous sands) or isolated; e.g., distal turbidites –more likely to reflect overpressures of surrounding shales.

(3) The first way to identify drained sands and pressure dissipation, therefore, is to create P-D plots to visualise pressure data and look for pressure reversals.

(4) Pressure reversal= pressure loss, no reversal=increase in pressure with depth.

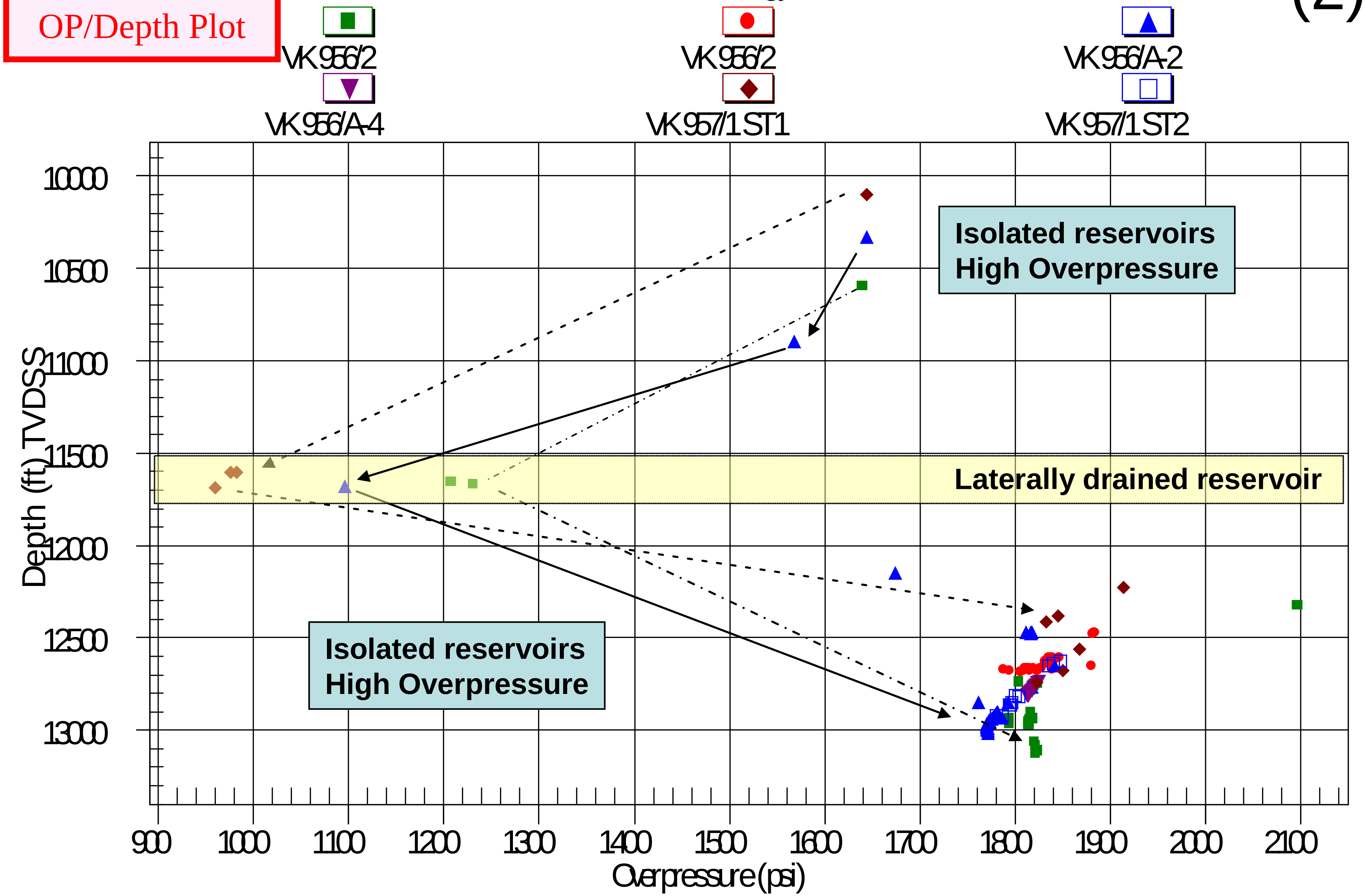
(5) Have to establish whether shales are overpressured - <u>However</u>, no direct data (RFT, MDT, FMT, DST) in the shales as permeabilities are too low to take samples; therefore, overpressures in shales can be calculated from
using pressures recorded in isolated sands or just use pressures in isolated sands directly to establish regional shale pressure gradients.

Viosca Knoll Formation Pressure Regression

PressureView3 GeoPressure Technology Ltd

(2)

OP/Depth Plot

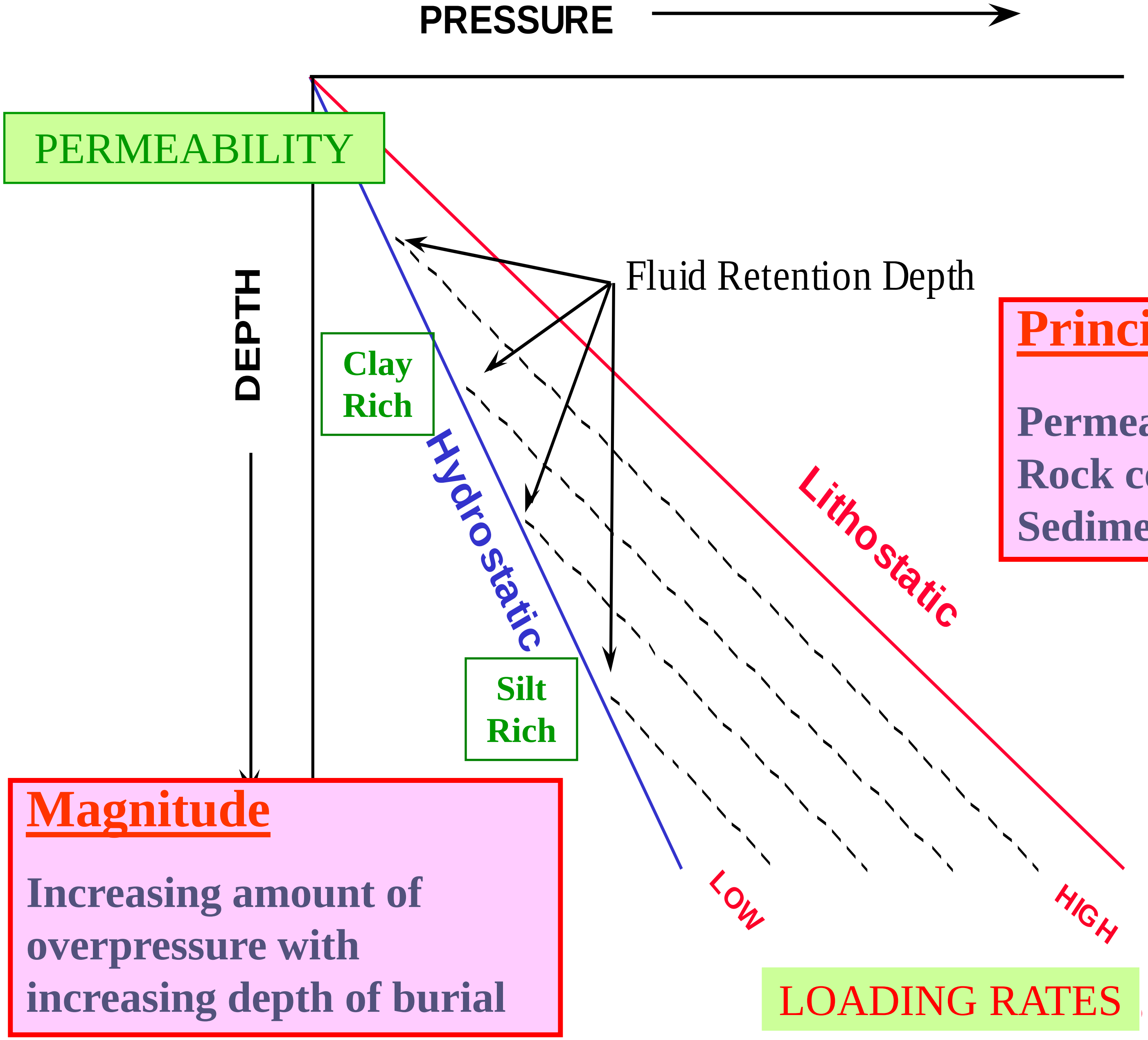


Isolated reservoirs High Overpressure

Laterally drained reservoir

Isolated reservoirs High Overpressure

Controls on Top of Overpressure



PRESSURE

DEPTH

PERMEABILITY

Fluid Retention Depth

Clay Rich

Silt Rich

Hydrostatic

Lithostatic

LOW

HIGH

LOADING RATES

Magnitude

Increasing amount of overpressure with increasing depth of burial

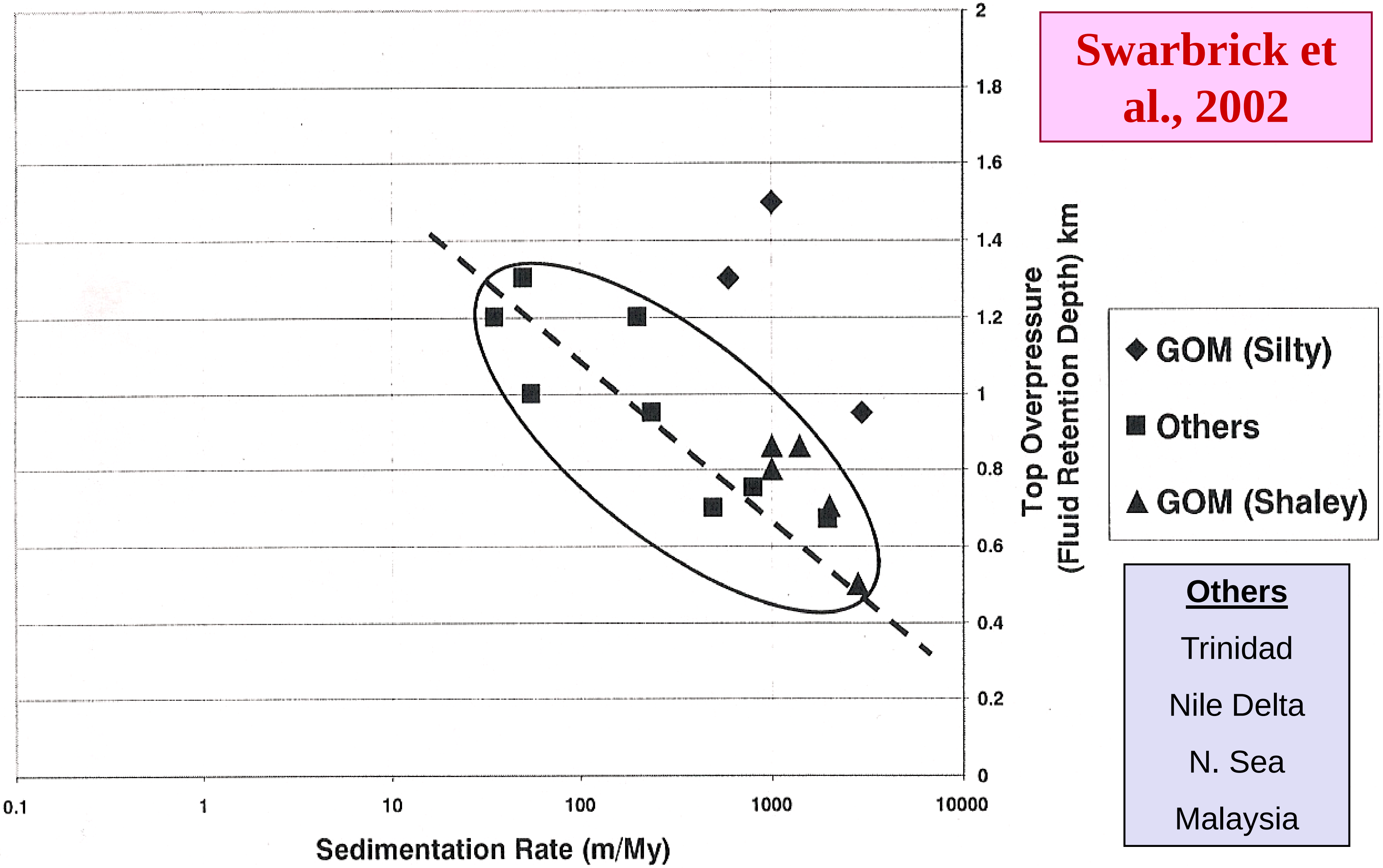
Principal controls:

Permeability
Rock compressibility
Sedimentation rate

Plot of Sedimentation Rates vs Top Overpressure

(3)

Swarbrick et al., 2002



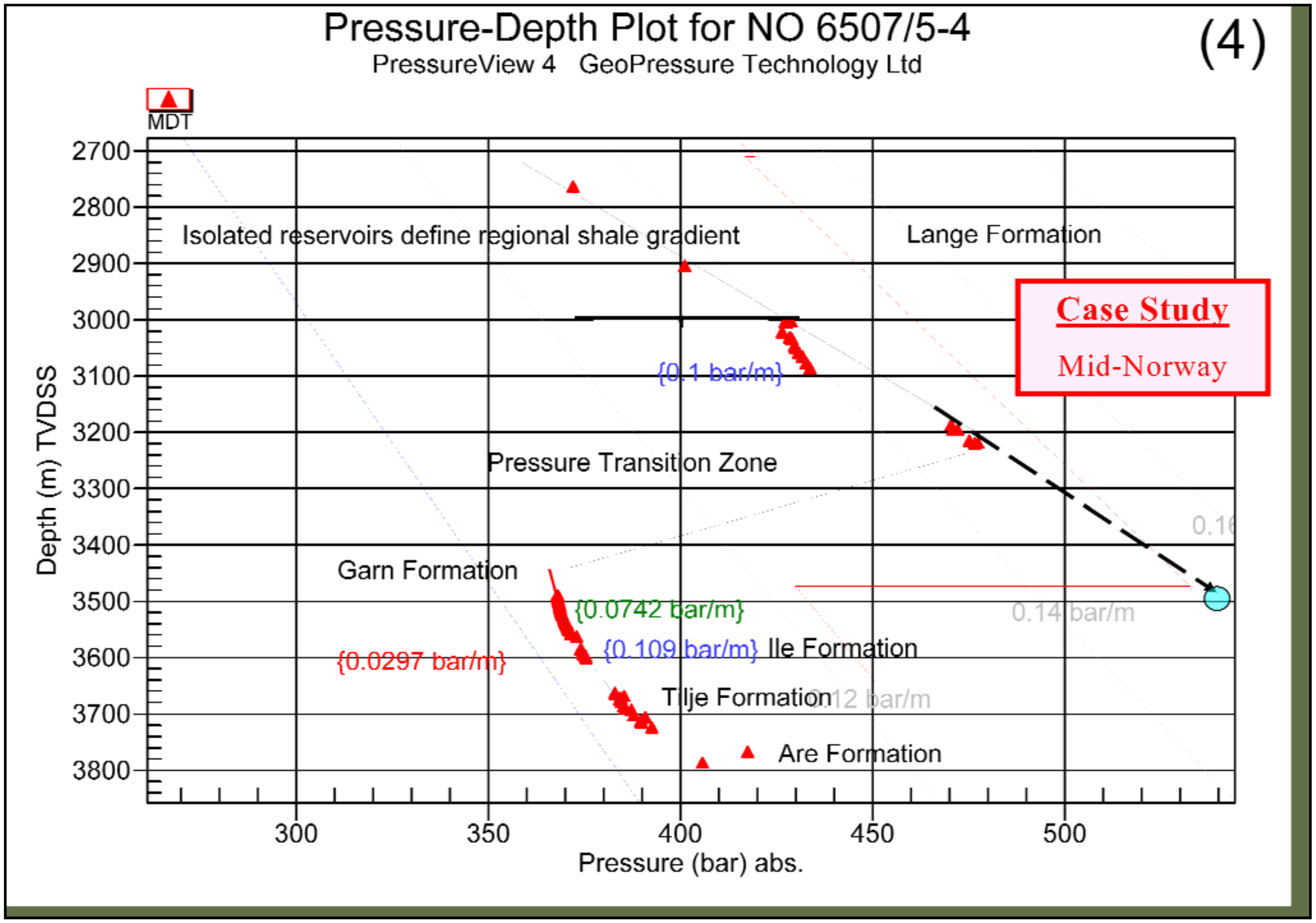
Others

Trinidad

Nile Delta

N. Sea

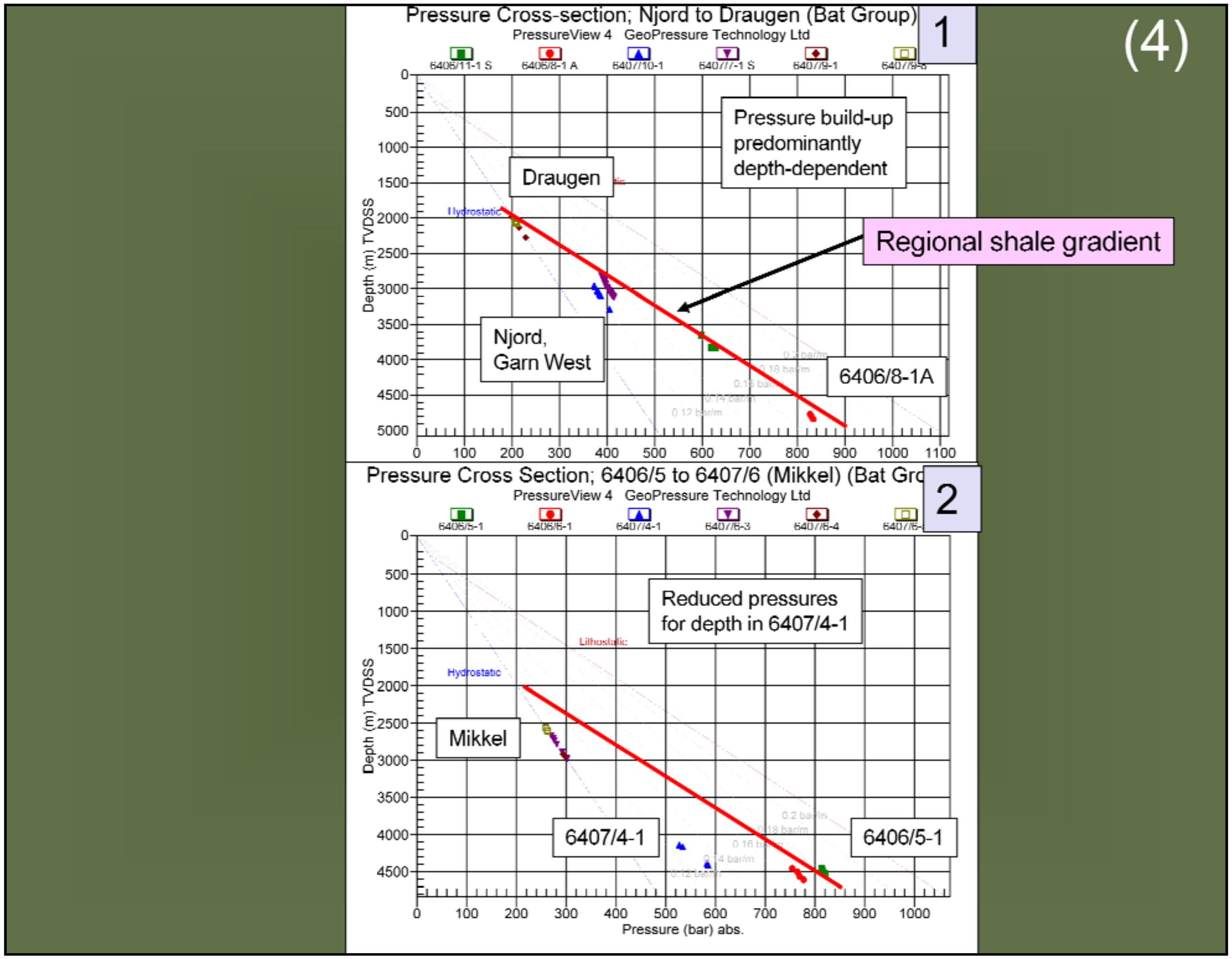
Malaysia



Example of a well in the LP area from Skarv Field – hydrostatic, red line=mud weight, MDT data record pressures in sands, fluid gradients.

(a) In Lange Fm. series of intra-formational reservoirs, locally petroliferous, up to 4 per well, that have direct pressure measurements within them – here sands and shales are in pressure equilibrium and define a regional shale gradient – i.e., the expected build-up of pressures with depth.

(b) In this well, a major pressure regression occurs, suggesting pressure loss has occurred –i.e ,less than expected pressures for depth of burial.



Referring to the four pressure x-sections – differential pressure loss across the Halten Terrace.

Conclusions

- Deep-water sediments are typically overpressured
- Shale pressures (prediction) are not always in equilibrium with reservoirs (calibration)
- Shale pressure profiles controlled by loading and shale properties
- Regional shale gradients identify anomalous pressures

Reference

Mann, D.M., and A.S. Mackenzie, 1990, Prediction of pore pressures in sedimentary basins: Marine and Petroleum Geology, v. 7, p. 55-65.

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Questions

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