

# **PS Pore Pressure Prediction in Challenging Areas – “Reducing Uncertainty by Understanding Rock Behaviour”\***

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## **Abstract**

In extensional Tertiary deltaic systems where compaction disequilibrium is the main source of overpressure generation, porosity/effective stress relationships can be utilised to predict pore pressures. These techniques rely on measurement of abnormally high porosities in shales at depth, referenced to those expected in a normally compacting sequence.

These approaches tend to underestimate pore pressure in situations where cementation occurs, where temperatures (>100-120°C), deep fluid expansion mechanisms (e.g., gas generation) are present or chemical compaction (porosity no longer related exclusively to effective stress) occurs. Also, in carbonate lithologies, pore pressure prediction using effective stress/porosity relationships is invalid, and therefore other approaches are required. In areas where there is increased tectonic stress, pore pressures will be underestimated if vertical stress loading is assumed the primary source of overpressure generation. Pressures in reservoirs/sands and shales also may be out-of-equilibrium, depending on sequence net/gross and lateral extent. Finally, sub-salt is problematic for several reasons, including the definition of a normal compaction curve.

Therefore, a series of “non-standard” approaches are presented based on world-wide experiences, whereby mechanisms of overpressure generation are identified and quantified in shales; e.g., using velocity/density cross-plots, carbonate pressure prediction is discussed and facies controls on pressure build-up and retention are detailed (e.g., laterally drained reservoirs). Also, understanding of rock properties adds confidence to pressure prediction in areas of limited data. By first using standard techniques related to vertical stress, then using these non-standard approaches allows more robust geological pressure models to be constructed.

## **References**

Hoesni, M.J., 2004, Origins of overpressure in the Malay Basin and its Influence on petroleum systems: Ph.D. Thesis, University of Durham.

Lahann, R.W., D.K. McCarty, and J.C.C. Hsieh, J.C.C., 2001, Influence of clay diagenesis on shale velocities and fluid pressure: Offshore Technology Conference paper 13046.

O'Connor, S.A., R.W. Lahann, and R.E. Swarbrick, 2007, Mid Norway pressure study: GeoPressure Technology & IHS Energy.



# Pore Pressure Prediction in Challenging Areas

“Reducing uncertainty by understanding rock behaviour”

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Devastating rig fire due to a blowout believed to result from inaccurate pore pressure prediction.

East Timor Sea

## Pore Pressure Prediction: A User Guide

Pore pressure prediction revolves around the compaction state of shales relative to their confining stress, usually the vertical stress (also known as the overburden).

Pore pressure prediction uses the Terzaghi stress relationship between total stress (S), effective stress ( $\sigma'$ ) and the pore pressure (PP) in the simplified equation;

$$S = \sigma' + PP$$

### Assumptions:

- > Source of overpressure is disequilibrium compaction (ineffective de-watering)
- > “Porosity” can be imaged (e.g. seismic internal velocity, ITT, Resistivity, Dx-Exponent)
- > Shale is at its maximum effective stress (i.e. no recent uplift or inflationary pressure increase)

The magnitude of pore pressure can be determined using either an empirical function (e.g. Eaton Ratio Method) or deterministic solution (e.g. Equivalent Depth Method). Both methods require development of a “normal compaction trend (NCT)” which acts as a reference porosity-effective stress relationship.

***Determination of a NCT is itself a challenge in many areas, or a source of uncertainty in results.***

Finally, shale-based pressure prediction can be compared with direct reservoir pressures, but care must be taken as lateral transfer along inclined but confined reservoirs, and lateral drainage, fluid and pressure escape to surface, can generate poor compliance between shale and reservoir pressures.

***Accurate pore pressure prediction results when thick shales are well imaged by wireline / LWD tools interspersed by thin, confined reservoirs which have been pressure tested.***

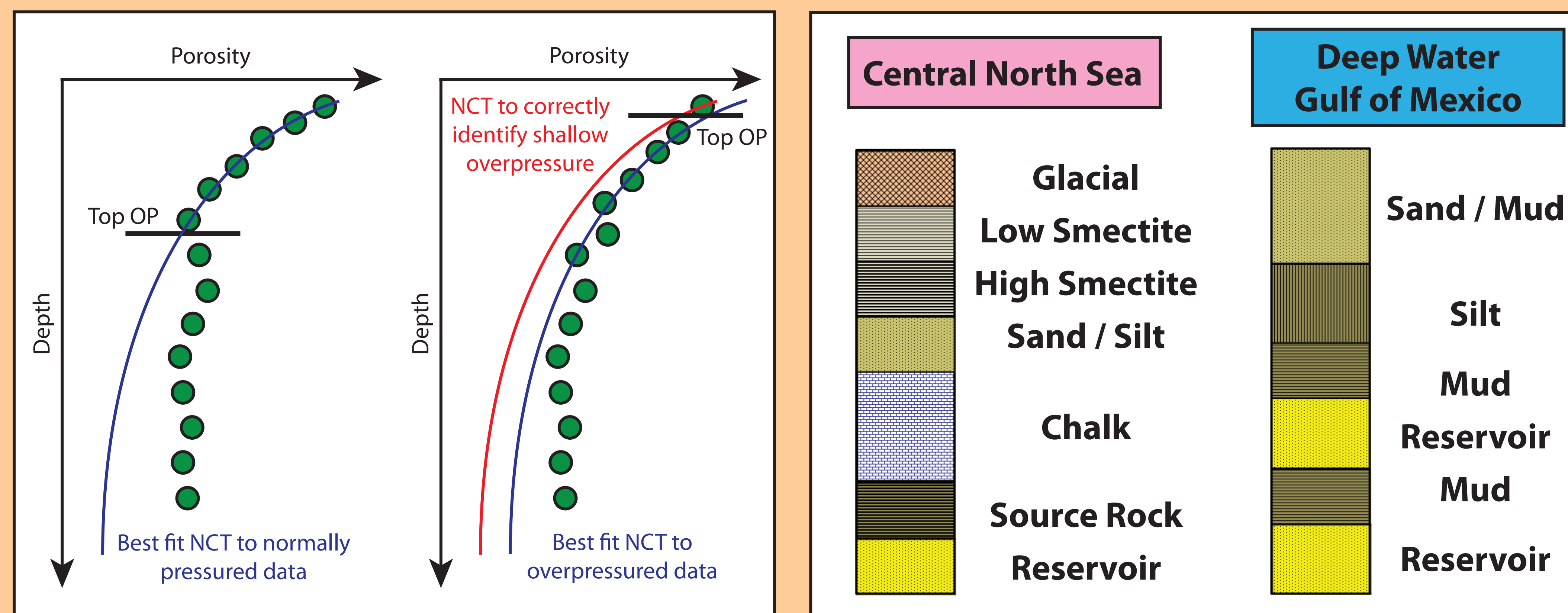


# What makes for "Challenging Areas"

The challenge for pore pressure prediction can be usefully summarised as:

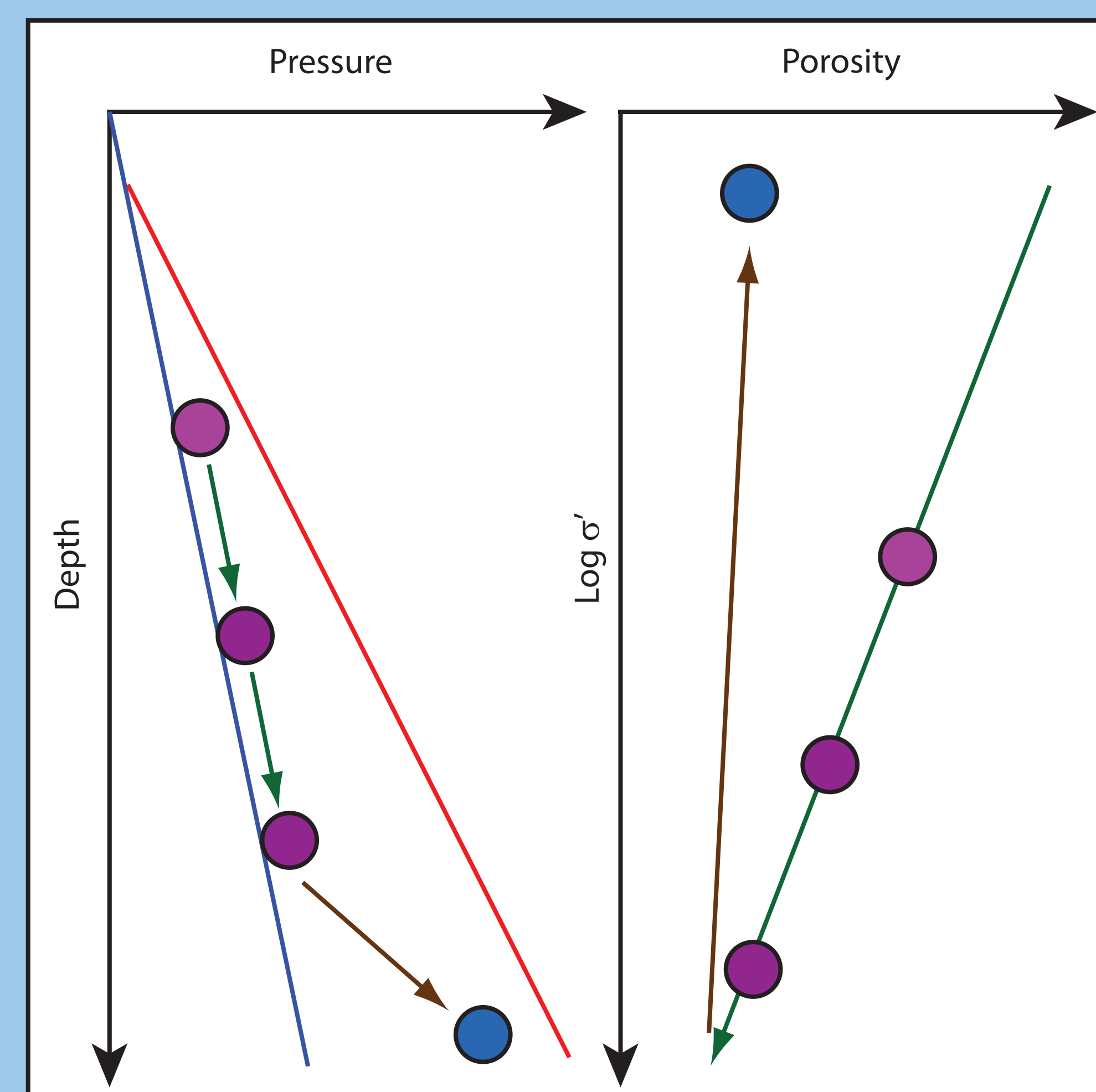
- (1) Poor data areas - either poor wireline / LWD logs and/or no direct pressure tests.
- (2) Shales not at their maximum effective stress, e.g. uplift or fluid expansion (primarily gas generation).
- (3) Shales which have undergone chemical alteration, e.g. lithification processes or mineral transformations (smectite - illite diagenesis).

**(1)** Typical difficulties with pore pressure prediction arise in deep-water settings where logs are not run top-hole (e.g. shallow top OP) as well as where shales vary widely within a single vertical succession (e.g. Central North Sea).

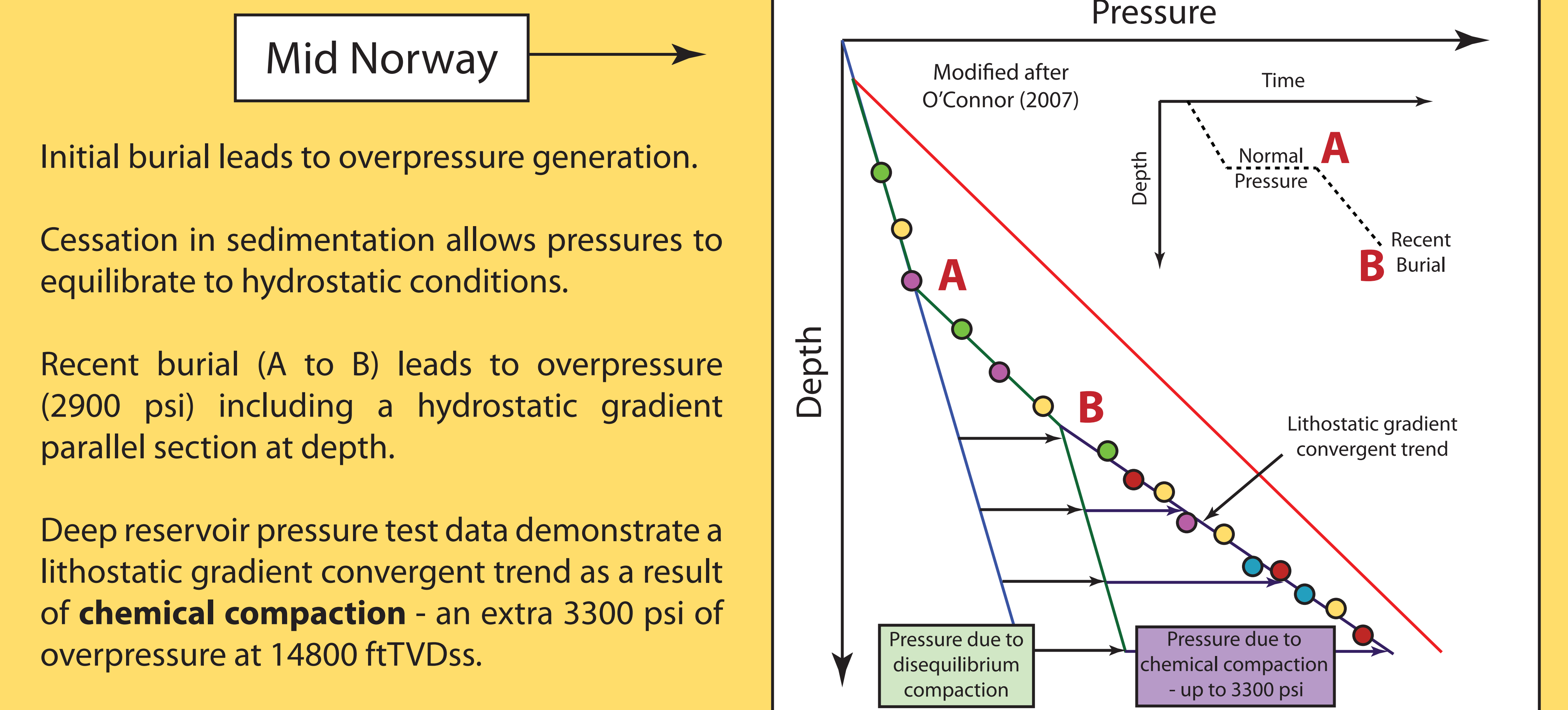
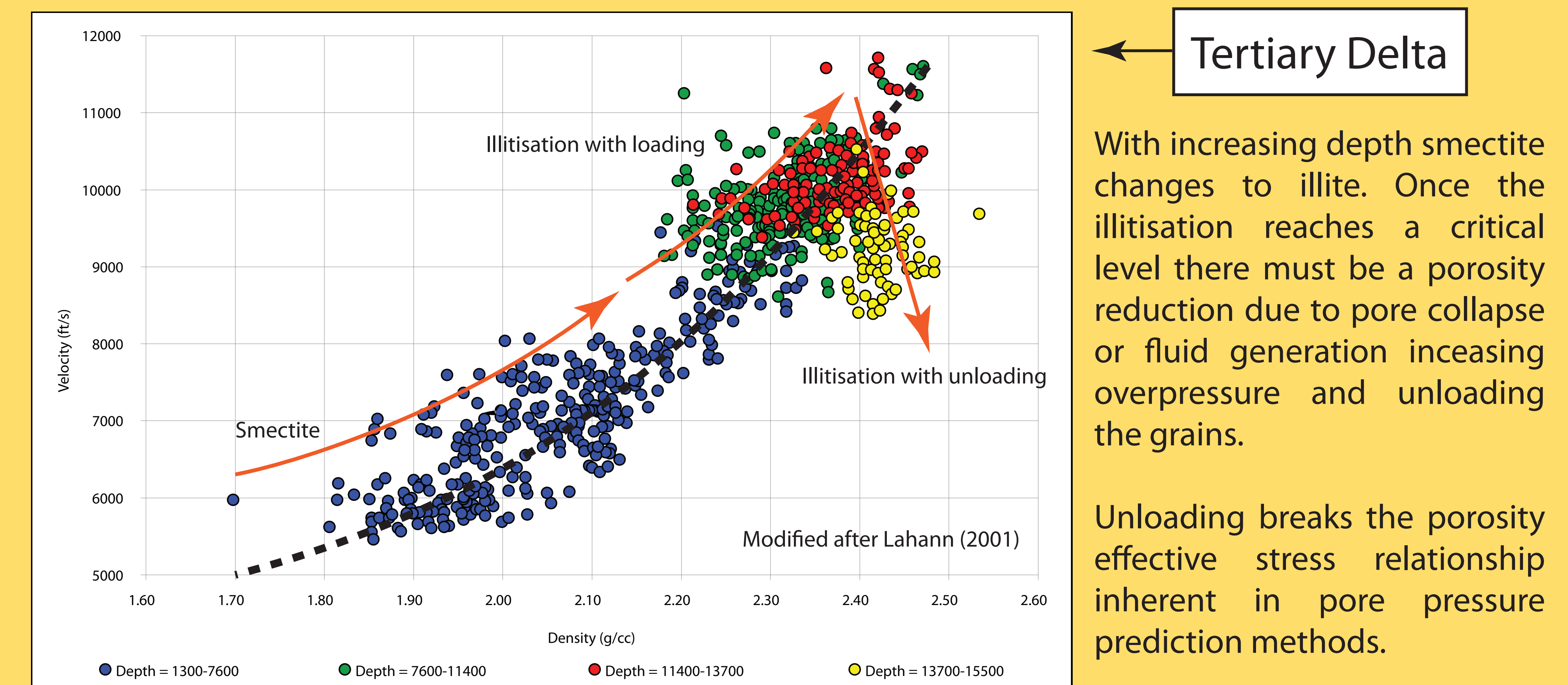


**(2)** Making a successful pore pressure prediction onshore is often frustrated by uplift and sediment removal such that the porosity of the sediments relates to earlier, deeper burial.

Pore pressure prediction will reveal higher effective stress than valid for the current depth of burial. The same effect results from fluid expansion and leads to under-estimation of the pore pressure.



**(3)** Since pore pressure prediction in shales relates porosity to effective stress, chemically-driven changes in porosity will lead to erroneous prediction.



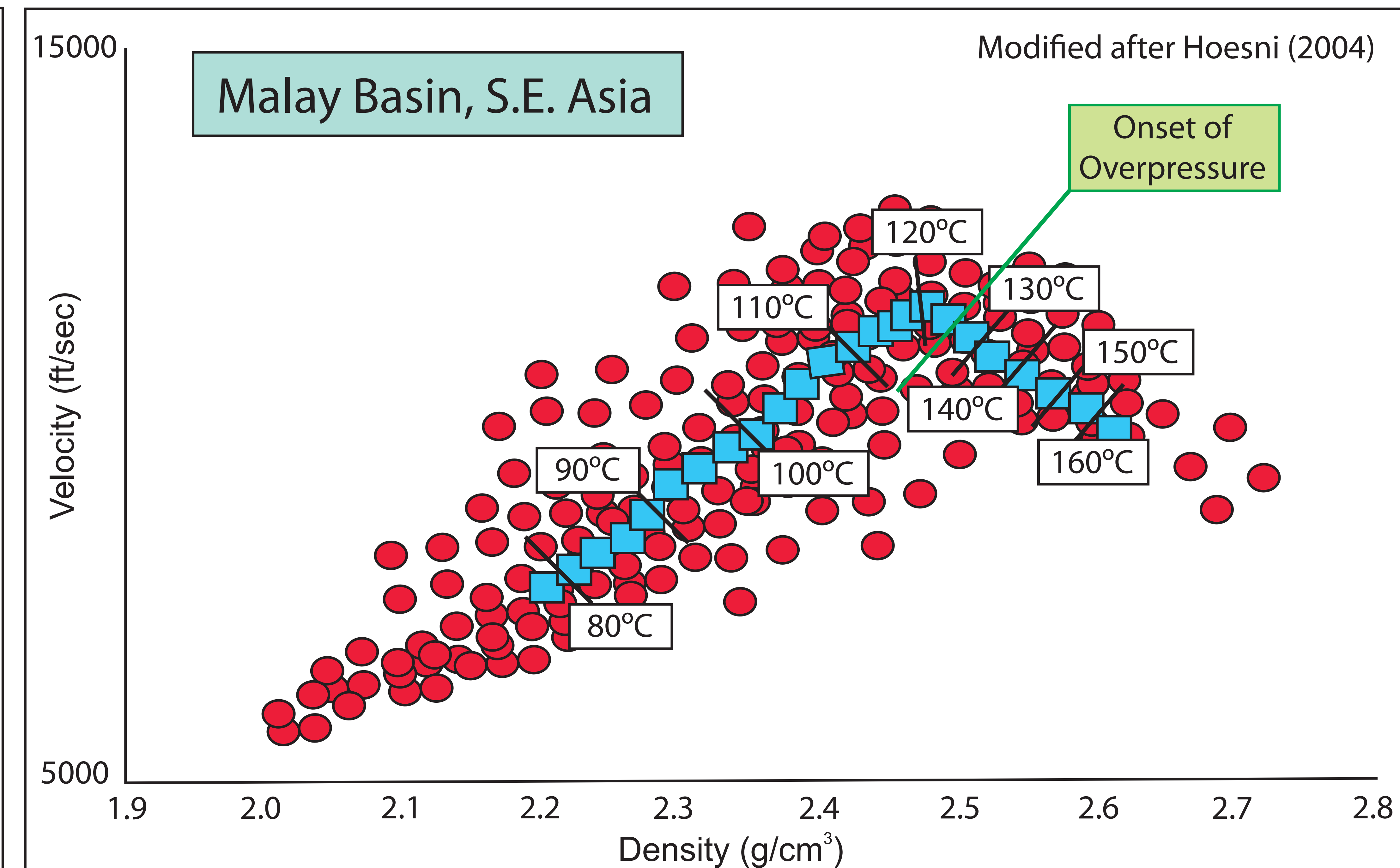
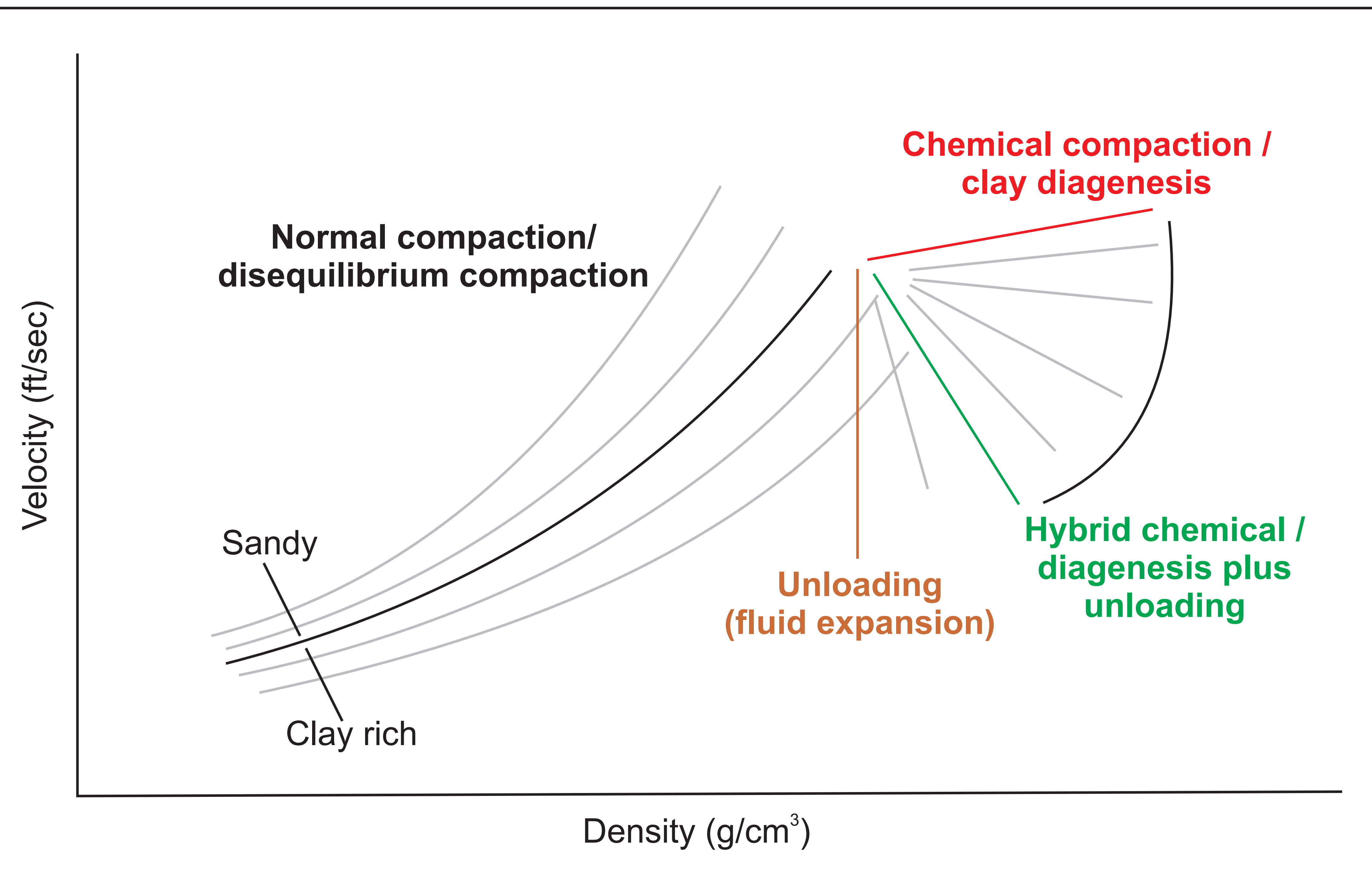


# How to recognise “Challenging Areas”?

Difficult pressure prediction resulting from fluid expansion (due to gas generation) and chemical compaction (with or without pressure generation) can be anticipated by applying the following techniques

(1) Determine mechanism using velocity and density

(2) Temperature > 100°C - 120°C



## Conclusions

- Porosity based pore pressure prediction techniques work best where a “normal compaction trend” can be reliably developed, the lithology is moderately constant, and the overpressure is due to disequilibrium compaction.
- In low temperature, non-mechanical regimes challenges relate to lateral transfer / drainage, poor data and lithological variability.
- Fluid expansion and uplift generate reduction in effective stress without being revealed in higher porosity (compaction is irreversible) leading to under-estimation of pore pressure.
- Chemical changes in shales modify porosity and destroy the link between porosity and effective stress associated with normal compaction behaviour and challenge traditional porosity-based pore pressure prediction techniques.

### References:

Hoesni, M.J., 2004, Origins of Overpressure in the Malay Basin and its Influence on Petroleum Systems (PhD Thesis), University of Durham.  
Lahann, R.W., McCarty, D.K. & Hsieh, J.C.C., 2001, Influence of Clay Diagenesis on Shale Velocities and Fluid Pressure, Offshore Technology Conference.  
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