A Global View of Clay Rock Normal Compaction

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Abstract

Porosity reduction during the burial of clay rocks, compaction, has been a subject of interest for many years (Athy, 1930, Mondol et. al., 2007). Contemporary research interest in this subject commonly includes the comparison of a number of normal compaction trends derived from basins as well as the results from compaction studies conducted in a laboratory. These comparisons show a wide range of compaction trends with the commonality being increasing compaction with depth, but at any depth a very wide scatter in trends is observed and making predictions becomes hard. Consequently, various studies have tried to understand the scatter in compaction trends by attributing the behavior to a number of geologic factors.

We propose that in most clastic dominated basins that clay rock compaction is actually fairly well constrained and predictable. A brief review of the published compaction trends suggests that outliers are from basins that have undergone a complicated geologic history and are now out of place and not at maximum burial depth. Our work supports recent evaluations of clay rock compaction which indicates that the composition of the clay rock does significantly affect the rate of compaction. Lahann, (2002, 2004), Katahara (2003), and Alberty and McLean (2003) support a similar conclusion that smectite-rich clay rocks will compact at a much slower rate than illite or mixed-clay rich clay rocks or shale.

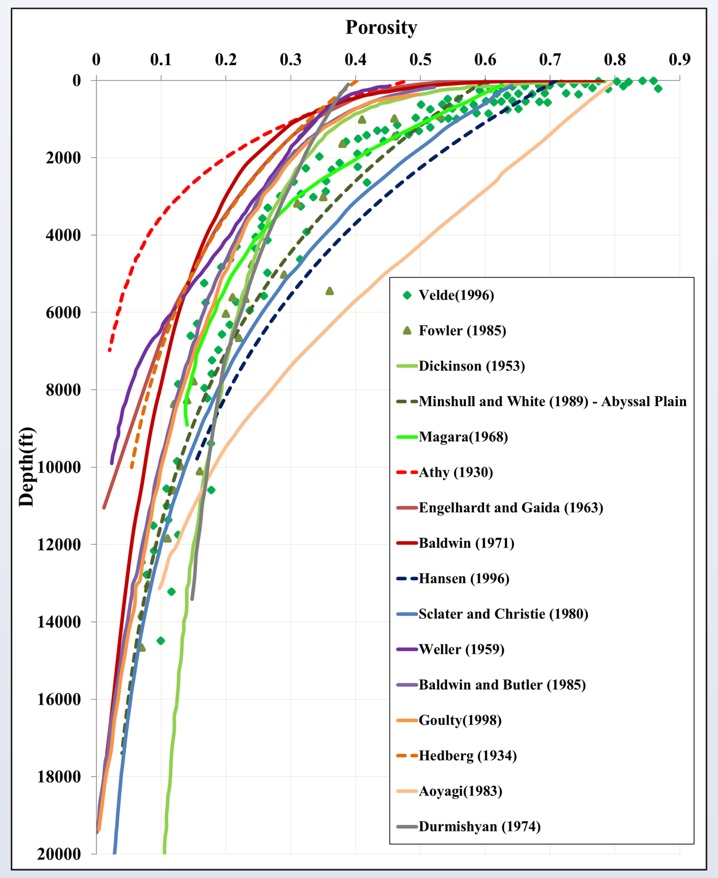
Normal Compaction trends

From basins currently at maximum burial depth

- Fowler (1985)
- Minshul and White (1989)
- Velde (1996)
- Magara (1968)
- Dickinson (1953)

Others:

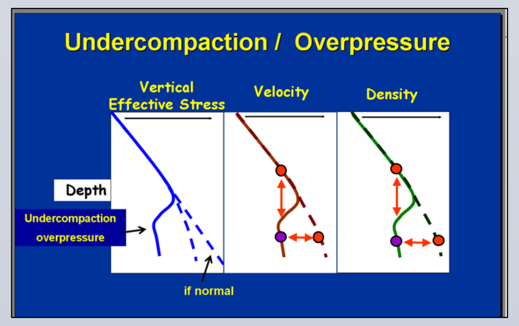
- Uplifted & deeply eroded
- Over-pressured clay rocks
- Curves re-worked from previous literature
- Laboratory compaction experiments, unknown sources



Upon increasing effective stress, smectite and illite grains follow different paths of porosity reduction.

Smectites are expandable and much more porous than illite grains due to presence of interlayer or intra-crystalline water, in addition to clay-bound water.

Most pressure to predict pressure equations relate an observed value compared to a “normal compaction” value



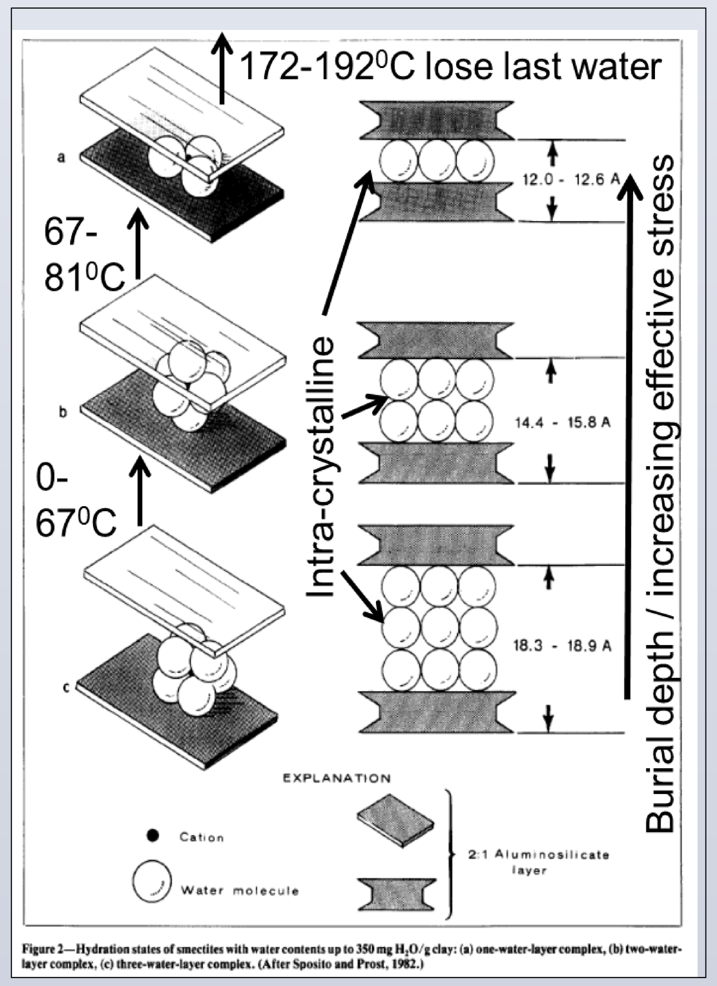
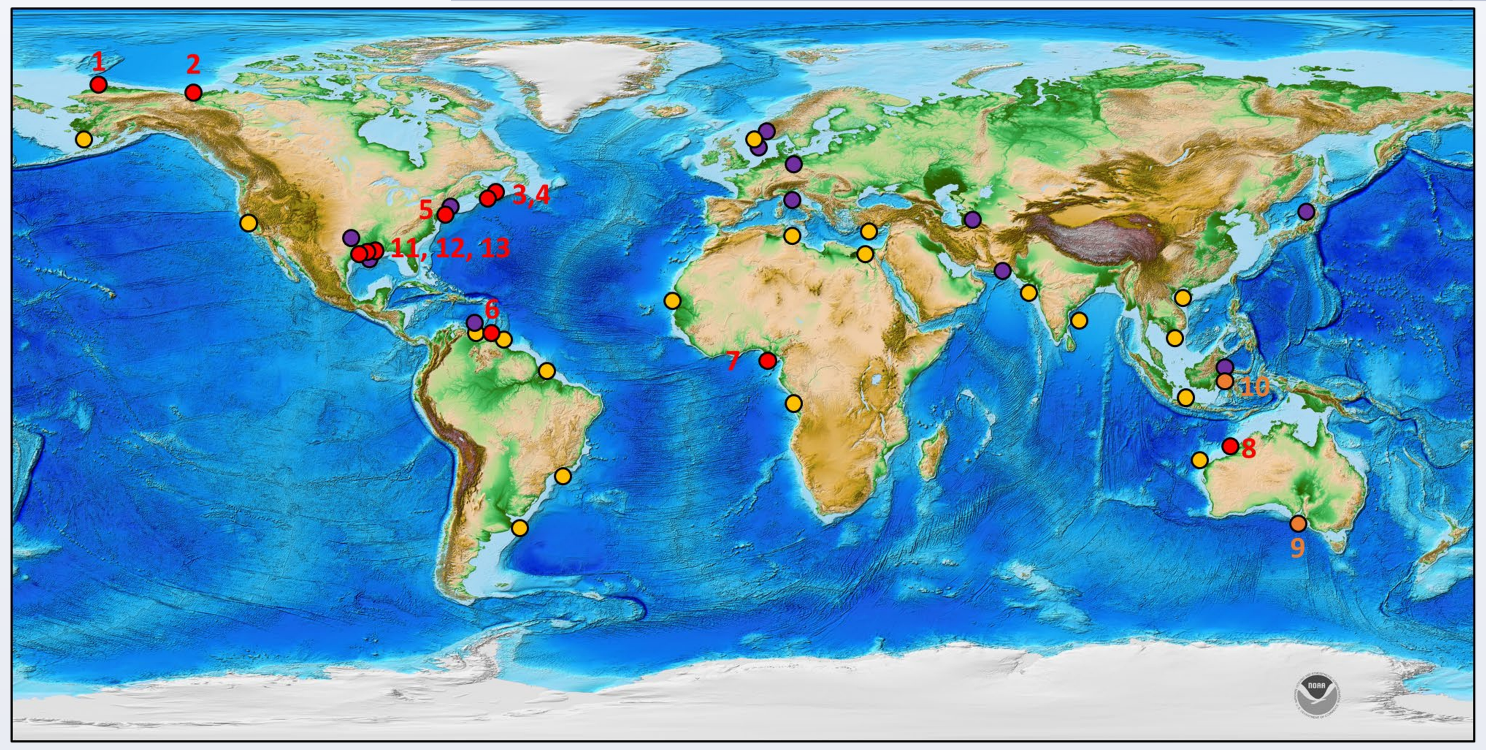


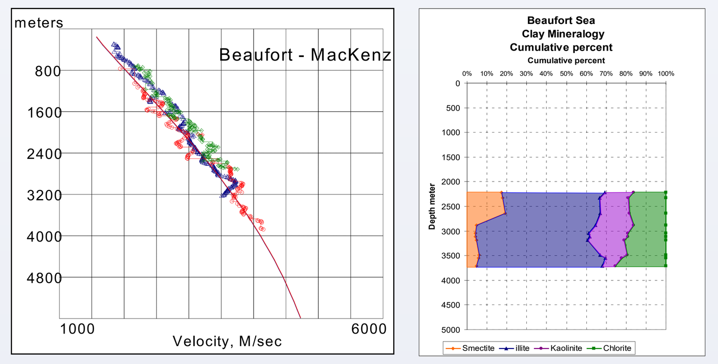
Figure 2—Hydration states of smectites with water contents up to 350 mg H_2O/g clay: (a) one-water-layer complex, (b) two-water-layer complex, (c) three-water-layer complex. (After Sposito and Prost, 1982.)

Global Compaction Trends and Clay Mineralogy

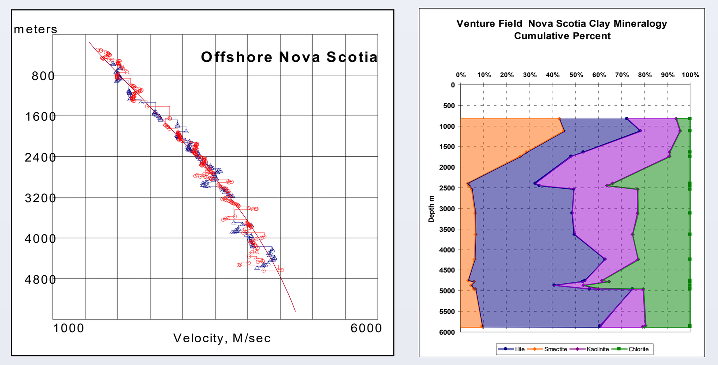


- Current clay mineralogy and normal compaction study
- Past experience of significant normal pressure section
- Ongoing Analysis
- Contemporary literature

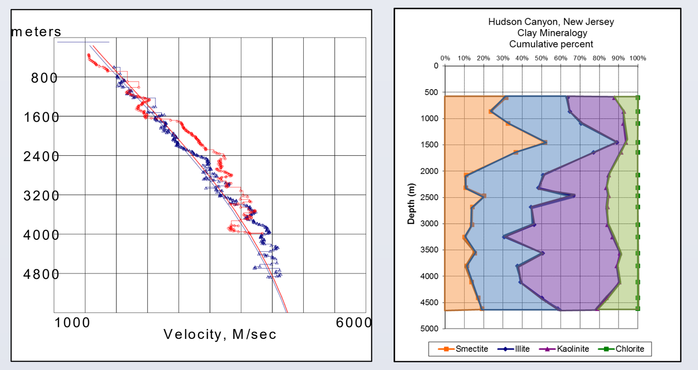
1,2. Beaufort – MacKenzie, Alaska



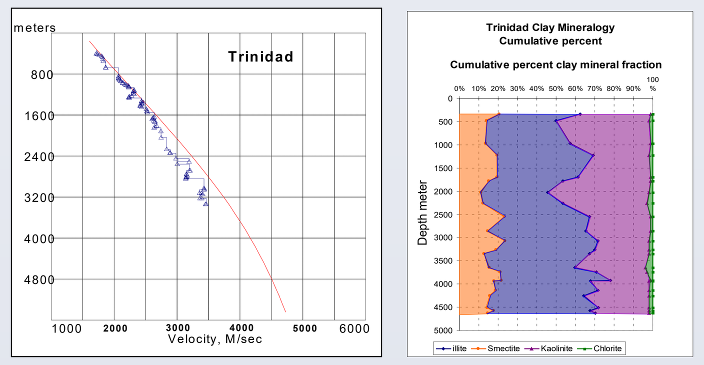
3,4. Nova Scotia



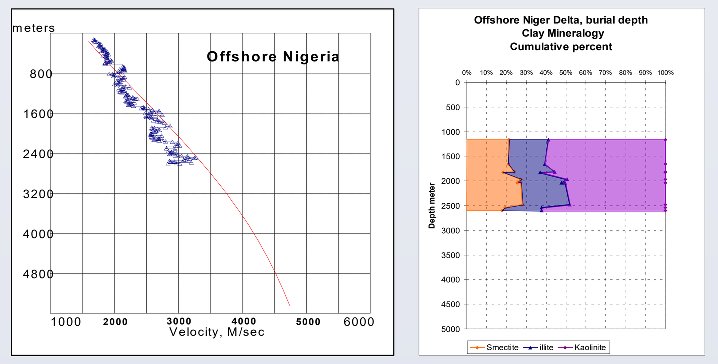
5. New Jersey



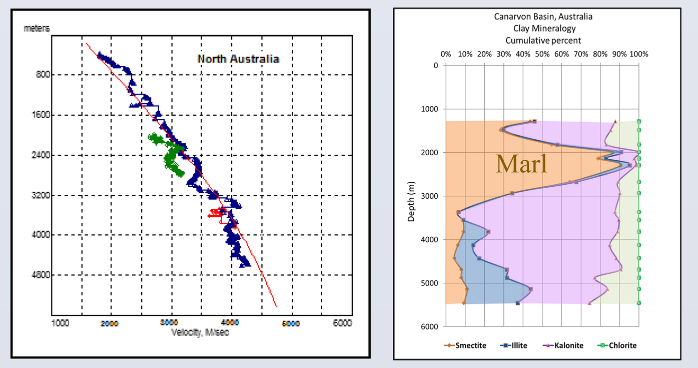
6. Trinidad



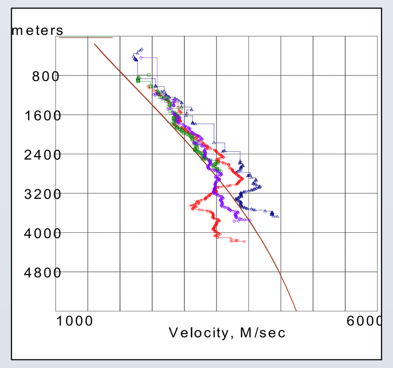
7. Nigeria



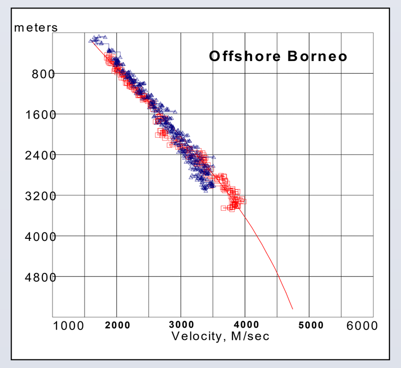
8. Canarvon Basin, Australia



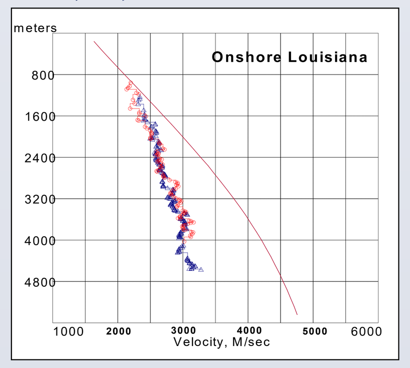
9. Otway Basin



10. Borneo



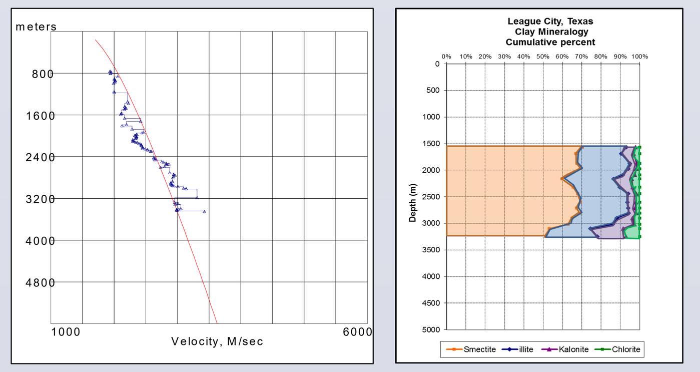
11,12, 13. Gulf of Mexico



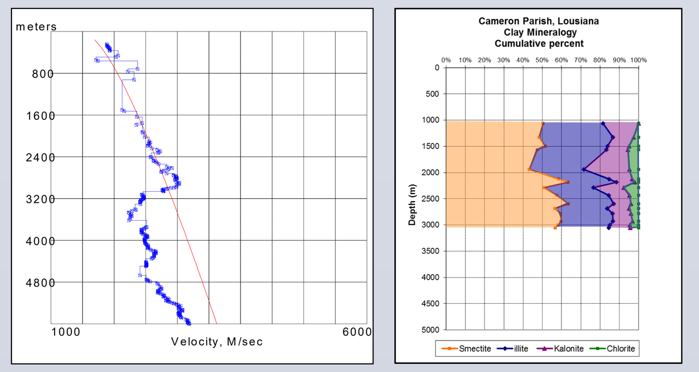
Compaction trends from Gulf of Mexico are significantly slower due to clay mineralogy

Compaction trends from Gulf of Mexico, smectite dominated mudstones and shales, have lower P and S wave velocities and porosity

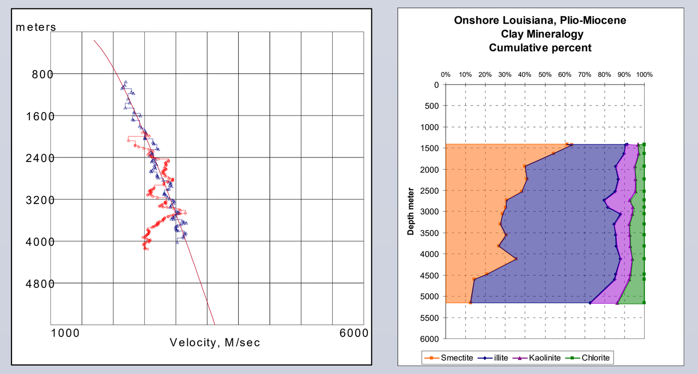
11. League City, Texas

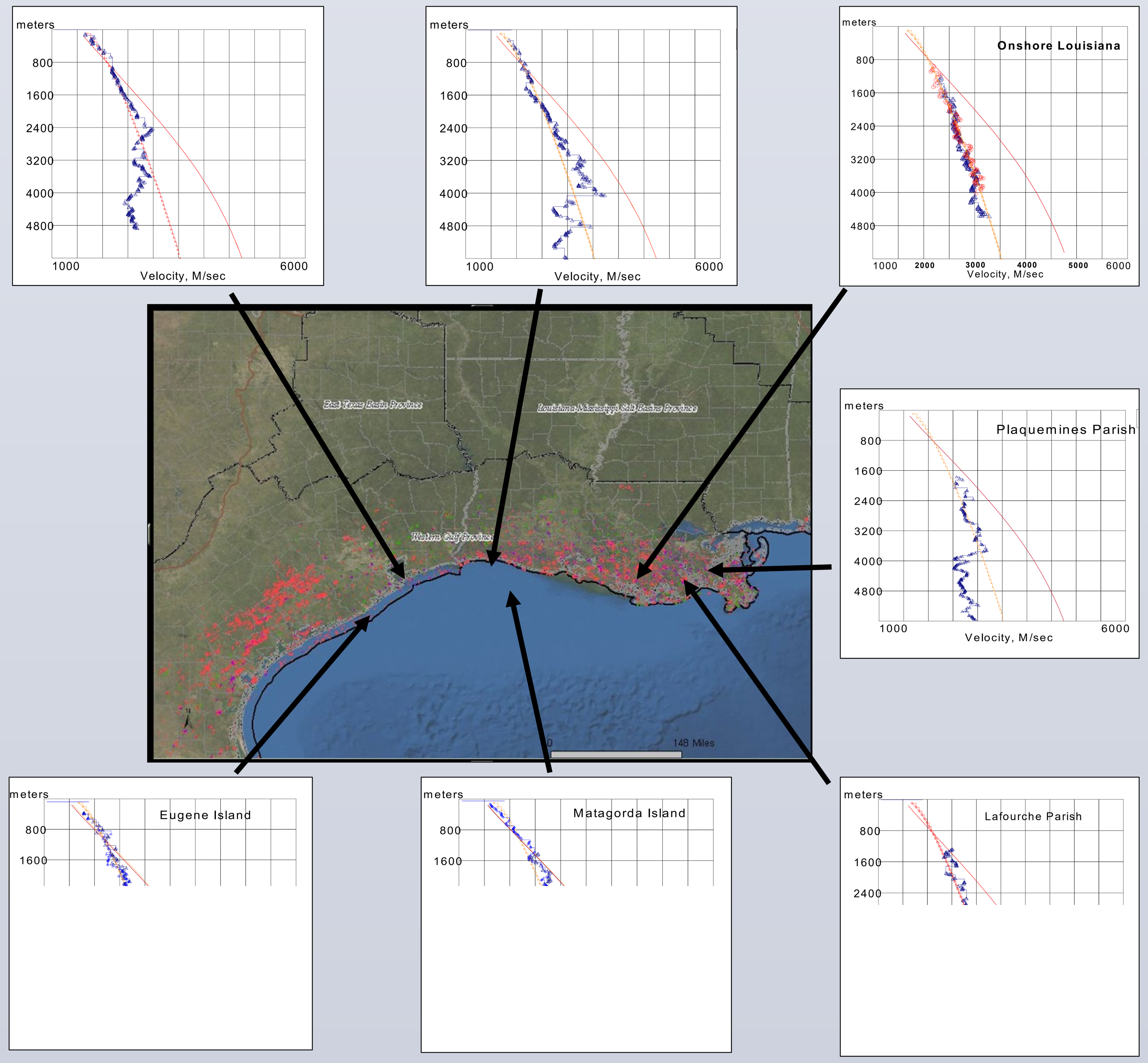


12. Cameron Parish Louisiana



13. Terrebone Parish, Louisiana



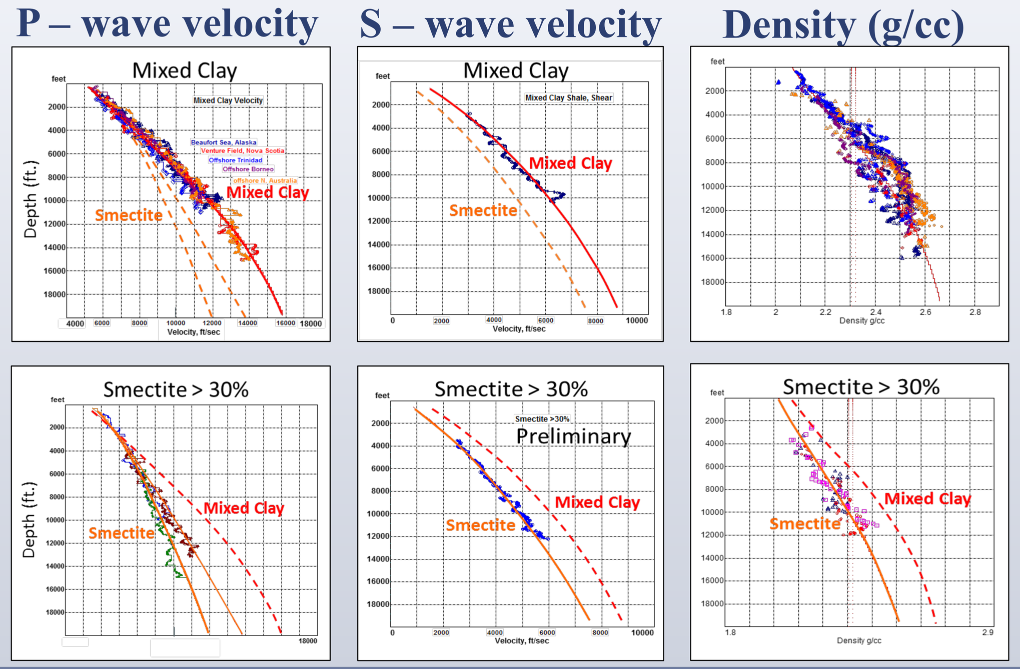


Smectite-rich and Mixed clay compaction trends

The largest control on petrophysical trends such as velocity, density and porosity of shales is the amount of smectite grains.

At smectite abundance > 30 %, we see a significant deviation from the mixed clay compaction curve

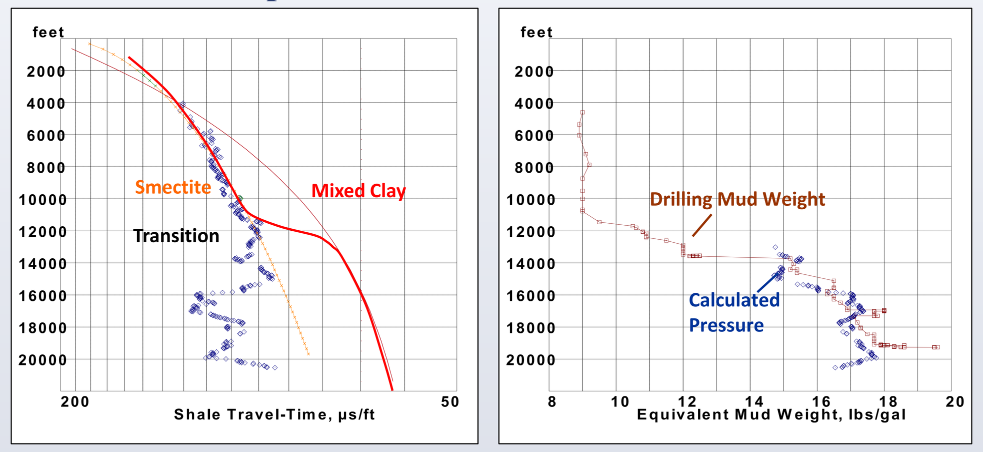
P – wave velocity | **S – wave velocity** | **Density (g/cc)**



Implications for Pore Pressure Prediction

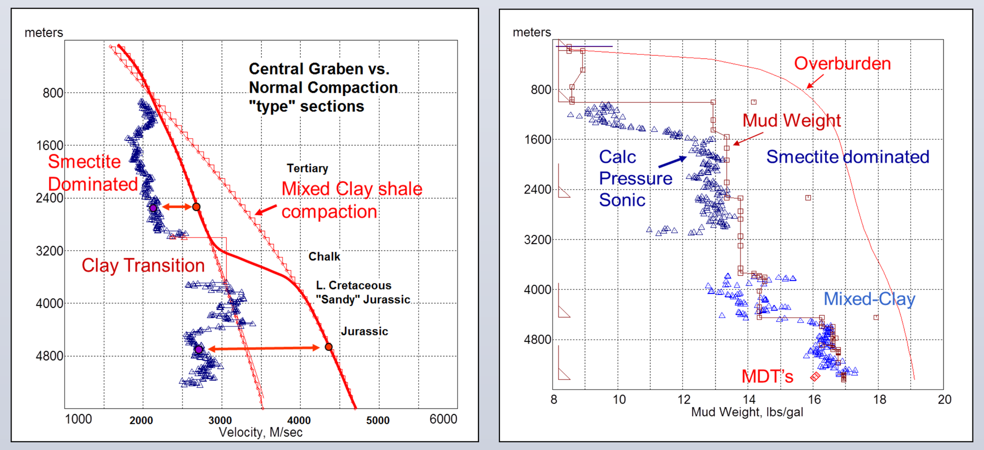
Smectite dominated curve accurately predicts pore pressure in shallow sections Gulf of Mexico and Central Graben, North Sea.

Pressure Interpretation from Gulf of Mexico Onshore



After smectite-illite transition depth (~10000 ft.) , mixed clay curve is used for accurate pore pressure prediction

Pressure Interpretation from Central Graben, North Sea



Results

- Clay rocks compact in a largely predictable manner with increasing effective stress
- Global examples indicate compaction is very similar for “mixed-clay” rocks
- Smectite content over 30% can significantly affect compaction

Using Bowers (1994)

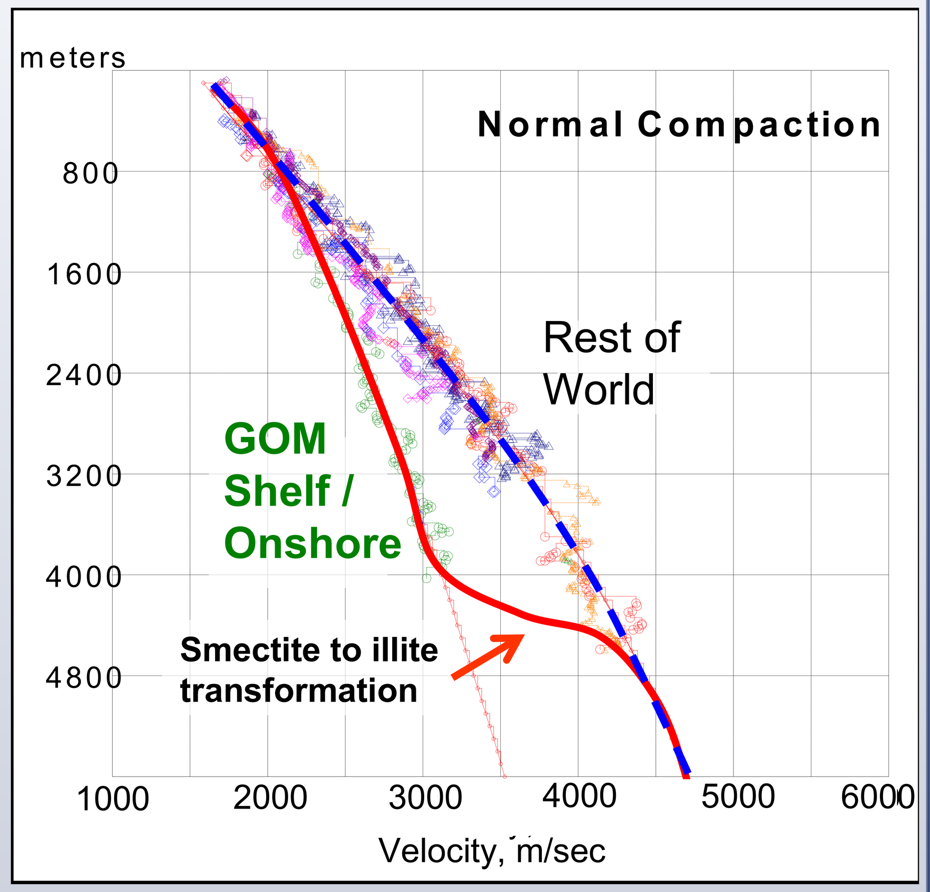
Velocity = 5000 + Aσ^B

Smectite-Rich

A = 14.0; B = 0.67 (to 0.68)

Mixed-Clay (rest of world)

A = 14.0; B = 0.72



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