Using Sonic and Seismic Indications of Coastal Plain Unconformities to Suggest Missing Sediments and Downdip Development of the Eastern Atlantic Coastal Plain and Shelf*

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Abstract

High resolution geological and geophysical investigations at the USDOE Savannah River Site utilized a series of deep boreholes plus deeper existing coastal plain wells to establish a series of regional cross-sections and basemaps. These cross-sections were made utilizing sophisticated wireline geophysical logs, core data, geotechnical direct push technology logs for shallow interrogation, and seismic data and were complimentary to the many regional cross sections and large scale maps made by historical researchers. These sections and maps were then used in regional seismic hazard characterization and evaluation and for other environmental studies. Additionally, both regional and higher resolution localized seismic data added to the overall efforts. The dominant sediments evaluated were Late Eocene through Late Cretaceous from the Upper Atlantic Coastal Plain, but sediments to possible Norian age were evaluated in the lower coastal plain and shelf.

During this work it became apparent that unconformities in both the Upper, Mid and Lower Atlantic Coastal Plain were strongly correlated to abrupt variations in sonic logs that translated from the deep to very shallow horizons. The major published regional unconformities as well as smaller sub-regional unconformities were apparently present in the data. Additionally, in the shallow horizons, geotechnical information was present that allowed for a calculation of estimated overburden or burial depth. This suggested that it might be possible to estimate the amount of sediment missing from an unconformable horizon. This was important in estimating the volume of sediment that moved downdip. Knowing the amount of missing sediment might aide in estimating uplift, subaerial exposure time, paleoclimate, burial depths and thermal history, and aide in the understanding of what geobodies might be present downdip. These may be important factors in evaluating the hydrocarbon potential of the lower submerged coastal plain and continental shelf.

For the Upper Atlantic Coastal Plain it is probable that more sediment is missing than remains. Shallow sediments, often defined in the literature as different aged or as a different formation, are possibly re-worked and mobilized downdip. These sediments are essentially localized regressive or transgressive expressions and have not moved downdip. Missing sediments, eroded and mobilized down slope become reservoir bodies or compartments. As expected, the Lower Coastal Plain logs suggest that the sediment estimated from the Upper

and Mid Coastal Plain to be missing is incorporated in the Lower Coastal Plain and the number of unconformities deceases. It then becomes possible to estimate the volume of sediment retained versus missing, allowing for an estimate of available sediment for reservoir rock.

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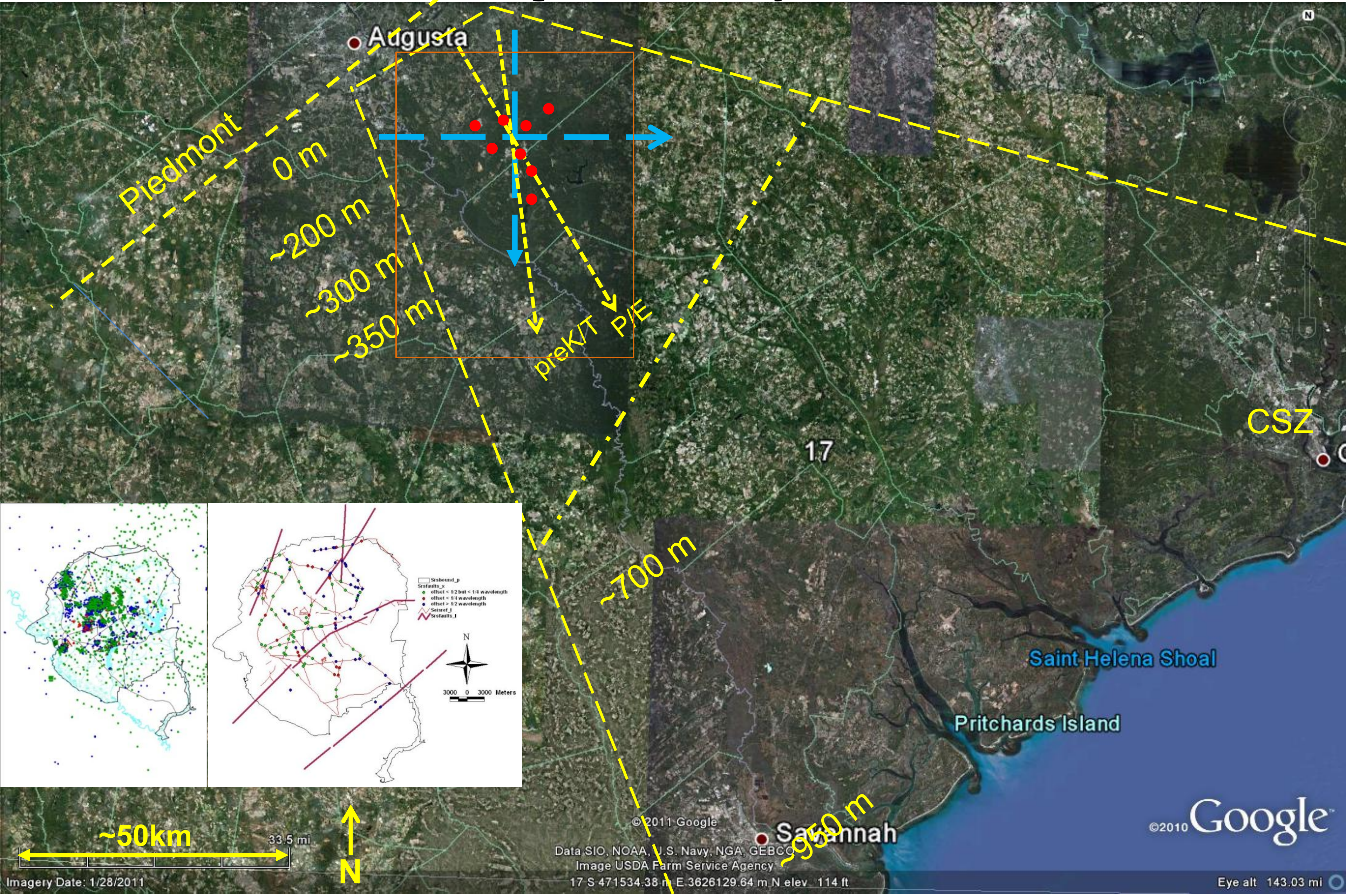
Our Goal is to:

- Present evidence that the unconsolidated sediments of the Upper Atlantic Coastal Plain have distinctive acoustic signatures tied to regional unconformities,
- Present evidence that it might be possible to derive the amount of overburden, or missing sediments, above the unconformities, and if so,
- Suggest that the amount of missing sediment originally deposited in a sedimentary sequence (based on an understanding of the true chronostratigaphy), presumably deposited down dip can be estimated (important in geo-engineering and reservoir analyses).
- We will use OYO P-Sh Suspension Log data acquired in deep basement boreholes as our primary source.

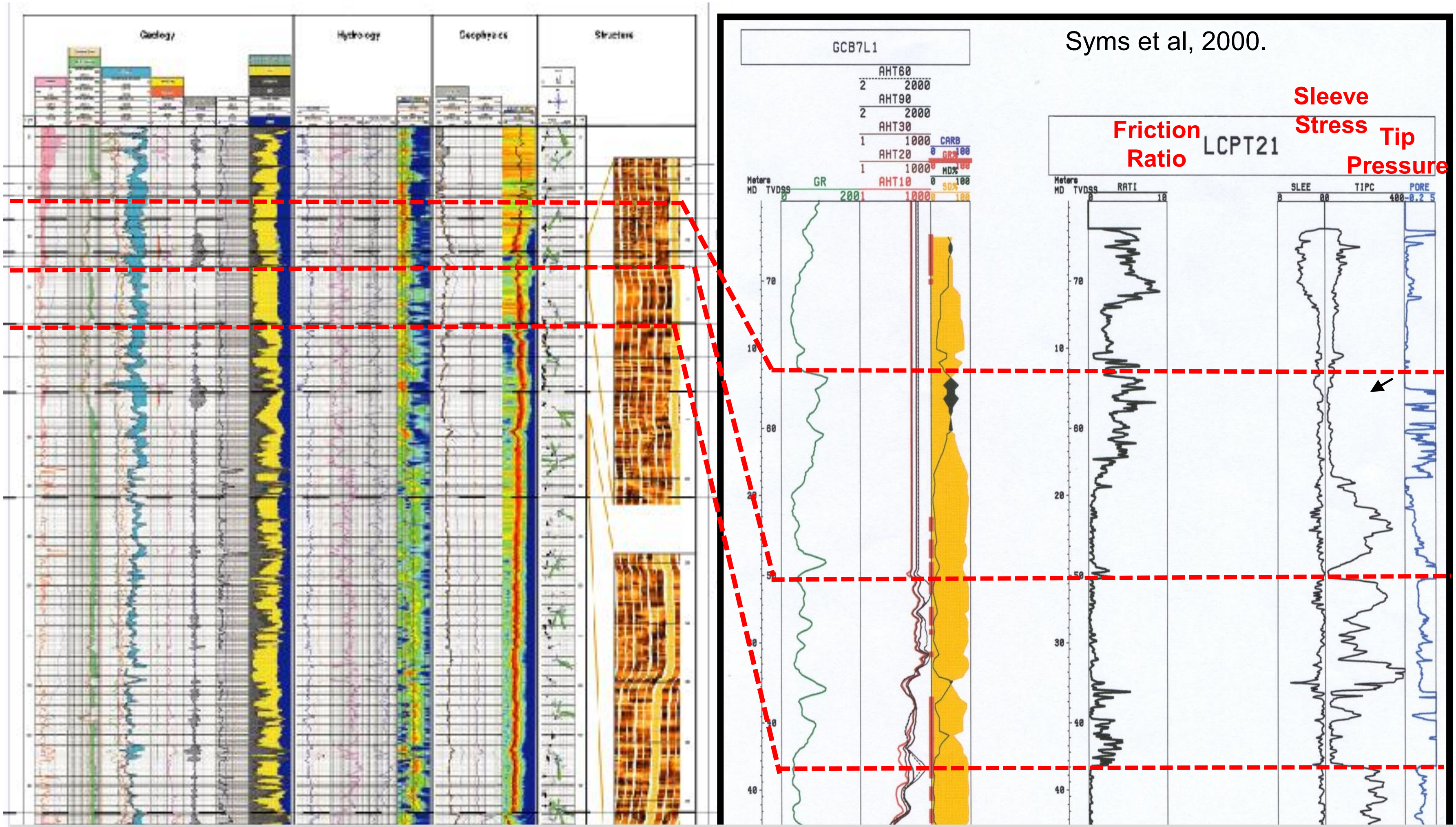
Background-Why

- Between approximately 1993 and 2002, geoscience researchers at the USDOE Savannah River Site conducted a well-funded, regional investigation of the SC/GA coastal plain. A database of more than 10,000 wells, borings, core holes (71 “basement” penetrations), direct push investigations; ~500 miles of surface seismic much of which was high resolution P&S data, 3D seismic surveys, OYO Suspension Log data, VSP surveys; approximately 2000 regional soil geochemical samples; VLF, TDEM, GPR, magnetic and gravimetric surveys; outcrop samples; palynology and biostrat; plus much more was created. These studies were completed primarily for siting new high hazard nuclear facilities (MFFF, PDCF, TEF, APT, etc.) and to support long term environmental stewardship.
- Numerous scientific and technical papers resulted from this work but mostly for internal DOE reports (gray literature) and occasionally classified. However, many observations made during the evaluation of these data were never published. This paper discusses one of the unpublished observations.

Background - Study Area



Typical Sediment Character

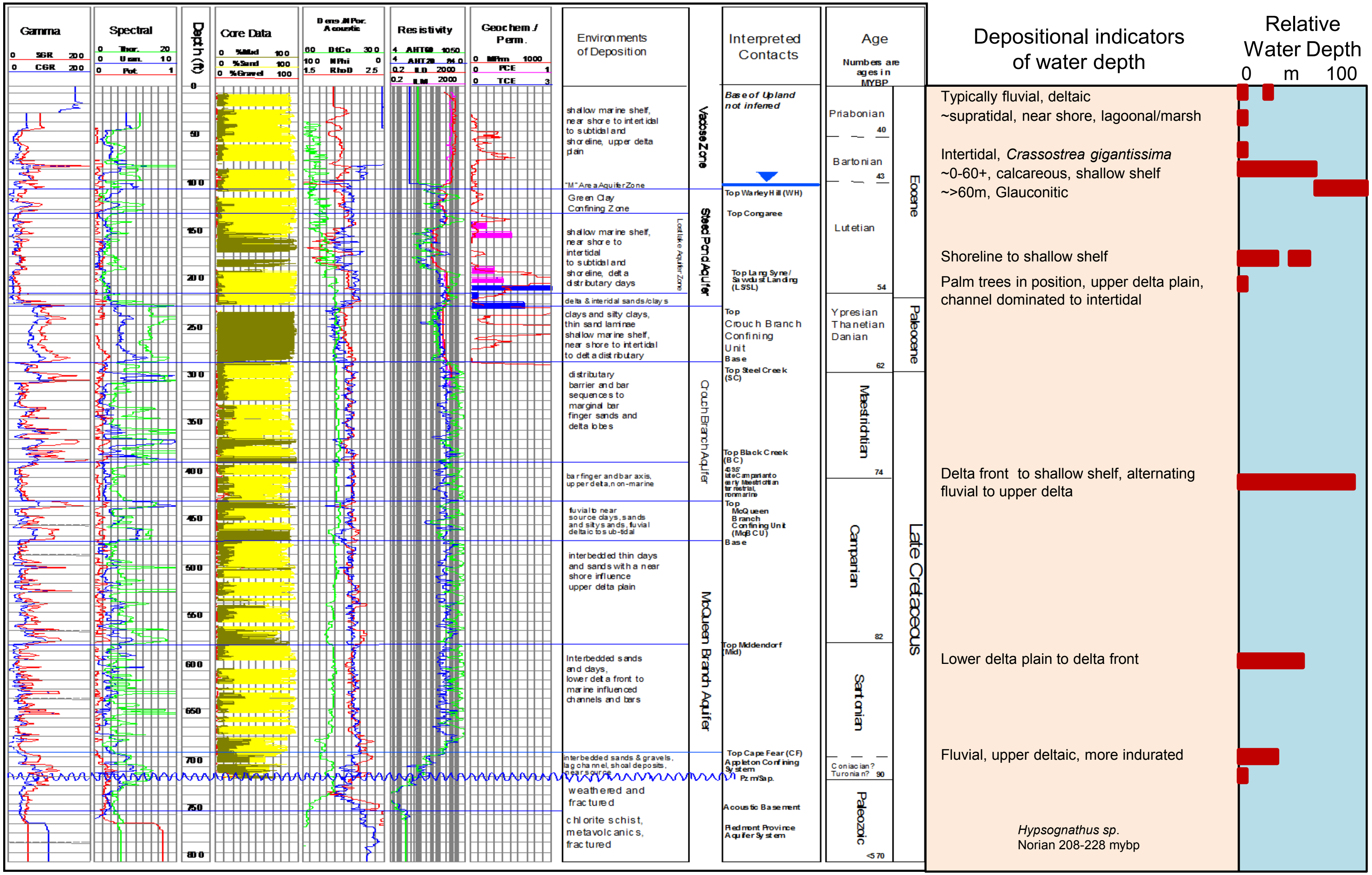


Advanced Geophysical Log to Standard Geophysical Log to CPT and Core.

Ten deep advanced geophysical borings with core were tied to seven deep wells with oil field type log suites and core plus another 28 deep hydrologic calibration wells with high quality logs and core all then tied with approximately 800 monitoring wells with standard gamma ray –resistivity logs, many with core, and approximately 1300 direct push CPT logs. Many CPT logs were co-located with borings and wells to help define a high-resolution shallow engineering profile. Typically we had a very high resolution stratigraphy and correlation capability in the upper 100 meters.

After Fallaw & Price, 1995; Aadland et al, 1995; Wyatt & Harris, 2000

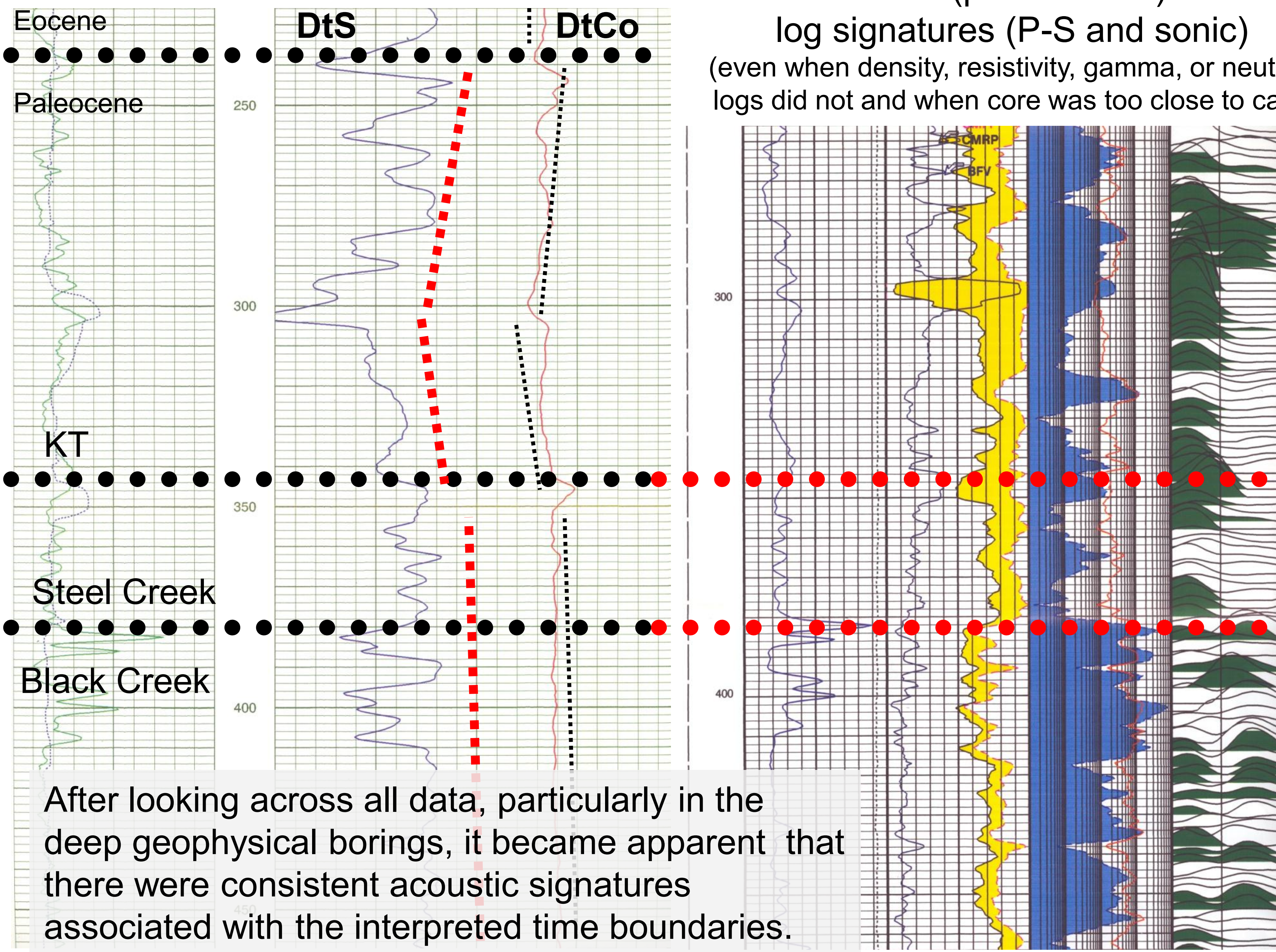
Deposition as an Indication of Overburden



Regional correlations and abundant core allowed us to develop a very good stratigraphy and depositional history tied to locally interpretable geophysical signatures. Using LandMark it was possible to visualize multiple logs, core and seismic data in one view to develop Chrono-, Litho-, and Hydro-stratigraphy.

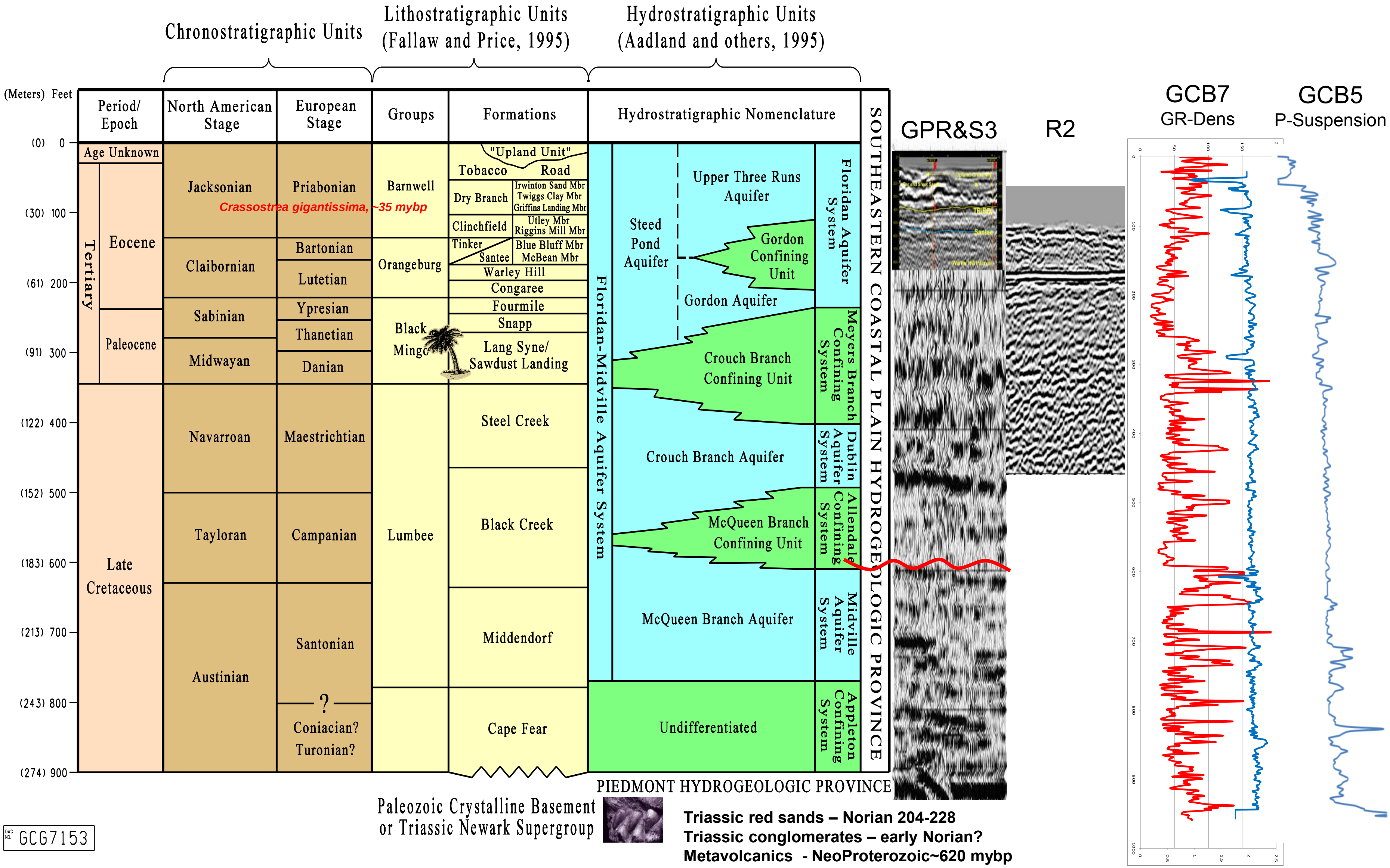
GCB-5.1

Most major lithostratigraphic boundaries had distinctive (predictable?) acoustic log signatures (P-S and sonic)
(even when density, resistivity, gamma, or neutron logs did not and when core was too close to call).



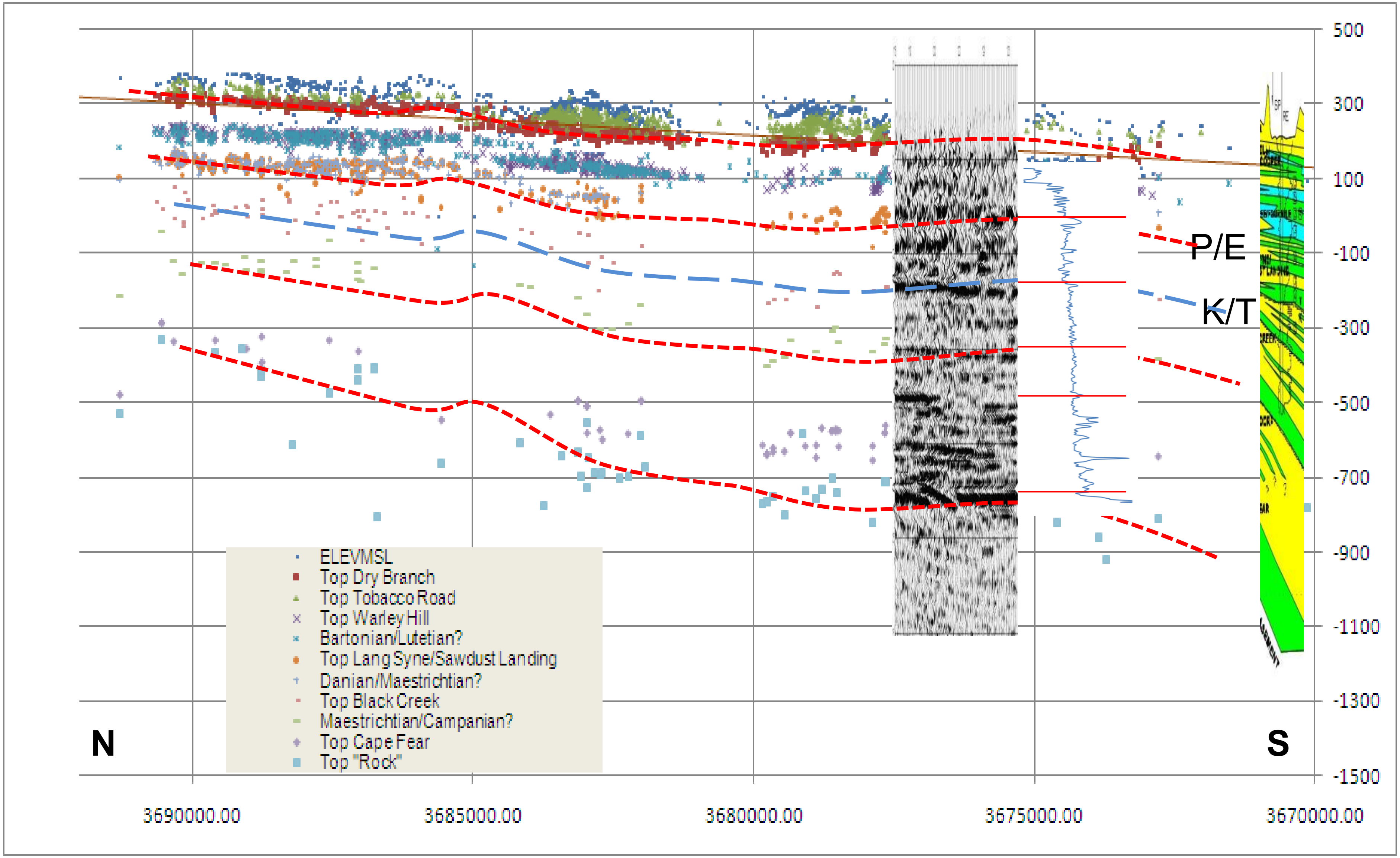
After looking across all data, particularly in the deep geophysical borings, it became apparent that there were consistent acoustic signatures associated with the interpreted time boundaries.

Comparison of Chronostratigraphic, Lithostratigraphic and Hydrostratigraphic Units with approximate seismic response. The sonic data typically had predictable signatures associated with all known major unconformities.



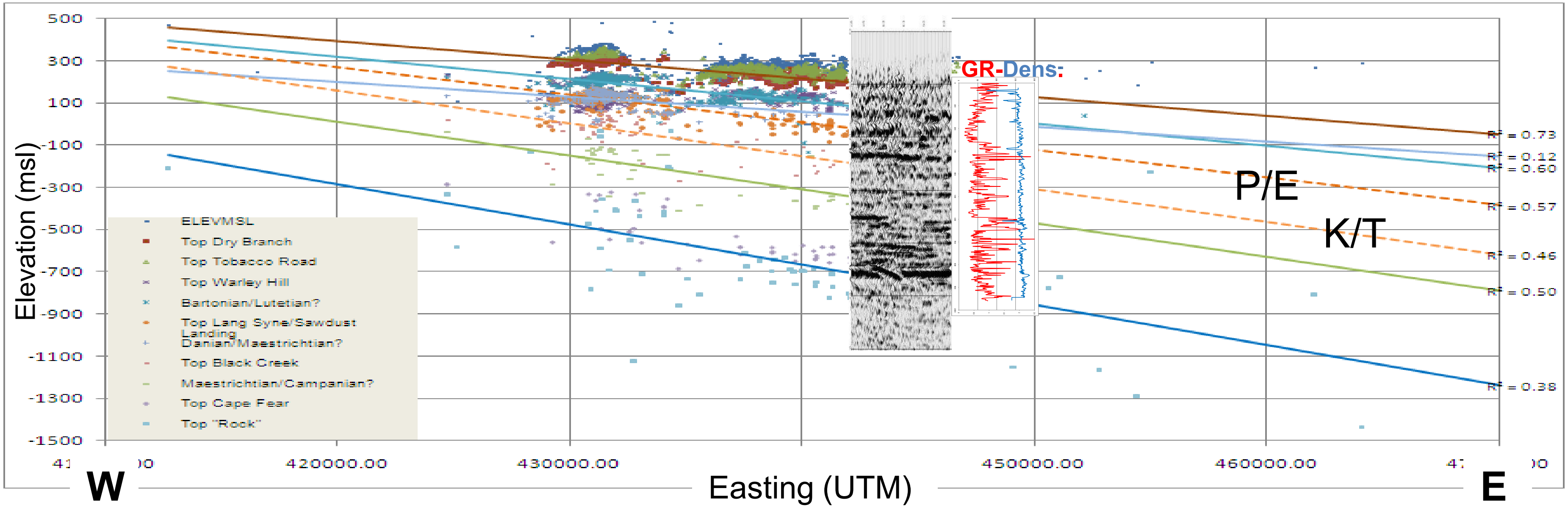
(Dysart et al, 1983; Aadland et al, 1995 (and embedded references); Aadland and Thayer, 2000; Wyatt et al, 2000)

We verified this by looking at acoustic log and seismic response across high data density areas. Agreement was generally excellent.

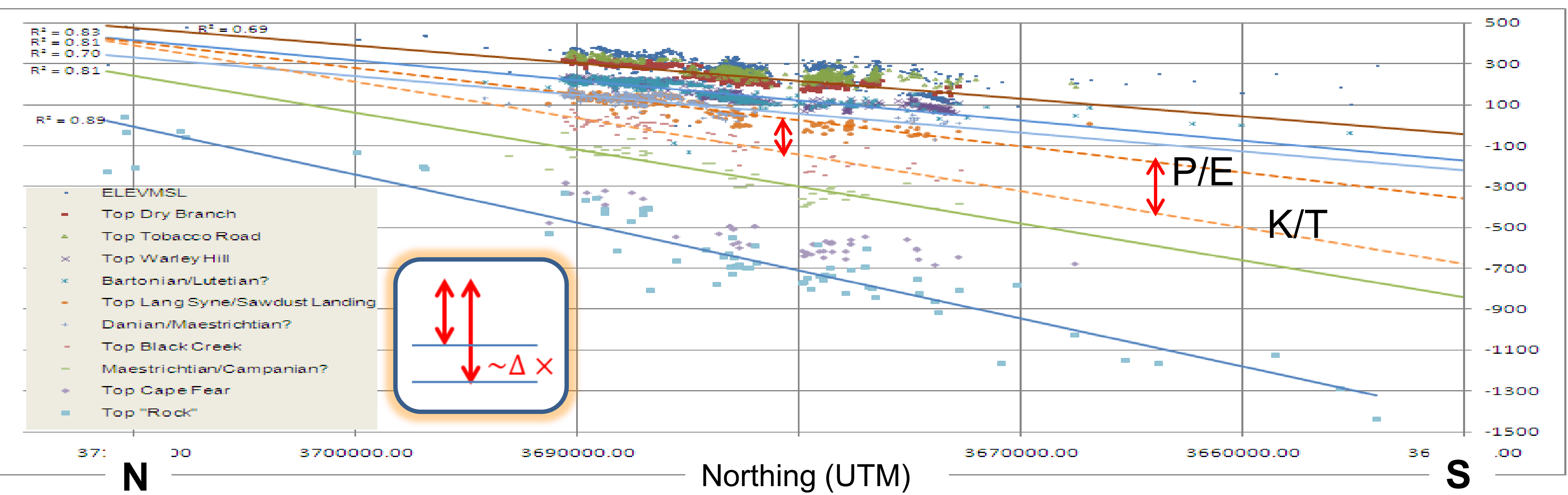


2,002 boreholes & CPT's, 3,936 tops

We then expanded to include data from a larger regional - conceptual perspective.

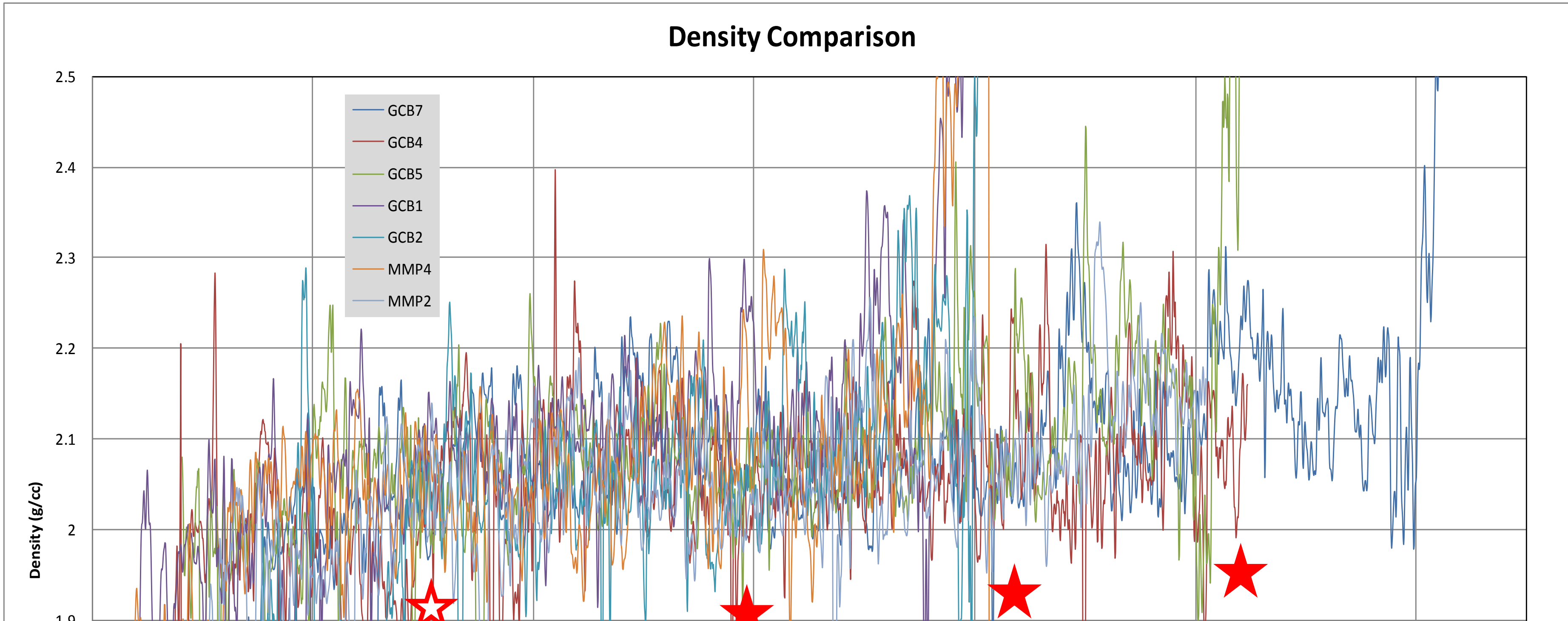


Could we predict how much sediment should be further downdip as shown by thickness based on the calculated historic overburden?

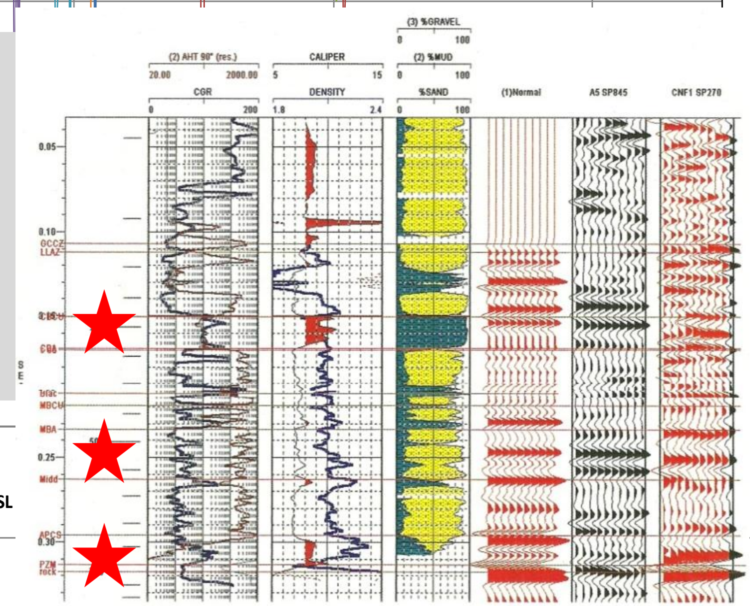


Working Assumptions

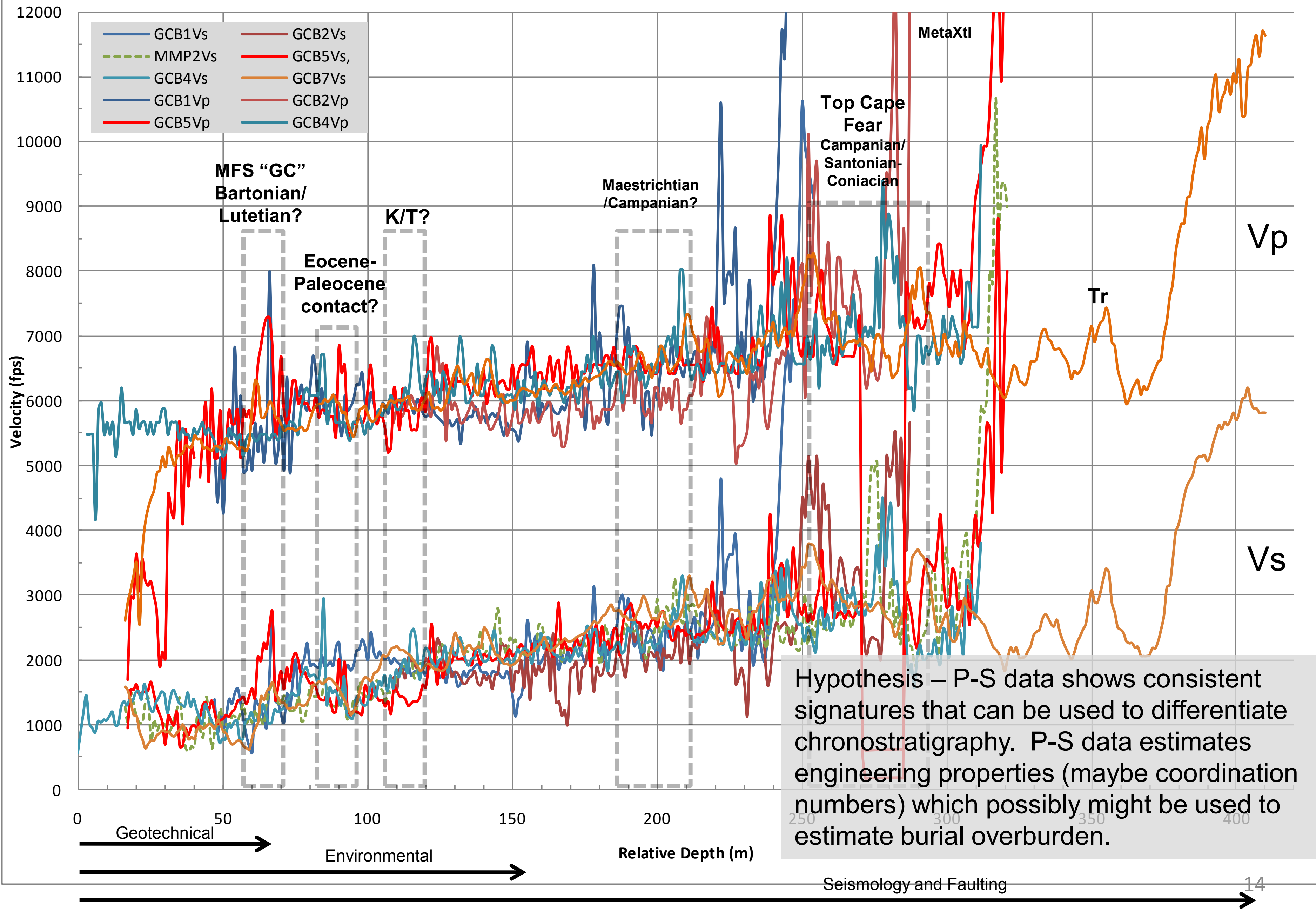
- The correlated sonic and seismic data are indicating both lithostratigraphy and the major regional unconformities. These constrain the regional chronostratigraphy.
- The sonic data are tightly correlated with stratigraphy.
- Engineering stratigraphy typically corresponds with lithostratigraphy but not always; hydrostratigraphy typically corresponds to lithostratigraphy but not always; chronostratigraphy typically corresponds with lithostratigraphic breaks that indicate the regional unconformities (almost always).
- Sediments are in equilibrium, i.e. not over or under consolidated, and that modern lithostatic pressures are normal, i.e. rocks are fully saturated and have similar porosities.
- Gravity and normal burial are prime preconsolidation factors (…i.e., no glaciers or other surface loading) however some diagenetic alterations have occurred particularly in shallower horizons, with various effects, AND that deposition proceeds to least comprehensive energy (zero overburden).
- Depositional variation and diagenesis form primary distinguishing features for much of the lithostratigraphy, especially in the Cretaceous, however, there are possible geomechanical variations between time packages that are indicated by acoustic (sonic) data.
- **Acoustic log responds to compaction > deposition > diagenesis.**



Synthetic seismic calculations from density logs and/or wireline sonic typically only gave us 3-4 ‘consistent’ seismic horizons. In general, density was useful but demonstrated much less character than sonic data, i.e. less modeled “kick”.

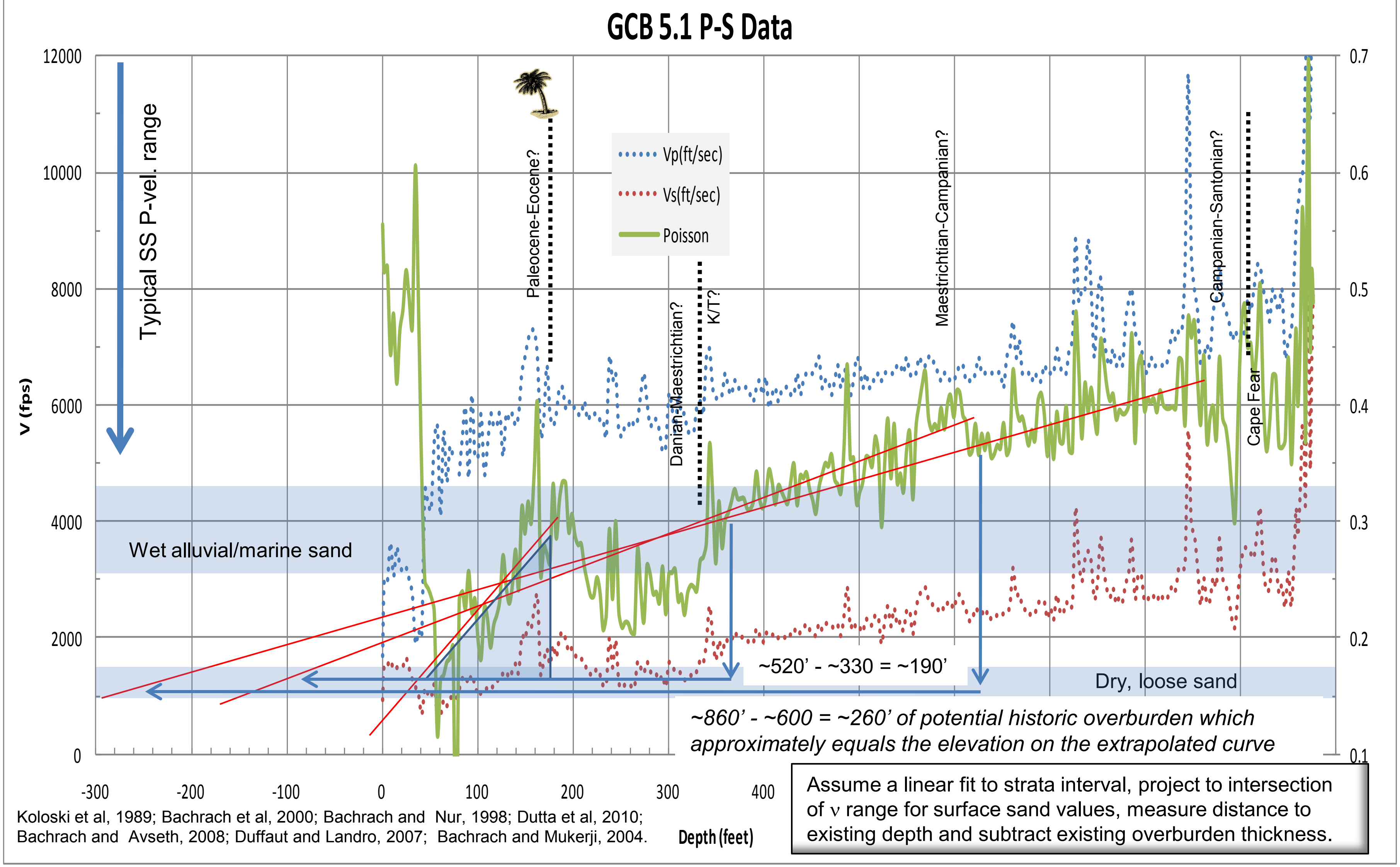


Suspension Data



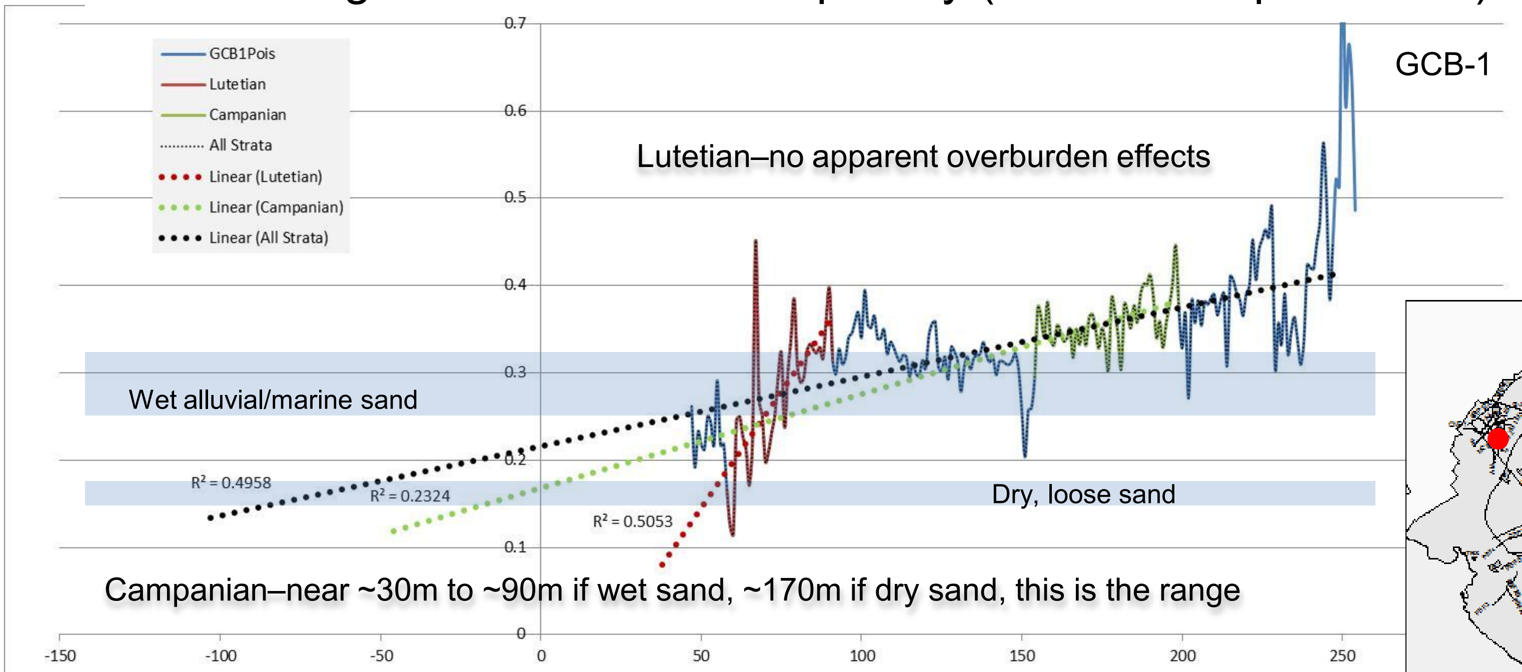
Hypothesis – P-S data shows consistent signatures that can be used to differentiate chronostratigraphy. P-S data estimates engineering properties (maybe coordination numbers) which possibly might be used to estimate burial overburden.

Testing The Theory using Poisson's, ν

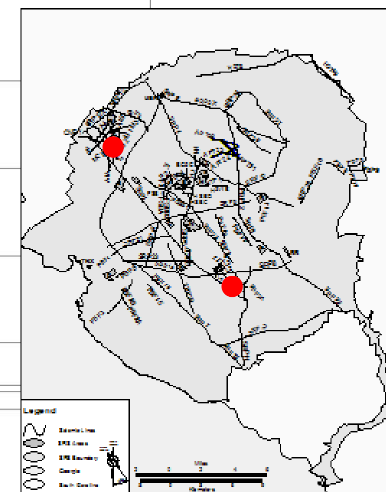


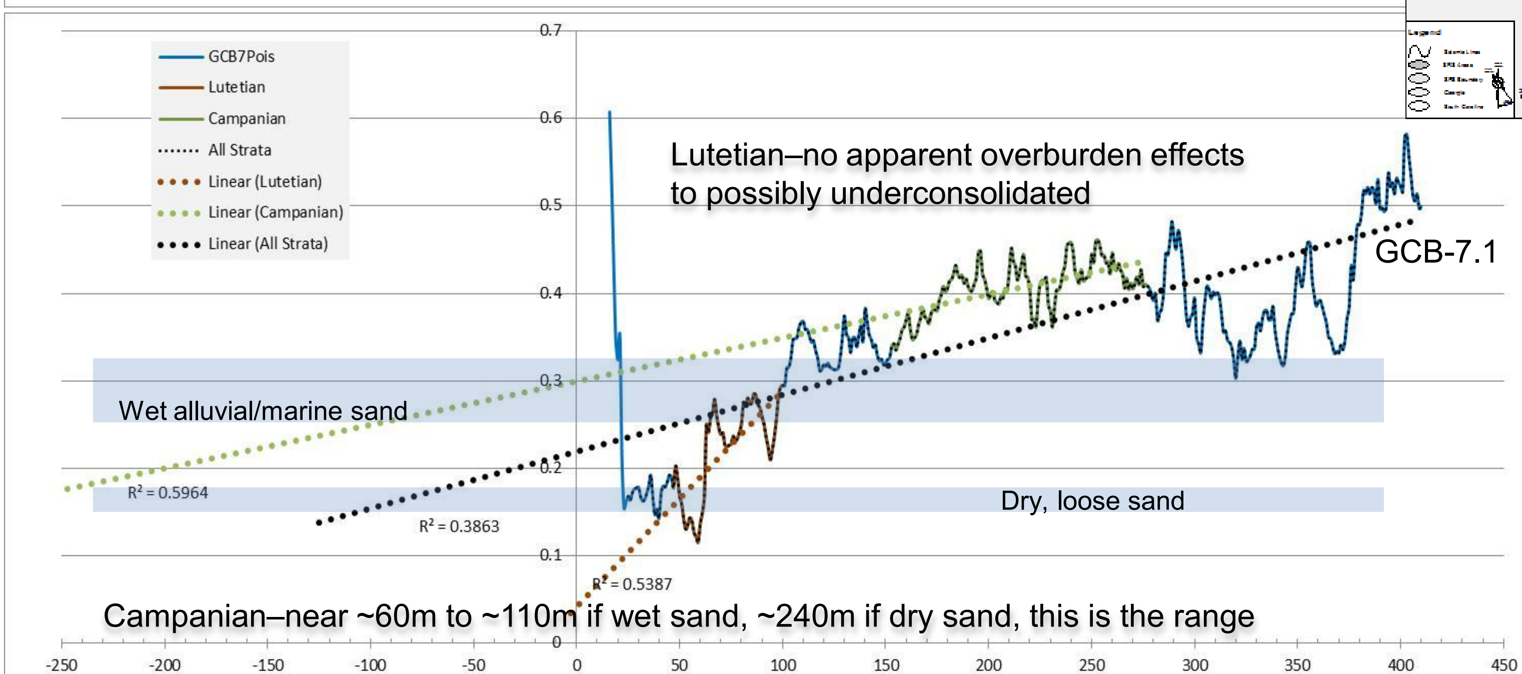
If using the assumption that deposition proceeds to least compressive energy (zero overburden), and using typical P-S and ν values for unconsolidated surficial sands, and extrapolating a "normal" increasing-with-depth acoustic signature to its ultimate unconsolidated value, and allowing for current burial status, then historic overburden thickness might be derived.

Initial testing to see if this works spatially (and if it is reproducible).

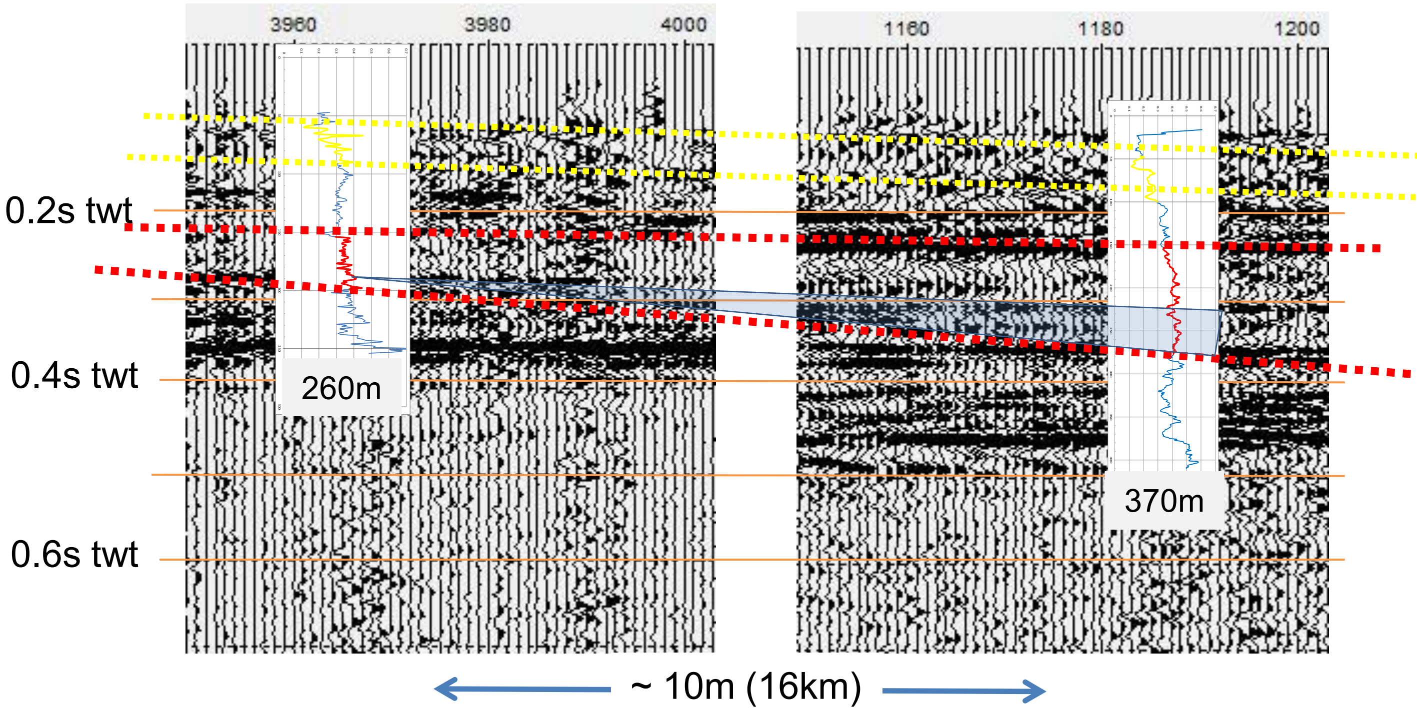


Note: depth variance



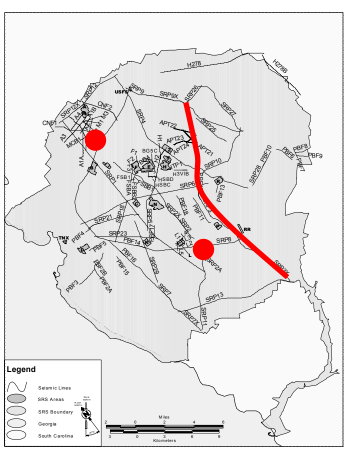


Continued testing to see if this works spatially (and is reproducible with respect to the seismic, an error check). Two seismic sections, same line, one updip, one downdip.



In the Campanian we seem to pick up about 0.05 sec of additional sediment (0.05s twt x ~6100AvgVfps = ~150 ft (45m). From the previous slide the updip data suggested a possible overburden range of ~30m to ~90m for a wet sand, and up to ~170m if a dry sand. The downdip location suggested ~60m to ~110m if a wet sand and ~240m if dry sand. Not very refined but is it reasonable?

Trying to compare to possible denudation/erosion rates suggested too wide a variation for comparison (Gullily, 1964; Stanford et al, 2002, Matmon et al, 2003).



Conclusions & Future Work

- We believe the P-S data provide very good indications of chronostratigraphy, sediment packages between major coastal plain unconformities, generally equivalent to Stages.
- If our assumptions are valid, and this process works, then it seems possible to project a Poisson's value for a Stage to a zero overburden, uncompressed value. This projection may indicate a range of original overburden, now eroded and deposited down dip. This is important for understanding geo-engineering, for potential reservoir analyses, and could be a possible mapping and evaluation tool/process.

- Much future work needs to be done including:
  - Additional research into the efficacy of using P-S data (or other sonic data) for historic overburden, depth of burial, studies
  - Evaluating better models for extrapolation & refining estimates, i.e. linear versus log or power extrapolations
  - Extrapolated values need to be vetted against seismic data and high-quality deep coastal borings
  - Can Stages be further subdivided for burial history?

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