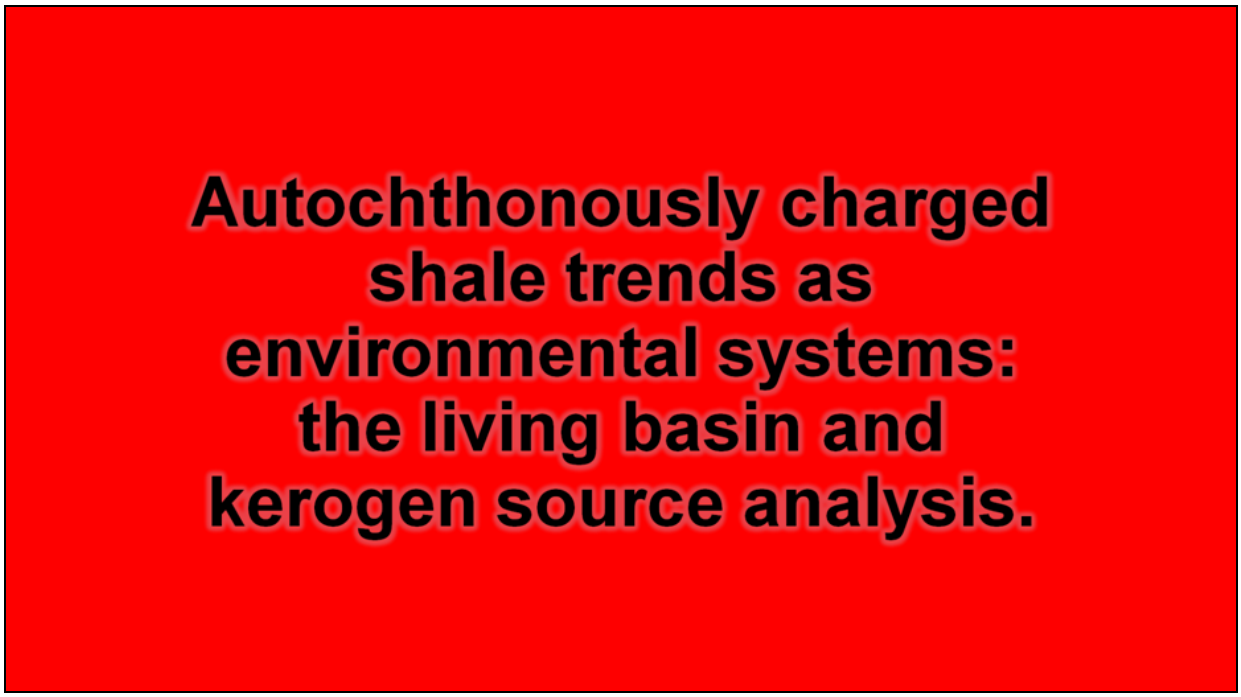
Slide 1



This slide show and talk was originally presented at the CCGS Luncheon for December 10, 2014.

As it states above, this is meant to apply to autochthonously charged resource basins and their carbon or kerogen sources only. Strictly speaking, this is an anecdotal thesis and not a completed systematic study, although it appears consistent with the facts gleaned from multiple smaller studies.

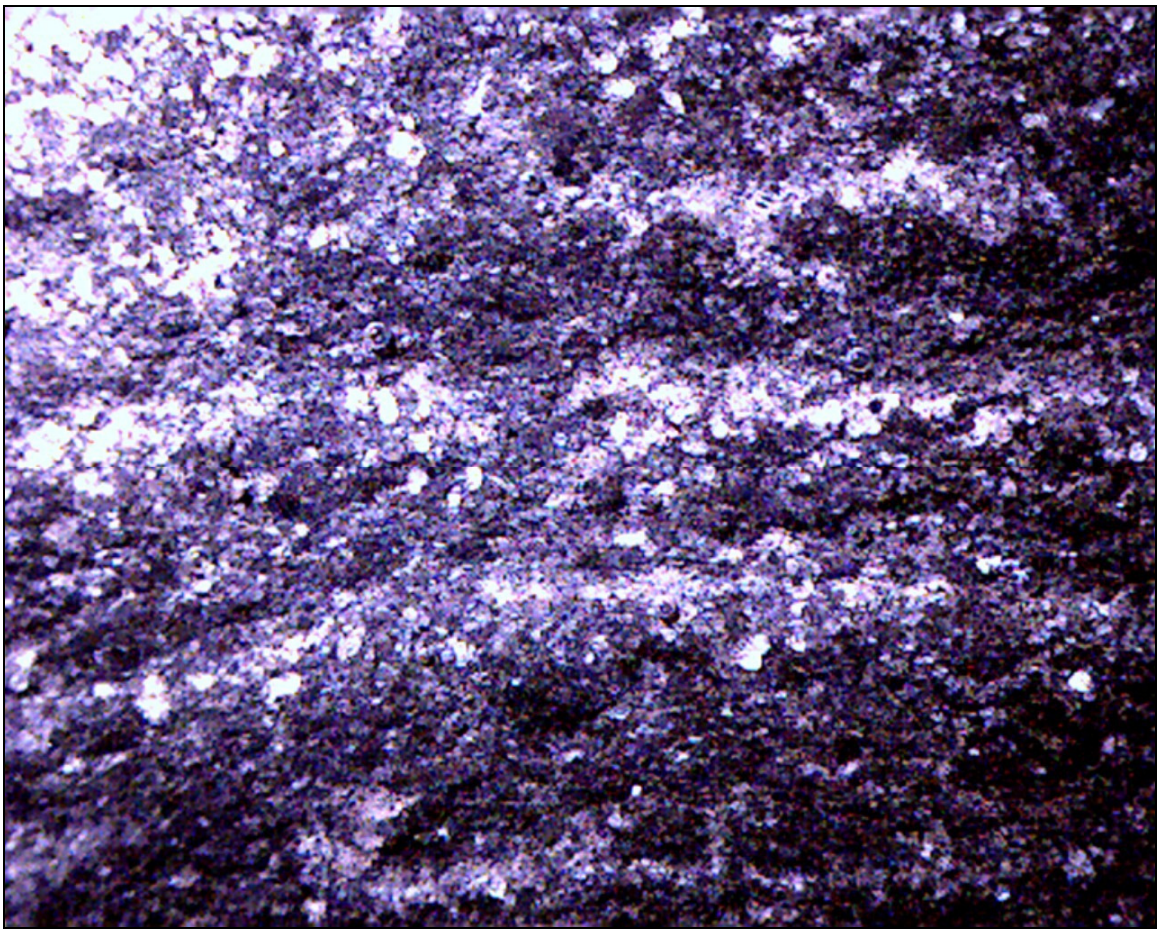
Many of the images or slides were borrowed from websites, references are supplied. I claim no copyright except where noted and usually bearing the heading of my company PaleoSource.

Slide 2

Source: www2.ohiodnr.com

This pictures an outcrop of the Marcellus Shale. Even at this resolution one can see a dominant feature of the Marcellus: extremely fine lamination on a millimeter by millimeter scale of graded beds. Even in thin section, the alternation of high and low energy deposition is apparent .

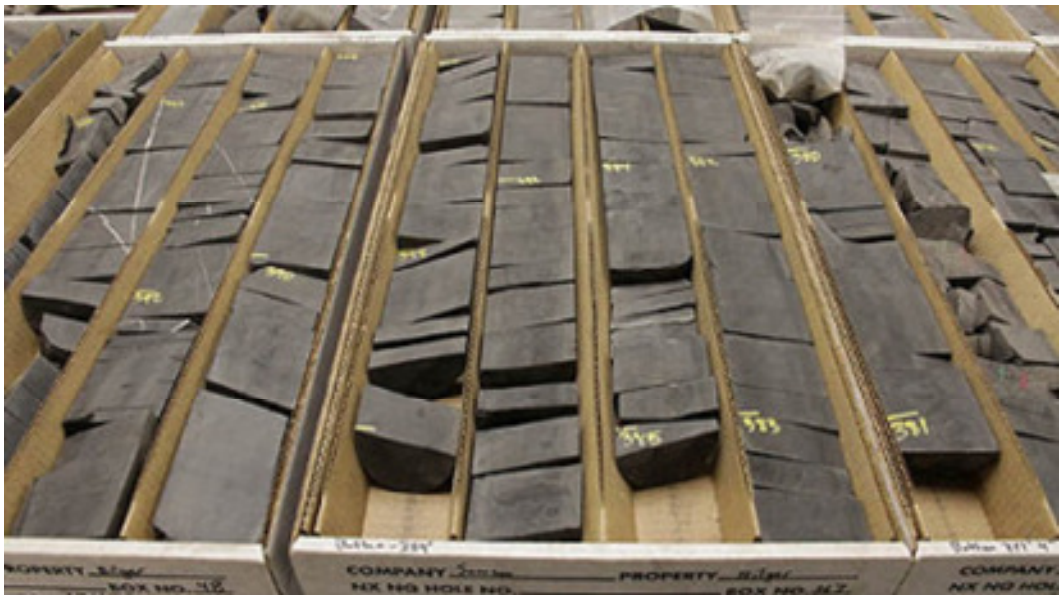
Slide 3



This is a stereoscopic view of a hand sample from the Lower Eagleford Formation. The dark bands are illitizing smectite clays in a calcite matrix and the finer, white bands are the recrystallized tests of planktonic foraminifera. This **microlamination** is an alternation of higher depositional energy from a terrigenous source with lower energy depositional bands from the water column. This was originally taken at 8x.

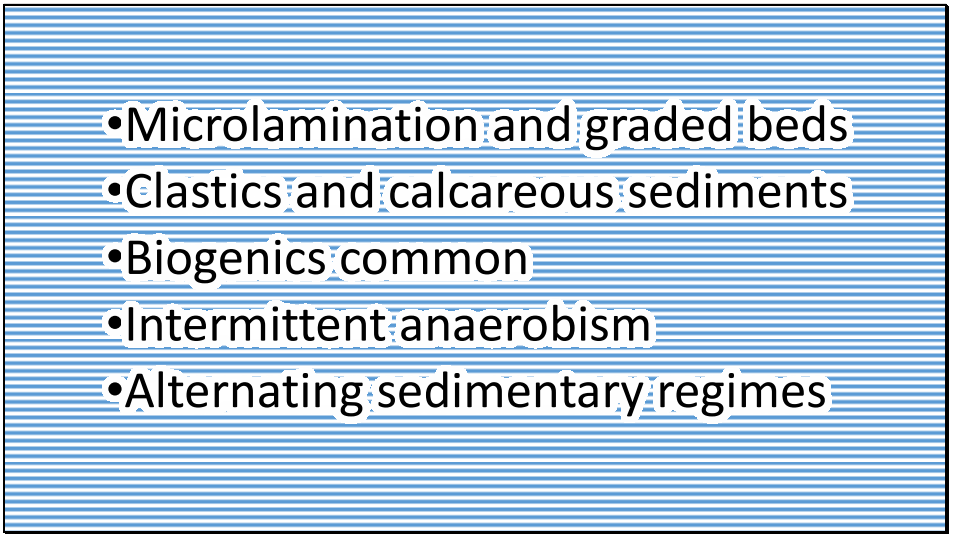
Slide 4

Source: www.post-gazette.com



This borrowed slide of the Marcellus Formation simply represents the scale at which we commonly view the microlamination that is found in all of the shale plays that I've studied so far. The lithology is often variable between predominantly calcite with shale, as in the Eagle Ford Fm, to fine clastics, as in the Marcellus Fm. The question arises as to the cause of this consistent character regardless of sediment source.

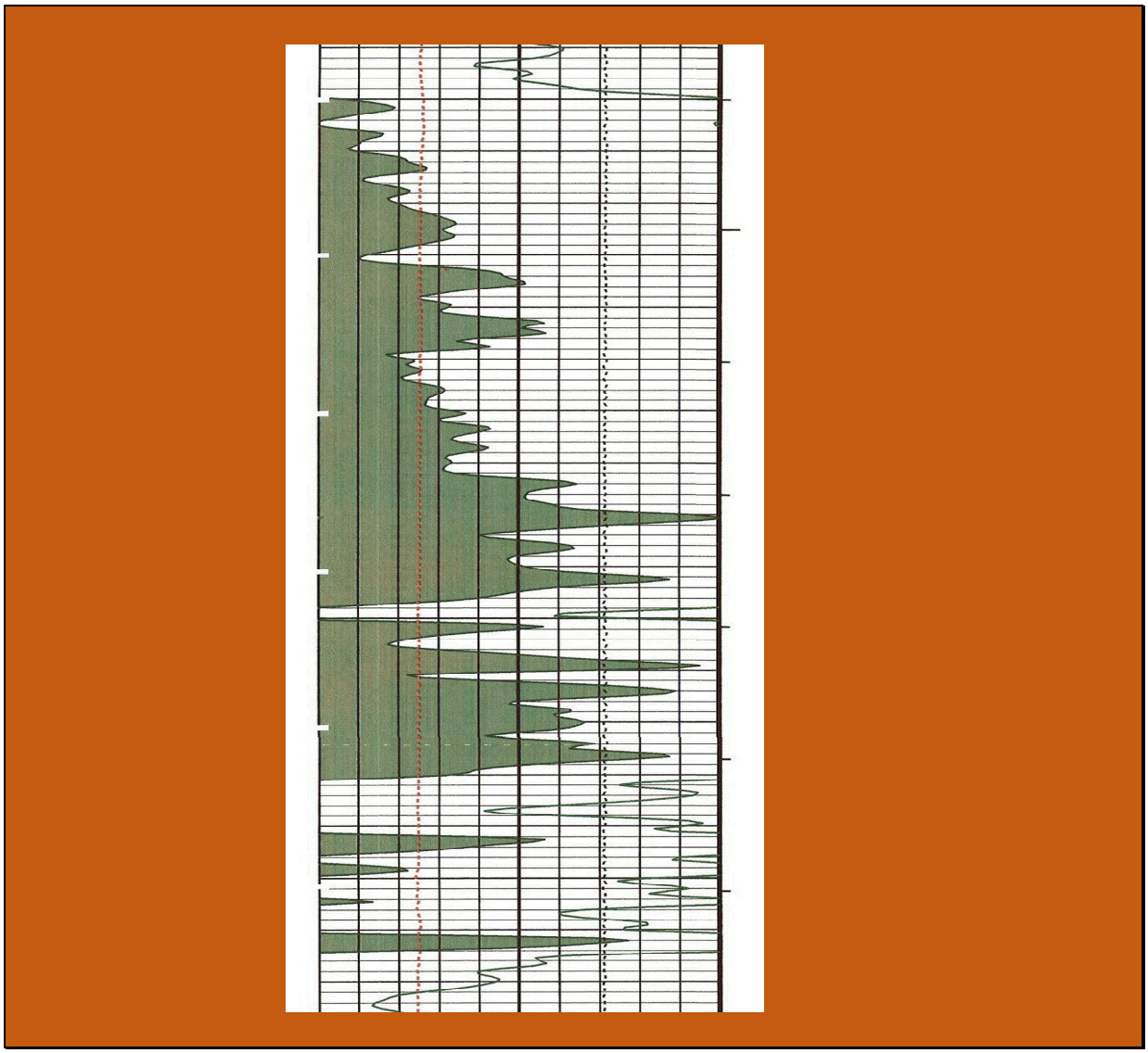
Slide 5



The observations:

1. Microlamination is common or universal to autochthonously charged formations whether characterized as shale plays, resource plays or source rocks.
2. This presence of calcite or other carbonates or clastics provides a seal or sealing matrix and makes the formation a candidate for fracking.
3. Biogenics, predominantly from terrigenous or near-shore sources abound in the form of molluscs or other bivalve invertebrates, echinoderms, plant remains, ostracods and other sources, abound in working shale plays.
4. Dark shales are often characterized as intermittent periods of anaerobism, often in direct contact with extremely aerobic fauna (note the Eagle Ford sample above). Even these "anaerobic laminae" may contain fauna of typically aerobic sources.
5. Lastly, there is a clear alternation in the energy regimes represented in the **microlaminae** of shale plays/resource plays.

Slide 6



The way we most frequently encounter the microlamination of shale/resource plays is in the pattern of gamma ray character as pictured here. As a matter of note, spectral gamma ray logs are preferred for basin analysis. The provenance of clastics provides a clearer picture of the source and, as you will see, of the expectations of product to be harvested from that basin.

Slide 7

Source: science.kennesaw.edu

The borrowed picture of this fresh to brackish water marsh/swamp/wetlands is my proposed answer to the source of all the above observations. All of the characters listed on summary slide ten (10) are attributable to the succession of rain forest/wetlands and freshwater marsh to brackish and saline swamps along the marine coastline.

Slide 8

Source: wikipedia.org/wiki/florida_mangroves

Coastal swamps and wetlands are the most productive biological systems on Earth and the most effective carbon sequestration system, as well. They slow the progression of clastic sediments to the basins they surround, allowing for biotic processes that degrade organic matter (kerogen), providing an aerobic/anaerobic chemical cauldron prior to delivery via riverine “flushing” to the final basinal destination (microlamination and alternating sedimentary energy).

Slide 9

Source: freshwater_marshes_usgov *or* www.ebabylone.com

The period of slowing or sequestration of sediments in the complex communities expose clays (shales) to long chain organic molecules that predetermine the final product options (kerogen type) available within a basin. Bonding that occurs between shale and organics also determines the nature of kerogen distribution to the basin and within the strata.

Slide 10

Marsh Effects

- Retention/ sequestration of clastic sediments
- Source of primary energy "fixing" – synthesis
- Ecosystem/ community for converting energy to complex organics – metasynthesis
- Central site of anaerobic environments

The first and second lines are issues addressed. Let's discuss the basis of the kerogen machine and the issues of intermittent anoxia.

Slide 11

Source: freshwatertuttle.wikispaces.com

A number of the biological components that produce high quality (Type 2 and 1) kerogens are concentrated and synthesized around coastal marshes. Even planktonic flora (basically bacteria) and faunas are concentrated around areas with dense concentrations of nutrients. In a typical large basin, floating algae are concentrated around the basin margins where nutrient access is greatest (and wind current distribution helps here, too). Algae and anchoring vascular plants, photosynthesis and bacterial degradation are only part of the burgeoning kerogen producing community.

Slide 12

Source: la.water.usgs.gov

Swamps and wetlands are complex and internally diverse systems, harboring oxidizing and anaerobic environments simultaneously with and great amount of interdependence. Photosynthetic products (including lignin or humic material) provide not only fuel for bacterial degradation, but constitute a base for a complex food chain that often supports the whole of a basinal ecosystem and determines its fossil kerogen.

Slide 13

Source: saltmarshlife.com

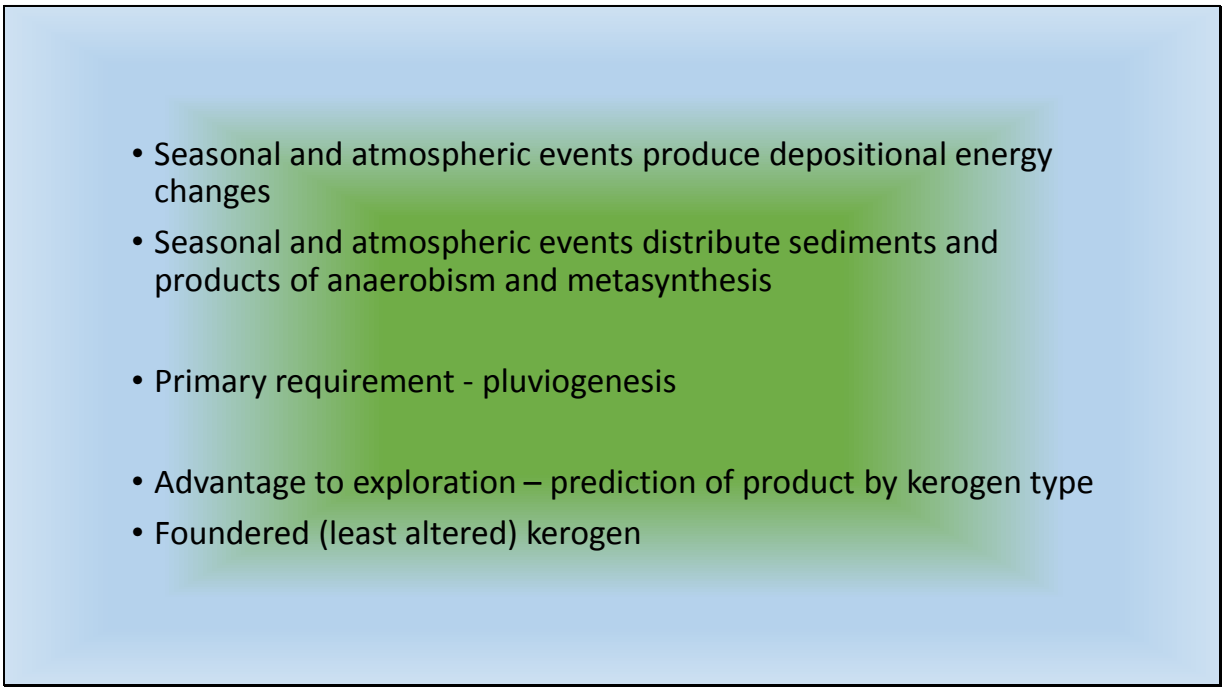
Forming complex, energy rich macromolecules, such as fat and protein, has a lot assistance. Thousands of extant species of molluscs, arthropods, protozoans and fungi and algae and so on contribute to the organic soup of wetland systems and the resultant kerogen. All of these species potentially feed into components of the fossil record, both directly and indirectly.

Slide 14

Source: merrylea.goshen.edu

Most of the anaerobic or anoxic shale laminae found in the basin are not necessarily *in situ*, but are formed along basin margins in the swamps that harbor the organics and associated shales. The anaerobic products here, often electrostatically bound to shales, are delivered fully cooked to their final resting place. The occurrence, volume and quality of the anoxic products here can be readily confirmed by donning waders. When you step into anoxia, you'll know it.

Slide 15

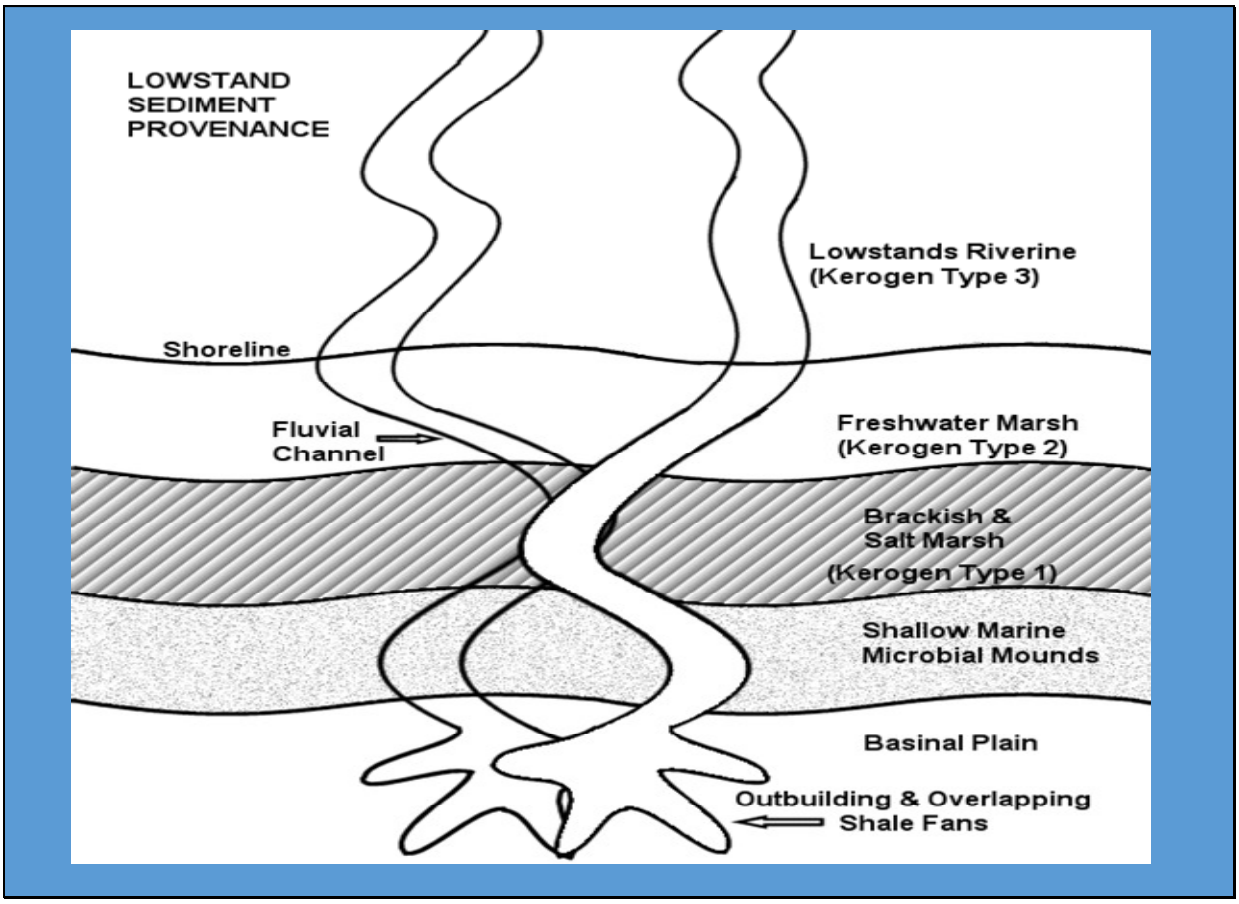


Seasonal and atmospheric events provide the means to flush clastics and organics from the swamps where they have rested and formed; these events being rainy seasons, flooding, storms and tidal currents. The seasonal or intermittent nature of such events is reflected by the microlamination , graded beds and energy and source alternation reflected in shale play deposition.

It should be well in evidence that the primary factor without which all others are moot is rain. A freely moving and energetic hydrologic cycle is the best single indicator of potential for the formation of a shale play. Rain formation or **pluviogenesis** is critical, whether locally or globally, to shale/resource play formation. This leaves us, again, with paleontologic and additionally isotopic records pointing the manner and quality of kerogen formation.

This is the essential payoff to understanding these wetlands systems for the explorationist – an abundance of clues to the specifics of source, kerogen quality (type) and best distribution models; a predictive method of product and location.

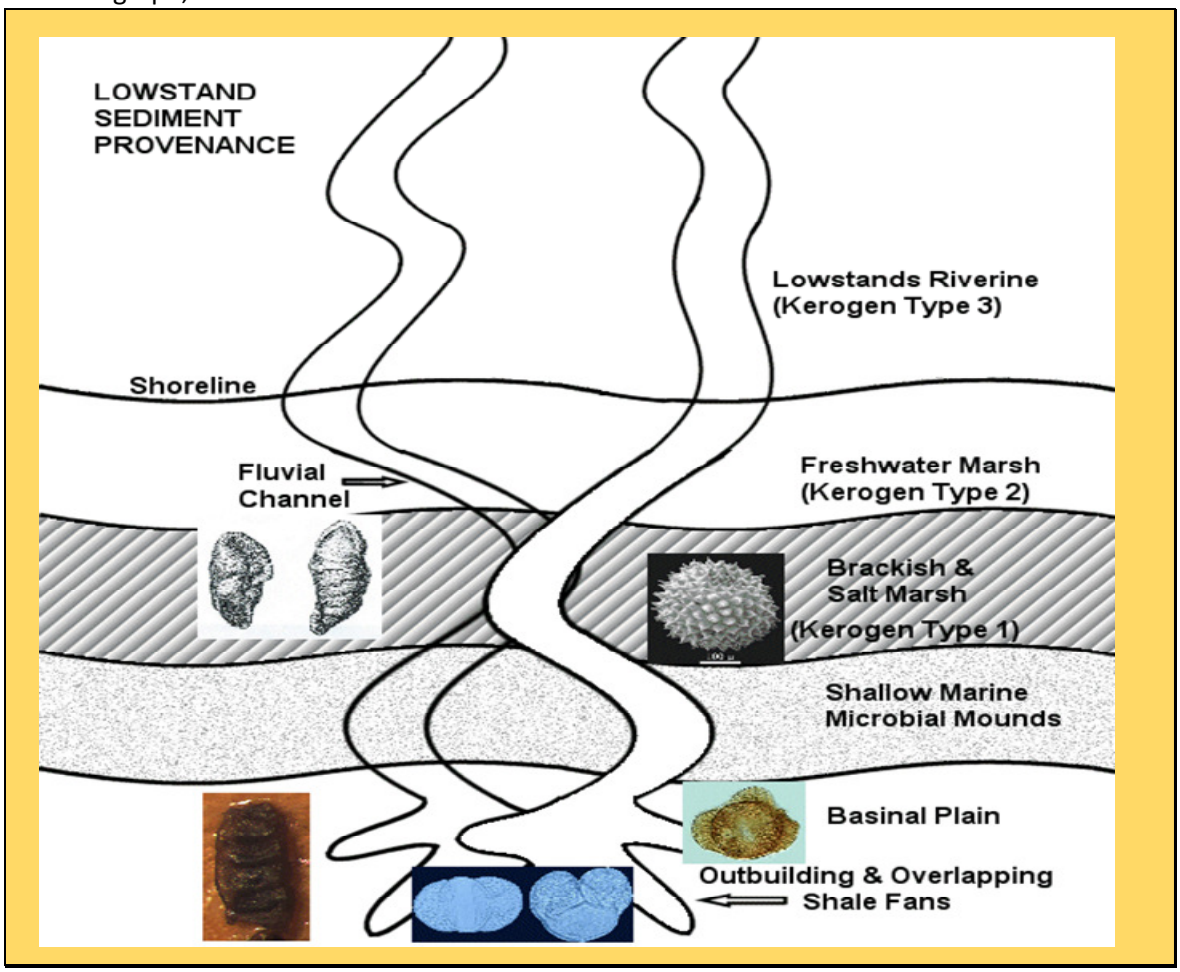
Slide 16



A typical lowstand sediment distribution model, highly generalized. The kerogen types most directly associated with the given biologic zone are listed. The first and foremost aspect of relative lowstand depositional systems is the tendency to minimize broad distribution of sediments from the transitional brackish and saline swamps, favoring a basinward movement and dominance of type 3 and, somewhat less, type 2 via channel and debris flows (outbuilding). This is typical of such plays as the Pearsall Group, associated with a long term relative low period in sea level. This typically yields gas with liquids. Some debris flows yield more limited source results, such as the Fayetteville, which produces only dry gas from humic sources of lowland plants.

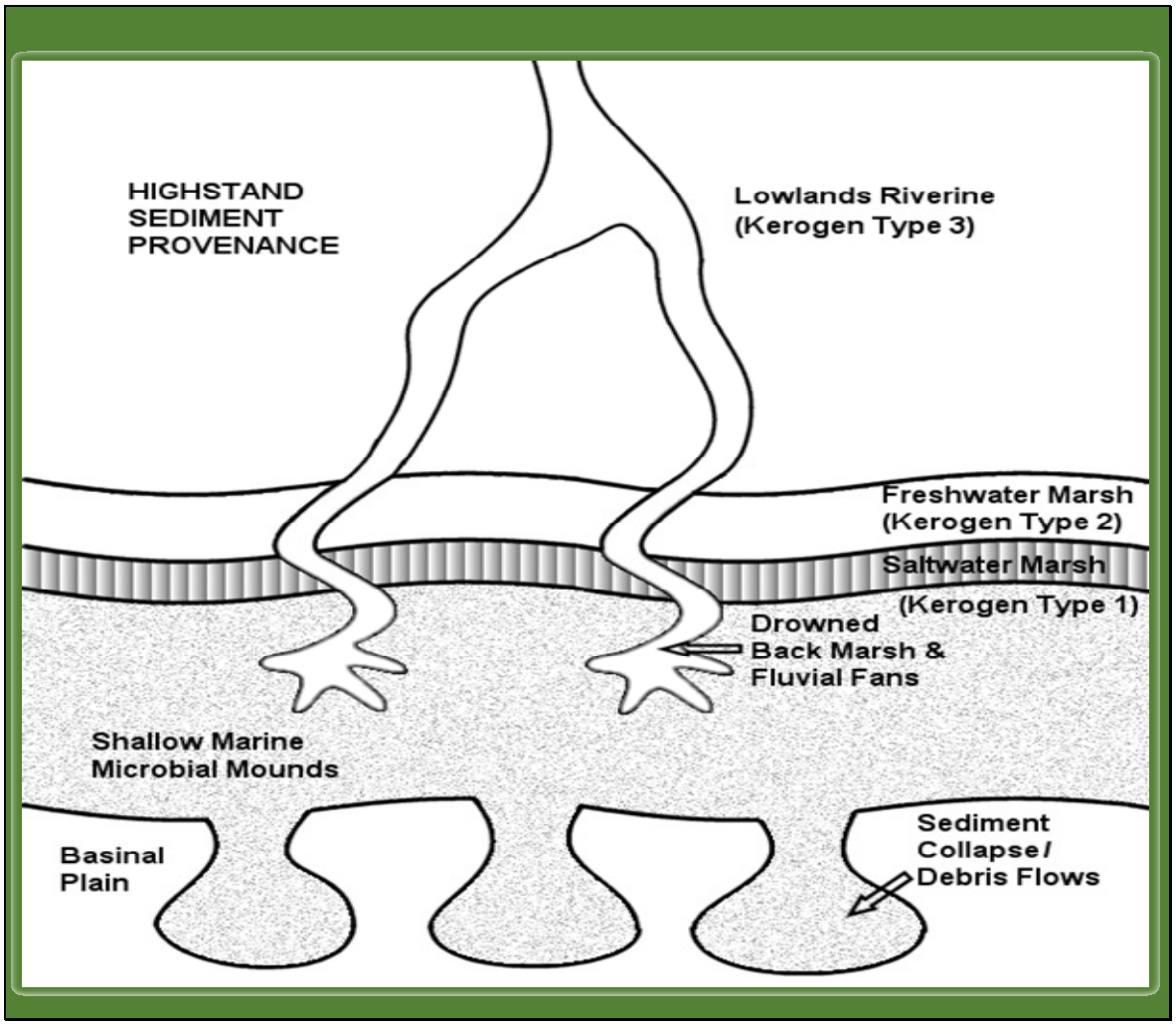
Slide 17

Sources: Starting in upper left, going clockwise -
H.B. Brady 1876 "Monograph of Carboniferouse and Permian Foraminifera" London Paleontographical Society 167 p. Plate VIII. --- Schaechter.asmblog.orgb --- www,sciteclibrary.ru --- imgarcade.com --- foram micrograph, no reference.



The lowstand depositional system is reflected by fossils, both faunal and floral. The pictures are examples the dominance of both in situ species, within their environments of origin (upper boxes) and reworked species (lower boxes) riding channel currents/ sediments. The distribution and dominance patterns of these **thanatocoenoses** (death assemblages) are clues to sediment/kerogen origins and the direction from which it comes, leading to predictive method for finding its maximum accumulation (sweetspot) and the product to be found (oil, gas, condensate).

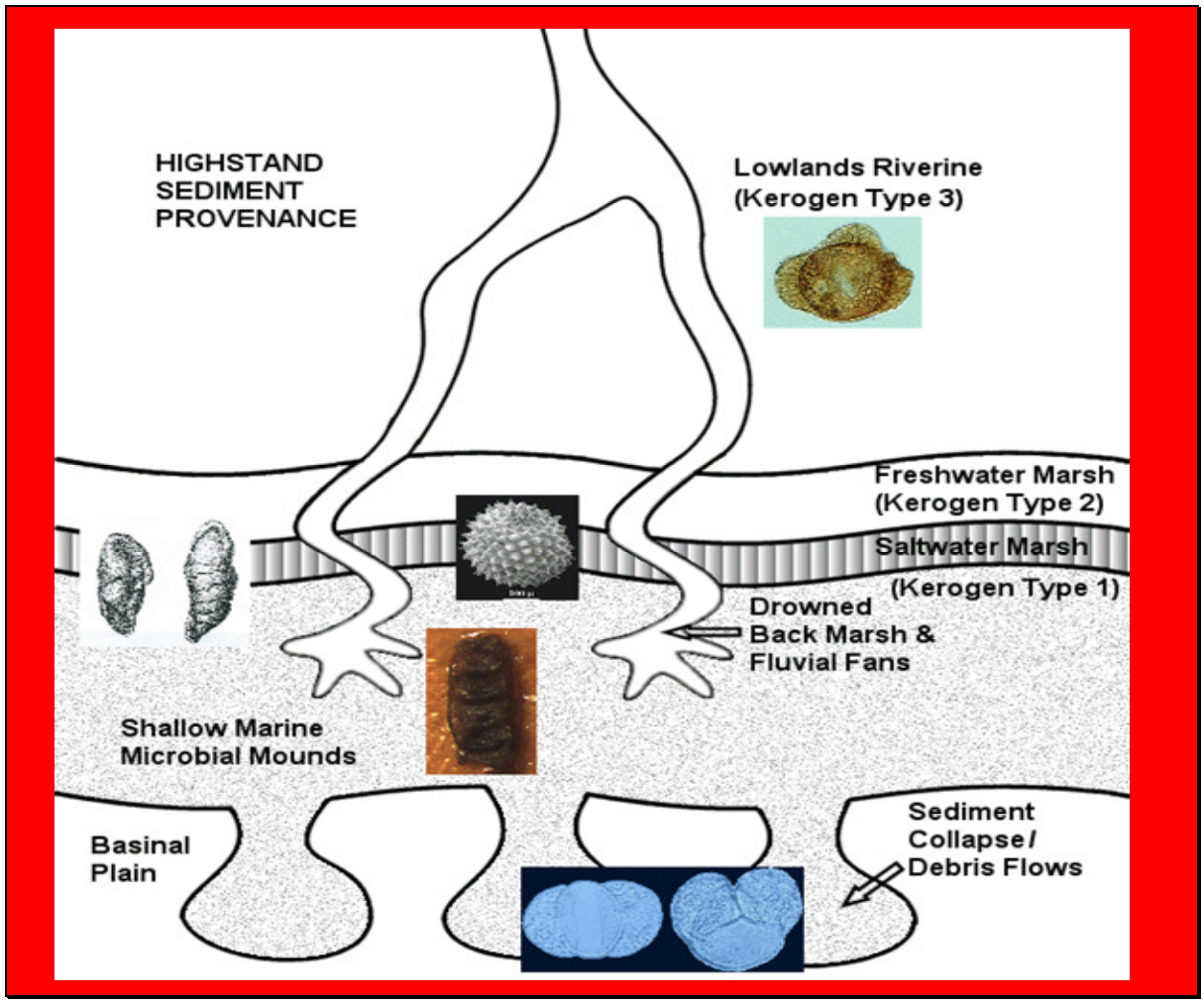
Slide 18



The highly generalized highstand depositional system: Channel accumulations are “drowned” back to backstepping progressions, foundering wetland and swamp sediments. Secondary distribution by mass slides and microlaminated debris flows become a prominent basin deposit.

Slide 19

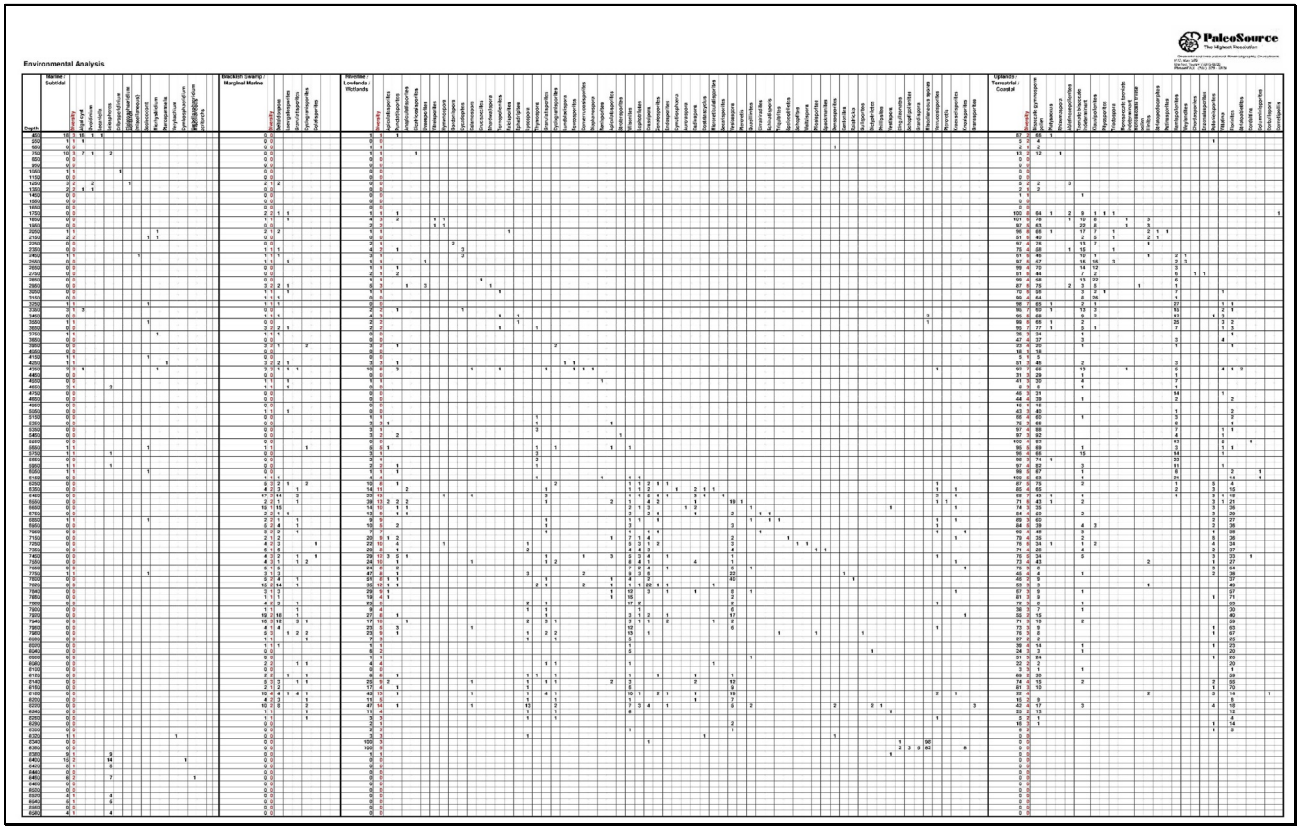
Sources: Same as Slide 17



Foundered wetlands/swamp sediments during highstand deposition form thick microlaminated sequences of seasonal deposition containing rich type 1 and type 2 kerogen concentrations which may be secondarily moved basinward by collapse systems (mass wasting) and less often by liquefaction and gravity flows. Some components of humic kerogen are still winnowed into deep basinal environments by having very low density and remaining durably in suspension.

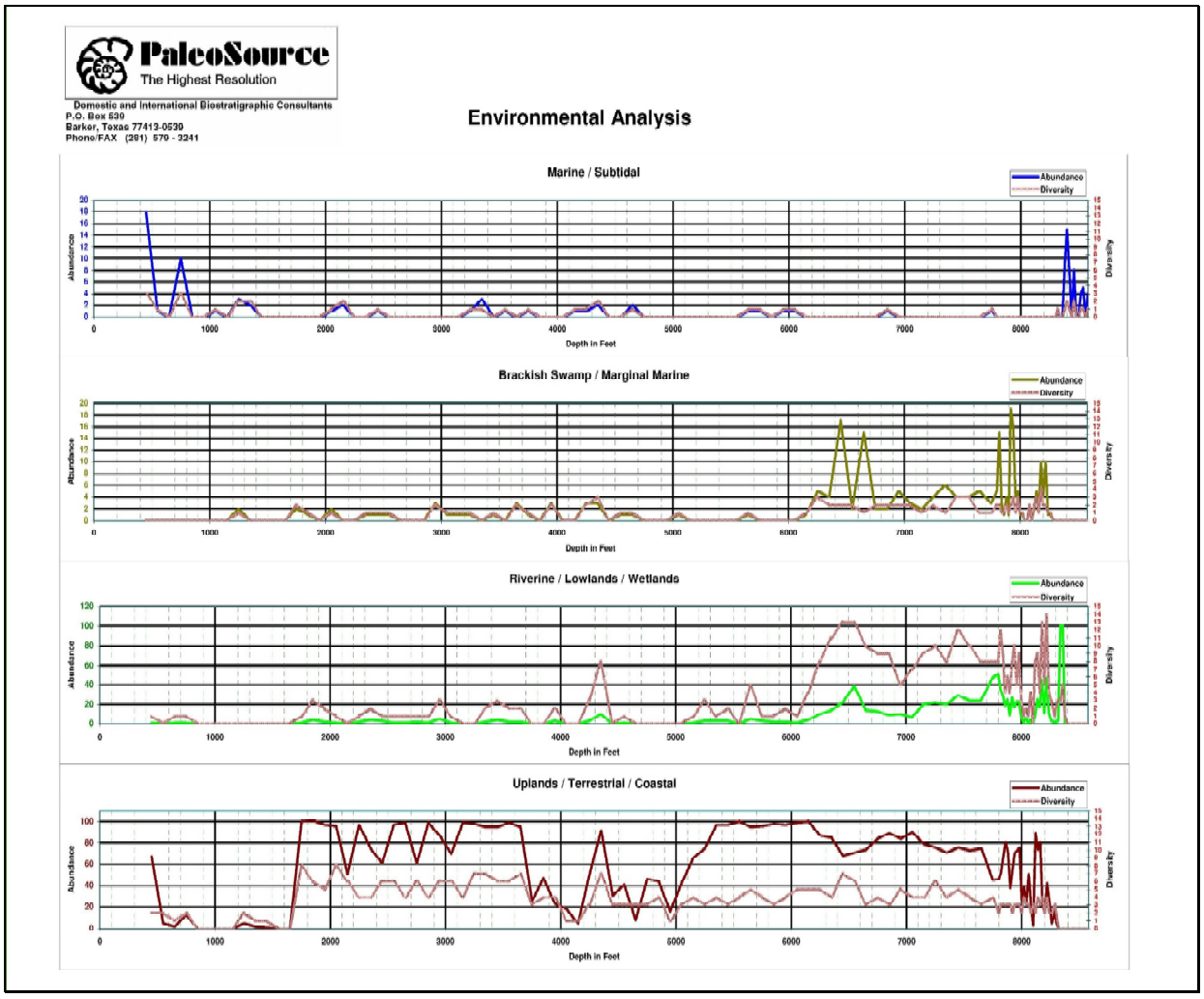
Some updip floral components (lowland origins) have broad distribution and very low dominance over the highstand shelf. Transitional environment foraminifera are narrowly distributed and may be used to identify collapse sediments.

Slide 20



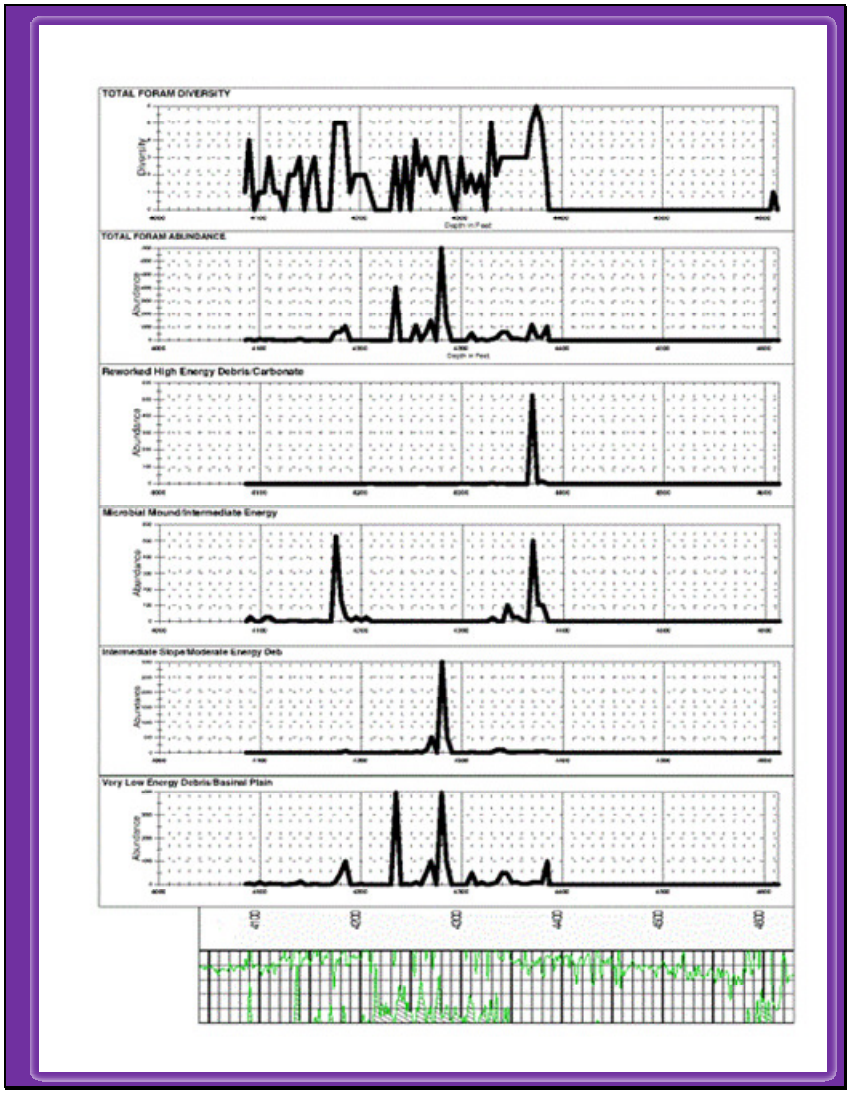
This example, taken from data on the Cline Fm, shows the environmental distribution of organisms by environmental source (see slide 21).

Slide 21



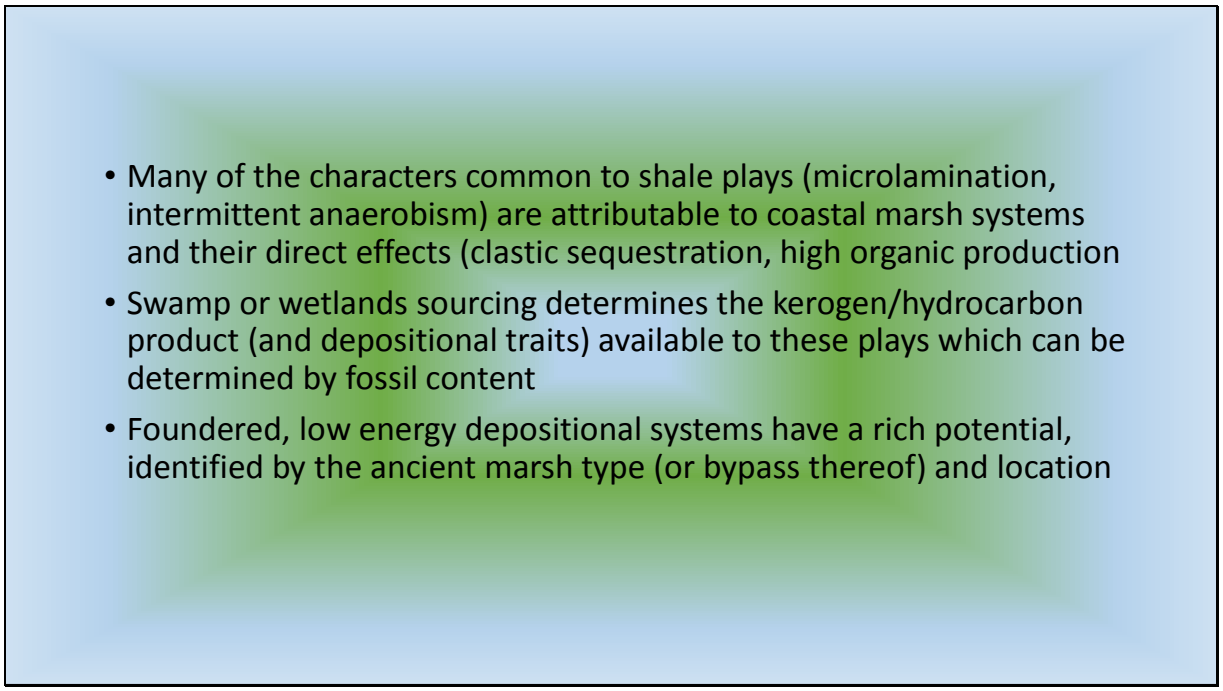
The same composite data above displayed as normalized relative abundance. The lower curve is the abundance of those organisms associated with the dominance of humic (type three) kerogen. The large waves of abundance are typical of lowstand, outbuilding sediment sequences and gas proneness, which was the case here. The second curve from the bottom is abundance of organisms transitional from type 3 to 2 kerogen and the third curve from the bottom is abundance of organisms typically associated with type 2 kerogen environments. The uppermost curve is the relative abundance of type one kerogen environments. The tight, frequent spiking of the curves toward the right of the curves indicates microlamination and high gamma ray values. Oil potential is accurately predicted by the curves above as well as indicating its coastal source.

Slide 22



The curves above indicate (from the top) foraminiferal data for 1) abundance, 2) diversity and 3,4,5) varied shelf marine trophic affinities and (lowermost curve) 6) humic trophic affinities. Note the gamma ray value curve at the bottom. The gamma ray anomaly starting two spaces from the left is characterized as a relative lowstand shale dominated by a sequence of rapidly deposited channel debris. Foraminifera species are of distributed by the sources of food they prefer (trophic affinities). When present in large numbers, you can determine what carbon source “brings them to the table”. In this set of curves, the lowermost curve suggests the dominance of humic kerogen source or gas proneness, which was the case. The dominance of humic sources only excluded the chance of significant liquid petroleum concentrations within the gamma ray zone.

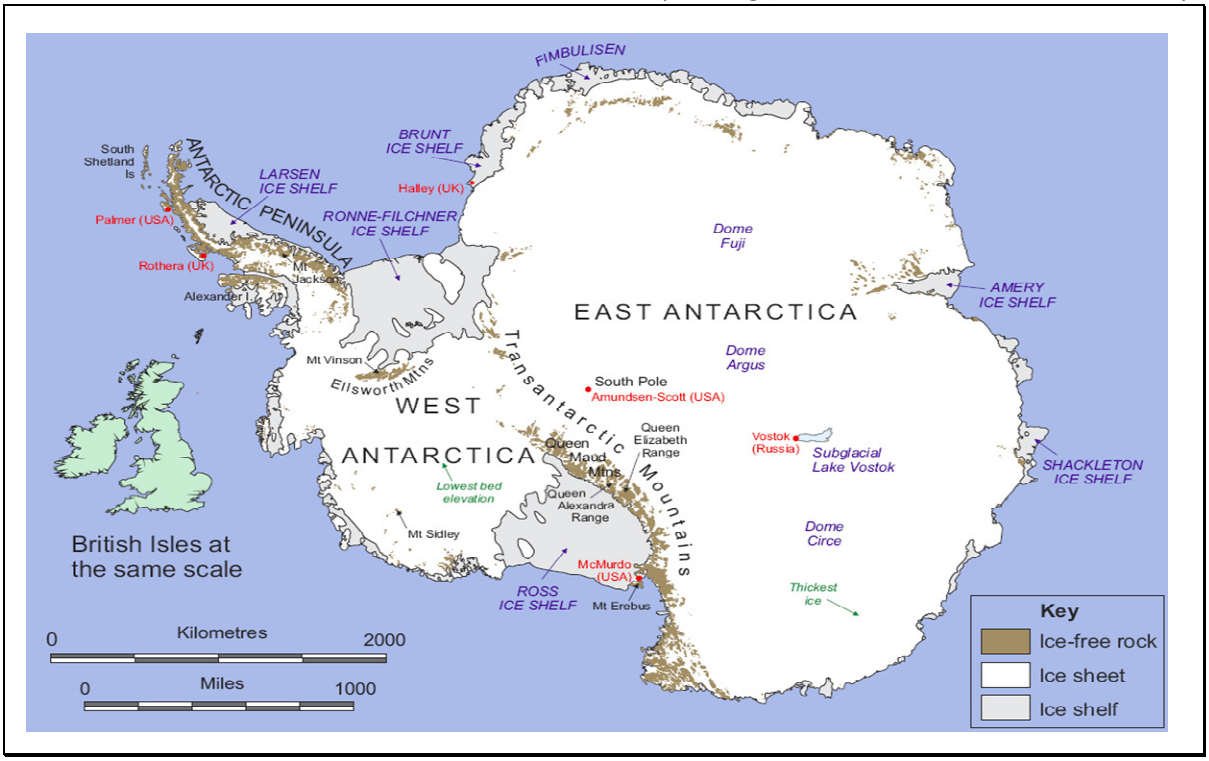
Slide 23



Along with the summary above, remember the key is rainfall or the hydrologic cycle and lots of it. One of the most prolific periods of Earth was the Carboniferous. The Carboniferous was characterized by heavy rain fall, high atmospheric partial pressures (percentages) of carbon dioxide and oxygen; very warm and wet. So… (next slide)

Slide 24

Source: scentofpine.org (credited to British Antarctic Survey)



This final component of my talk has created the most controversy. On Randy Bissell's encouragement and near insistence, I end my talk with a comment about circumstances around the Jackson Shale Fm or the "Fail Shale". In the Late Eocene or Priabonian Stage Antarctica assumed its current position at the South Pole. This did several things, like forming new, deep cold water currents, but mostly it formed new continental glaciers. This glaciation formed a worldwide unconformity, known in the Gulf of Mexico as the Glide Plane which uses the unconformity as a decollement surface. The reason for the unconformity was that atmospheric water deposited upon Antarctica was simply taken out of play globally, yielding a severe lowstand. Once captured as Antarctic ice, the water could not return as rain. Remember: no rain or significantly less rain, no extensive swamp system to charge shale plays. Thus, the Jackson Shale has no associated swamp/wetlands system, has no high TOC of coastal origin, has no microlaminated bedding and none of the things that go with it. Welcome to the Neogene Ice Age!