The Geochemical and Basin Modeling Aspects of the Jurassic to Lower Cretaceous Sourced Petroleum System, Deepwater to Ultra-deepwater Gulf of Mexico, Offshore Louisiana

Cole, G.A.[1], A.G. Requejo[1], A. Yu[1], J. DeVay[1], C. Taylor[1], P. Dougherty[1], F. Peel[1], C. Thomas[1], D. Ormerod[1], J. Zumberge[2], S. Brown[2], J. Brooks[3], B. Hoff[3], and T. White[1]
[1] *BHP Petroleum, 1360 Post Oak Blvd., Suite 500, Houston, TX, USA 77056*
[2] *GeoMark Research Inc., 9748 Whithorn Dr., Houston, TX, USA 77095*
[3] *TDI-Brooks International Inc., 7171 Highway 6 North, Suite 110, Houston, TX, USA 77845*

The petroleum system responsible for the oil and gas accumulations in the deepwater to ultra-deepwater Gulf of Mexico (GoM) are still poorly understood today in spite of dozens of well penetrations and thousands of kilometers of 2D and 3D seismic. Numerous papers have been published on the stratigraphic and structural framework of the northern Gulf of Mexico, but only a few papers have attempted to rigorously apply the petroleum system concepts. This is due mainly to a poor knowledge of the pre-Tertiary sequence, since it has not been penetrated to date. To place the petroleum system elements into perspective for the deepwater and ultra-deepwater GoM, this paper presents an alternative interpretation of geochemical and basin modeling elements. This perspective is integrated with results of 2D TemisPack and 1D Genex basin models to arrive at a new petroleum system model for the deepwater GoM.

The specific source rock interval in the deepwater GoM remains speculative, but the existence of a world-class source rock sequence is indicated by widespread seabed hydrocarbon seepage and by several deepwater to ultra-deepwater giant to super giant accumulations. A key unanswered question is whether different chronostratigraphic source units across the GoM are responsible for the geochemical variations observed in deepwater oils and seeps, or whether these differences result from gross facies changes in a single basin-wide, source sequence

Published data reveals a preponderance of proven source rock intervals throughout the GoM basin (Figure 1). Their ages can range from Oxfordian (e.g., Smackover Fm) to Tithonian (e.g., La Casita/Pimienta Fm) to Neocomian (e.g., data from DSDP Leg 535) to Cenomanian-Turonian (e.g., Tuscaloosa, Eagleford and Woodbine onshore and from Missssissippi Canyon 84, deepwater GoM) to Paleocene-Eocene (e.g., Sparta-Wilcox onshore and also in Missssissippi Canyon 84 offshore).

For the deepwater GoM, Wenger et al. (1994) published what has widely become known as the Exxon model. In the Exxon model, the southernmost oils/seeps are derived from an Oxfordian source, then become younger to the north, first Tithonian-derived, then Upper Cretaceous-derived. This model implies discrete source rock intervals across the GoM, although there is no direct evidence to support this view. Piggott and Pulham (1993) put forth an alternative model whereby most of the oils and seeps are derived from a major, single source rock located around the mid-Cretaceous unconformity (MCU) horizon.

Since these and subsequent papers were published in the mid-1990s, vast improvements in seismic data acquisition have allowed the source rock sequences around the east-central GoM to be imaged and mapped. This source package is encapsulated between the basement to 30 million year carbonate marker beds, and the most likely source rocks are located between the MCU and basement. As demonstrated by the Tithonian to Neocomian sequence sampled at different locales throughout the basin (e.g., DSDP 535), most if not all of this source rock sequence contains source rock potential. Source rock properties range from very organic rich, oil-prone condensed marl intervals to fair-moderate organic rich carbonate intervals.

Building on the earlier work, we propose that the primary source rock sequence for the deepwater GoM is most likely centered on the Tithonian and includes the Neocomian. We estimate that in the deepwater GoM it is between 150 to 200m thick with an average TOC of 5% and a Hydrogen Index between 550 and 700 mg/g. Figure 2 shows % Total Organic Carbon *versus* S_2 pyrolysis yield for the Tithonian from southern Mexico (Sonde de Campeche region), and from Mississippi Canyon 84 (Tertiary and Cretaceous data; Wagner *et al.*, 1994) and illustrates the excellent source potential of this sequence in different parts of the basin.

Secondary source rock sequences that may contribute hydrocarbons into the system are centered on the Oxfordian (estimated 50m net thickness with 2-3% TOC and 450-550 Hydrogen Index), and on the mid-Cretaceous unconformity (Turonian level, estimated 50m net thickness with 2-3% TOC and 350-450 Hydrogen Index). However, based on paleogeographic reconstructions at 160 Ma (Oxfordian), 145 Ma (Tithonian), and 135 Ma (Neocomian), the most favorable time for source rock development would have been during the Tithonian to lower Neocomian. Published data on the post-Neocomian sequence (Figure 2) suggests that thick Upper Cretaceous source rocks probably did not develop in the northern GoM as they did in other parts of the south Atlantic. Figure 3 shows a schematic of the proposed Tithonian source rock model.

Regional oil and seep geochemical data also indicate a "marl" as the dominant source type in the central deepwater GoM (Figure 4). In the west-central part of the study area, seep data indicate that some source "pods" may be more carbonate-dominated, whereas to the east the source pods become either more clastic-enriched or the paleoenvironment more dysoxic in nature.

1D and 2D basin models reaffirm the view that no single interval is responsible for charging the seeps and/or accumulations across the deepwater GoM. Over most of the region, the timing of expulsion from the basal part of the source sequence overlaps the upper parts, except along the extreme margins where burial was insufficient to mature the entire source section. There is only a single seep outside of the mature zones, which suggests that in those areas significant hydrocarbons have not been generated.

We conclude that the deepwater GoM oils and seeps represent a "mixed" system generated from a mature carbonate to marl source sequence centered on the Tithonian with variable contributions from Oxfordian and MCU sources, and that no single oil or seep can be attributed to a discrete chronostratigraphic horizon. Does this source sequence change in character from east to west? The answer appears to be yes, as we observe different "oil" types in the east than in the west. The source pods appear to be marl-dominated in the Green Canyon and Mississippi Canyon and Garden Banks regions, but in southern Walker Ridge and eastwards into Atwater Valley and Lloyd Ridge, their character varies from marl-dominated to "marly clastics" to clastic-dominated (Figure 6). We attribute these changes in source rock character to an influx of clastics shed from the Yucatan platform north into the basin during Oxfordian through earliest Neocomian time.

Selected References

Comet, P.A., J.K. Rafalska, and J.M. Brooks, 1993, Steranes and Triterpanes as diagnostic tools in mapping of oils, condensates and source rocks of the Gulf of Mexico region: Organic Geochemistry, vol. 20, p. 1265-1296.

Fiduk, J.C. et al., 1999, The Perdido Foldbelt, northwestern Gulf of Mexico, Part 2: seismic stratigraphy and petroleum systems: AAPG Bulletin, vol. 83, no. 4, p. 578-612.

Guzman-Vega, M.A. and M.R. Mello, 1999, Origin of oil in the Sureste basin, Mexico: AAPG Bulletin, vol. 83, no. 7, p. 1068-1095.

Piggott, N. and A. Pulham, 1993, Sedimentation rate as the control on hydrocarbon sourcing, generation, and migration in the deepwater Gulf of Mexico: GCSSEPM Foundation 14th Annual Research Conference, p. 179-191.

Santamaria-Orozco et al., 1994, Organic facies and maturity of Tithonian source rocks from the Sonde de Campeche, Mexico: in extended abstacts, LAOGC.

Santamaria-Orozco et al., 1998, Influence of maturity on distributions of benzo- and dibenzothiophenes in Tithonian source rocks and crude oils, Sonde de Campeche, Mexico: Organic Geochemistry, vol. 28, p. 423-439.

Wagner, B.E., Z. Sofer, and B.L. Claxton, 1994, Source rock in the Lower Tertiary and Cretaceous, Deep-water Gulf of Mexico: Transactions of the GCAGS, vol. XLIV, p. 729-736.

Wenger, L.M. et al., 1994, Northern Gulf of Mexico: an integrated approach to source, maturation, and migration, in Geological Aspects of Petroleum Systems: First AAPG/AMGP Research Conference Proceedings, 6p.

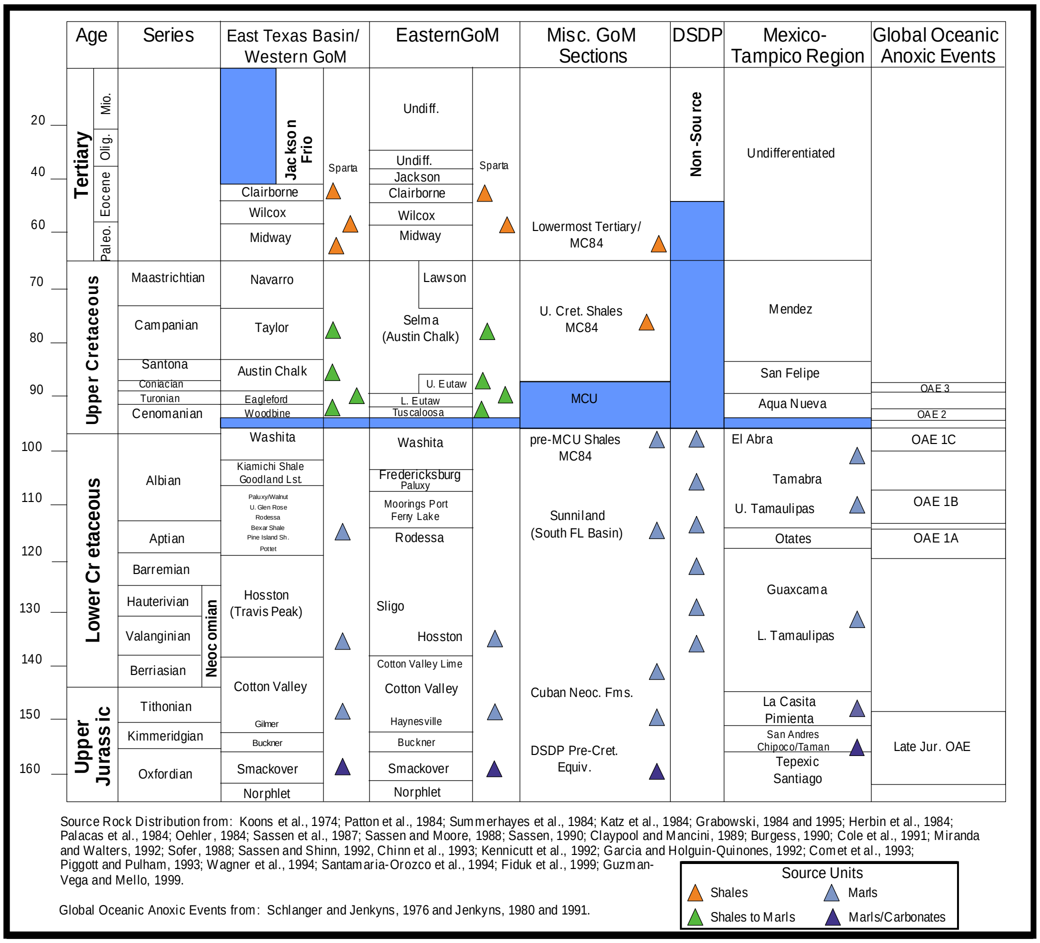
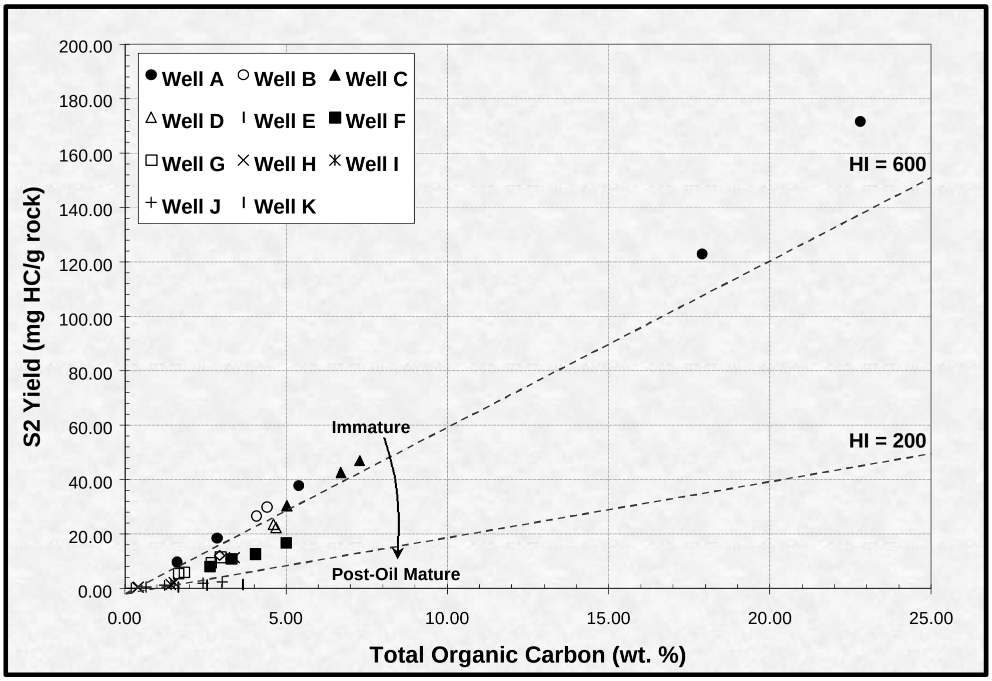


Figure 1: Stratigraphic chart showing source rock occurrences around the greater GoM basin.

Figure 2: (Upper figure) Tithonian source rock data from Sonda de Campeche, Mexico (Santamaria-Orozco et al., 1994; 1998) suggest excellent source richness and potential with TOC up to 20+% and S2 yields >100 mg HC/g rock in some intervals. (Lower Figure) Source rock data from the Mississippi Canyon 84 (King) well in the northern GoM (Wagner *et al.*, 1994). Thin intervals within the Upper Cretaceous and Lower Cretaceous (Cenomanian) attain good to excellent source richness and potential. However, net source rock thickness for an MCU source interval does not appear to be favorable for charging giant fields found in the GoM.



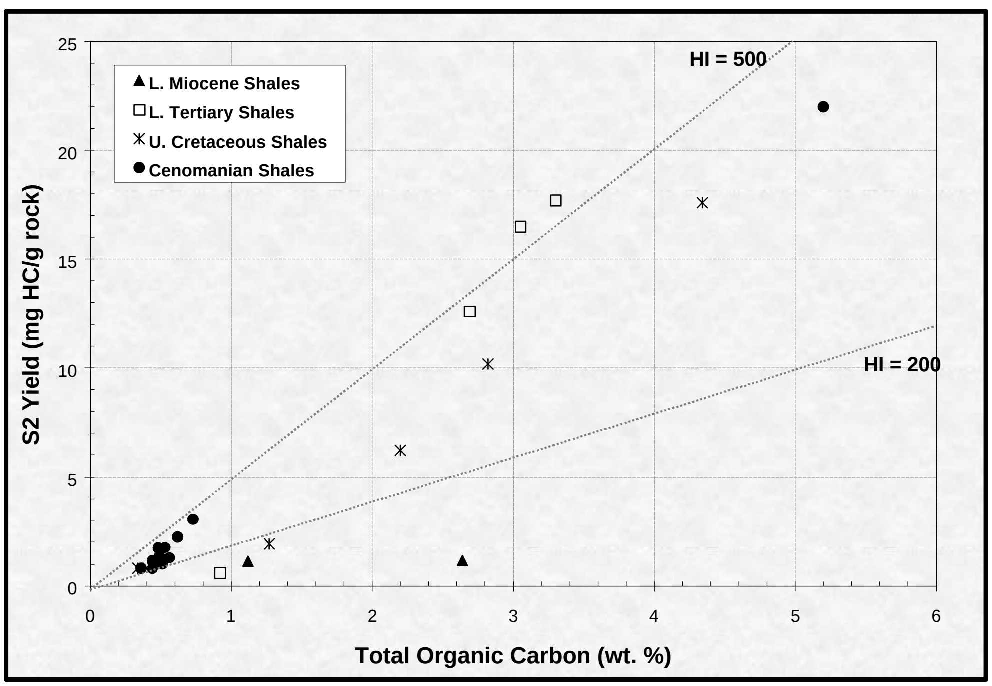


Figure 3: Schematic representation of proposed Tithonian source rock model. In this model, the primary hydrocarbon charge will be derived from mature Tithonian carbonates and marls in the Central GoM and clastic-enriched marls around the rim of the basin to the south and east. This model can account for most central GoM fields as well as the seeps located in the eastern and southern GoM.. Oxfordian carbonates and marls and Cretaceous marls and shales would also contribute hydrocarbons into the system.

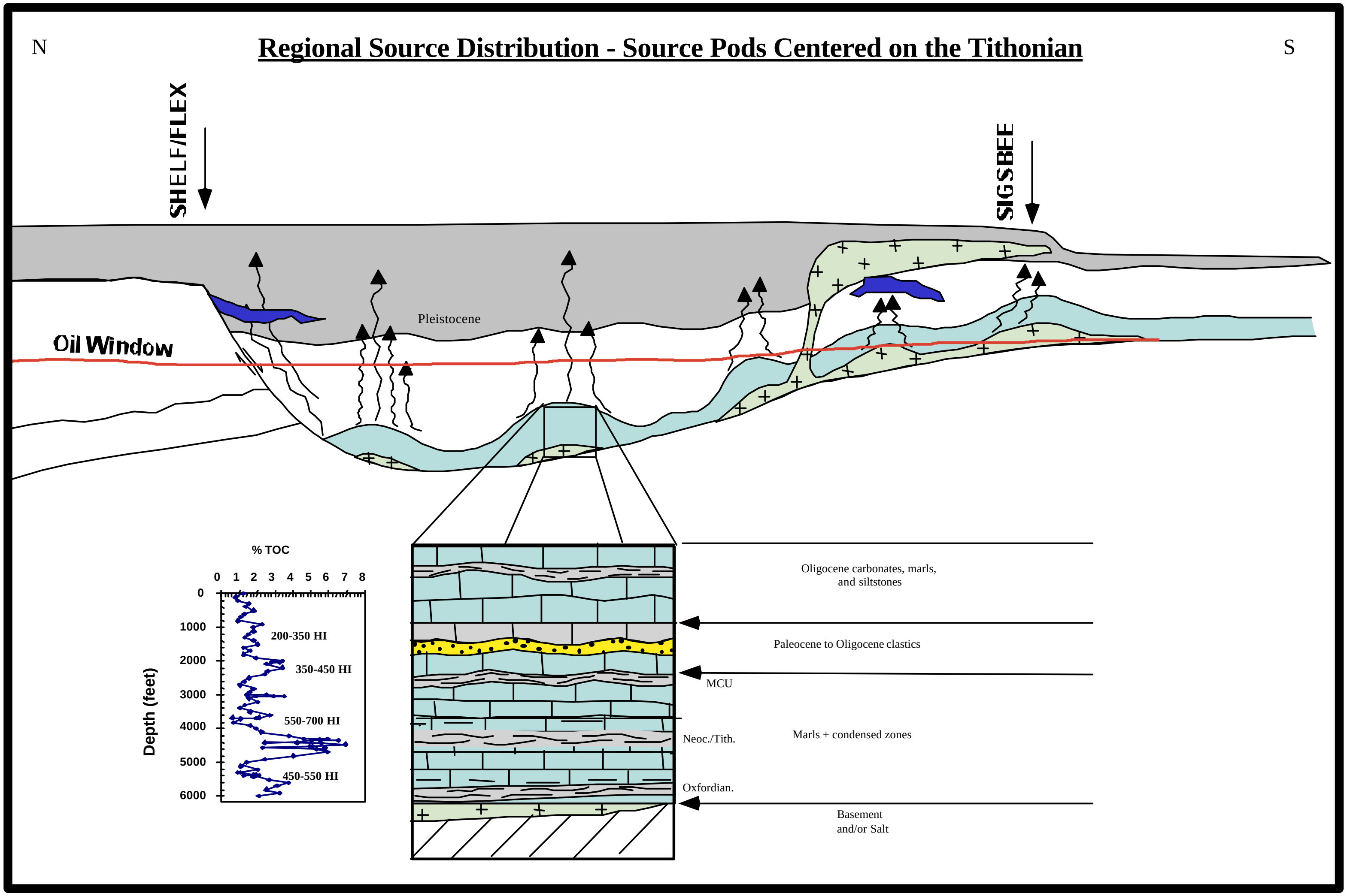


Figure 4: Source types from seepage and oils in the deepwater GoM.

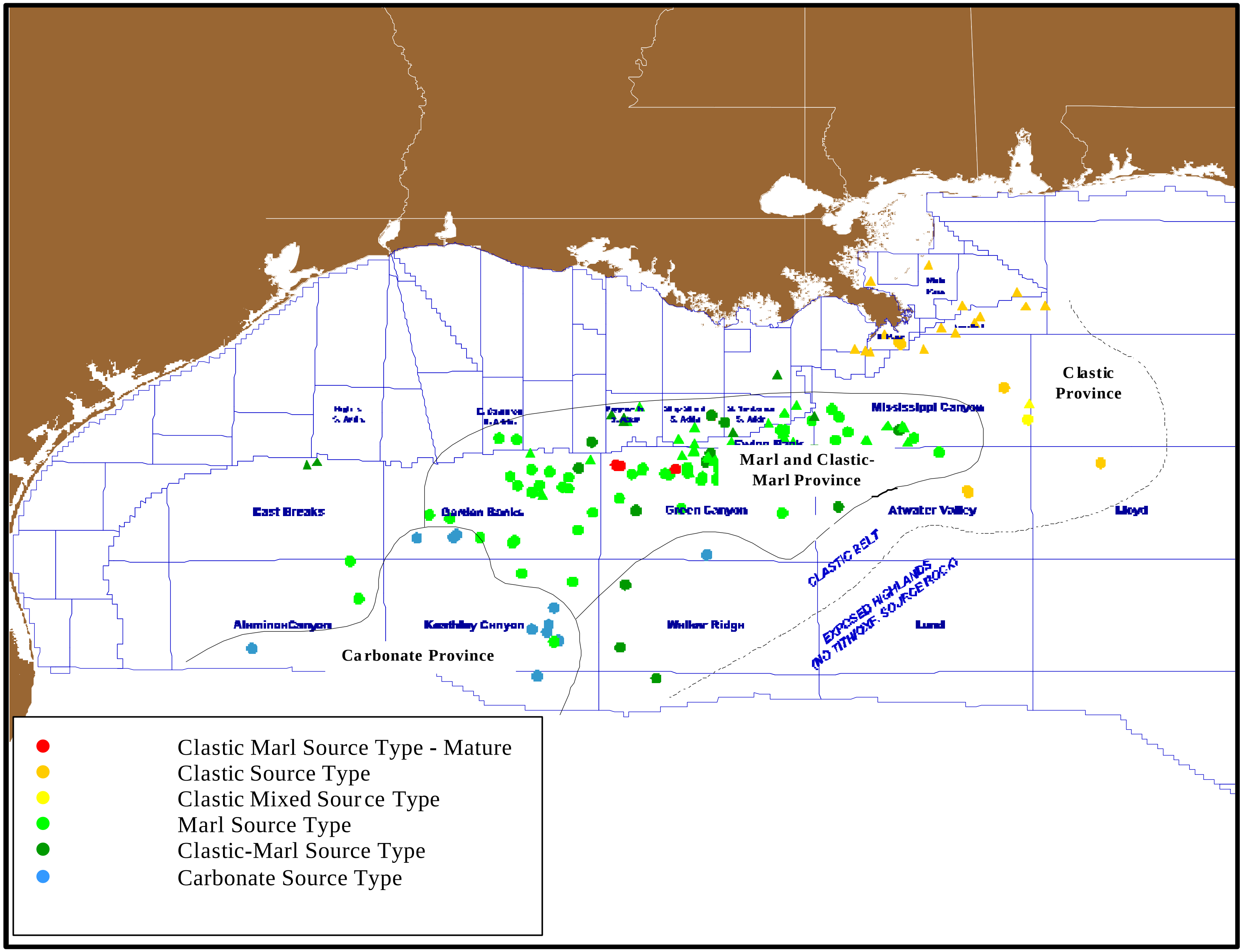


Figure 5: Source rock regimes in the deepwater GoM based on seepage/oil types and modeling results.