PS Carbonate Mud and Carbonate Source Rocks*

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Abstract

Studies of modern carbonate settings have documented varied origins for mud-size sediment, including disintegration of benthic and planktic organisms, precipitation from the water column, and mechanical breakdown of larger particles. Carbonate muds accumulate in protected “low-energy” settings on the platform top and are also exported to adjacent deeper-water settings. A limitation on source-rock deposition is a result of the need for high primary productivity levels and/or elevated organic preservation. Carbonate petroleum source rocks tend to be mud/wackestones developed in two geological scenarios:

(1) Low latitude, embayments or sags where they are interbedded or underlie evaporites - Preservation can be promoted by salinity or temperature stratification which reduces diffusion of oxygen into bottom waters and near-surface pore waters. These sources are generally thin and discontinuous due to deposition in shallow, fluctuating environments. Examples of this source type are the Jurassic Hanifa Formation of the Middle East, and the Lower Cretaceous Sunniland Limestone of South Florida.

(2) Shelves during periods of rising sea level – Formation of organic-rich sediment is promoted during major transgressions, which are times of high nutrient supply and poor oceanic ventilation. Carbonate source rocks of this type are often thick and widespread. Upper Devonian – Lower Mississippian examples of this type of source rock are the Duvernay Formation of Alberta, and the Domanik facies of the Timon-Pechora, Volga-Ural, and Caspian basins. Cretaceous examples of these rocks include the Sulaiy Formation in the Middle East; La Luna and equivalents in Venezuela, Colombia, Ecuador, and Peru; and the Austin Chalk of Texas.

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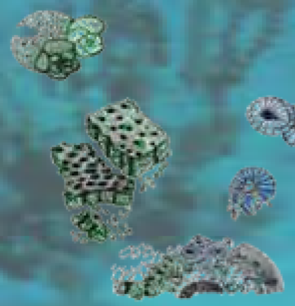
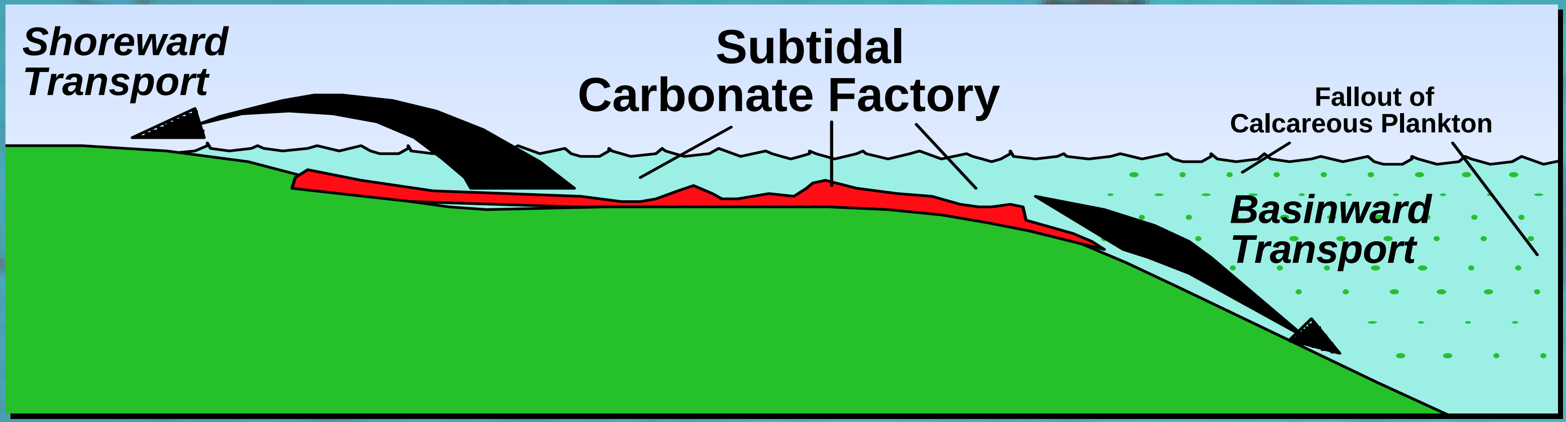
Codiacean Green Algae

Planktonic Foraminifera



Nannoplankton

Carbonate muds accumulate in protected "low-energy" settings on the platform top and are also exported to adjacent deeper-water settings. As a consequence of the "energy" of some of these settings, organic-rich, oil-prone carbonate source rocks may develop.



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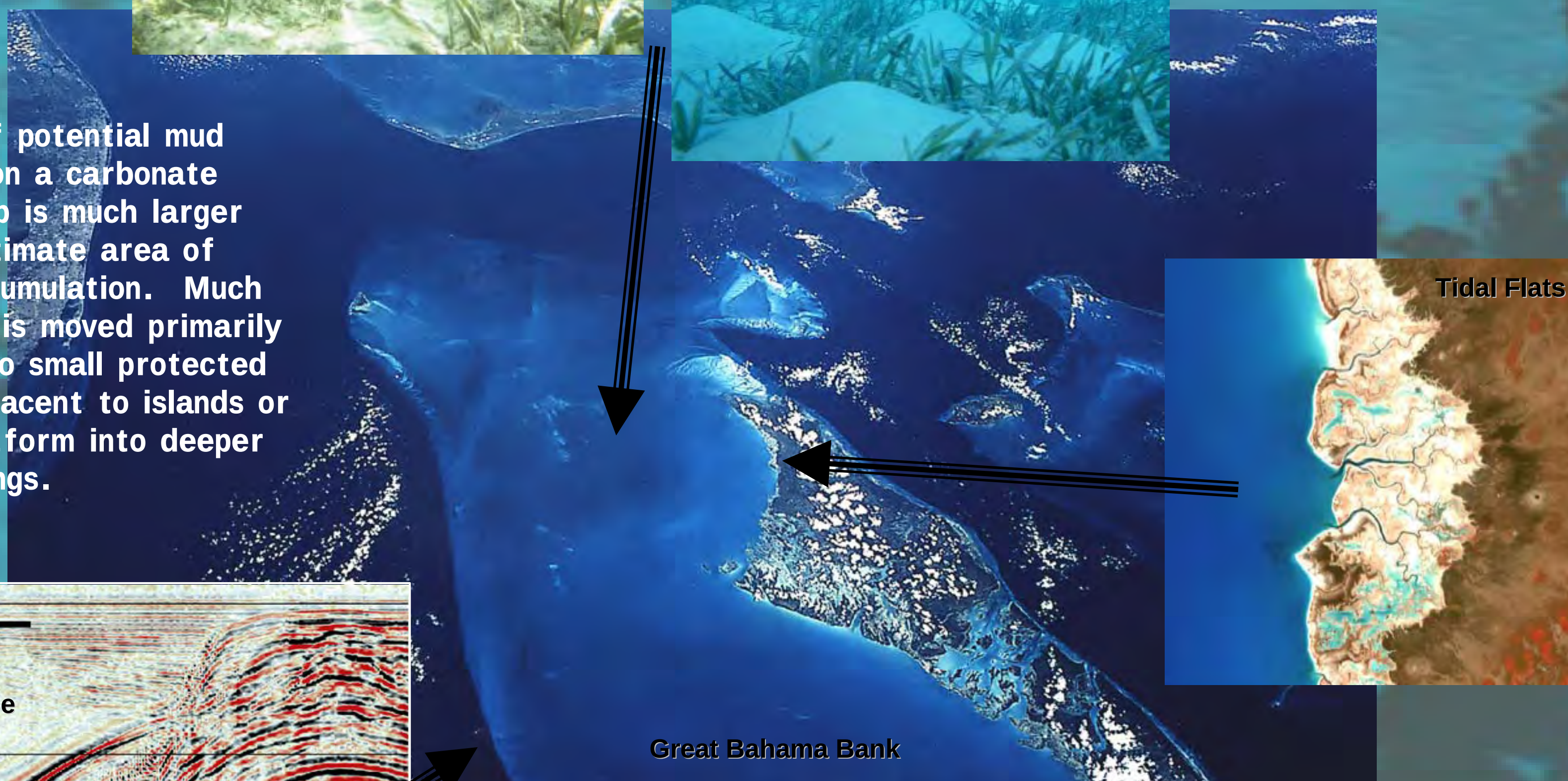
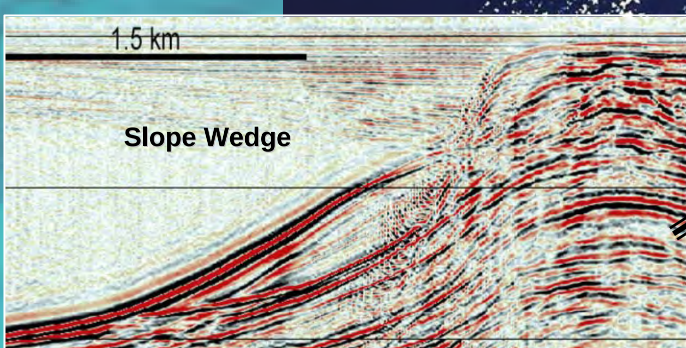


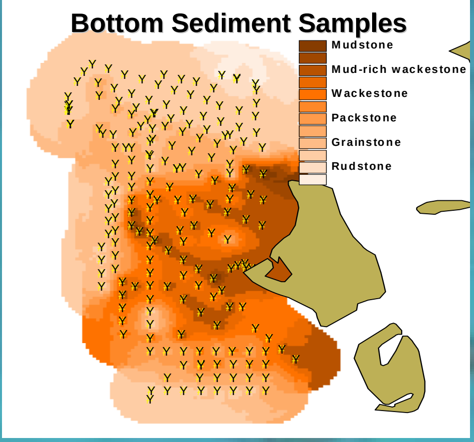
The area of potential mud production on a carbonate platform top is much larger than the ultimate area of subtidal accumulation. Much of the mud is moved primarily by storms to small protected settings adjacent to islands or off the platform into deeper water settings.



The organic matter associated with carbonate mud is largely autochthonous and when preserved is strongly oil-prone.

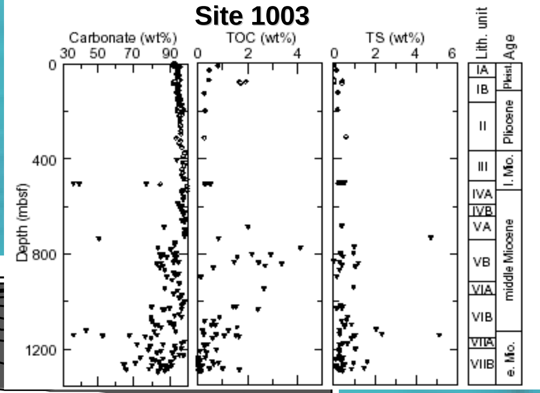
Carbonate Mud and Carbonate Source Rocks

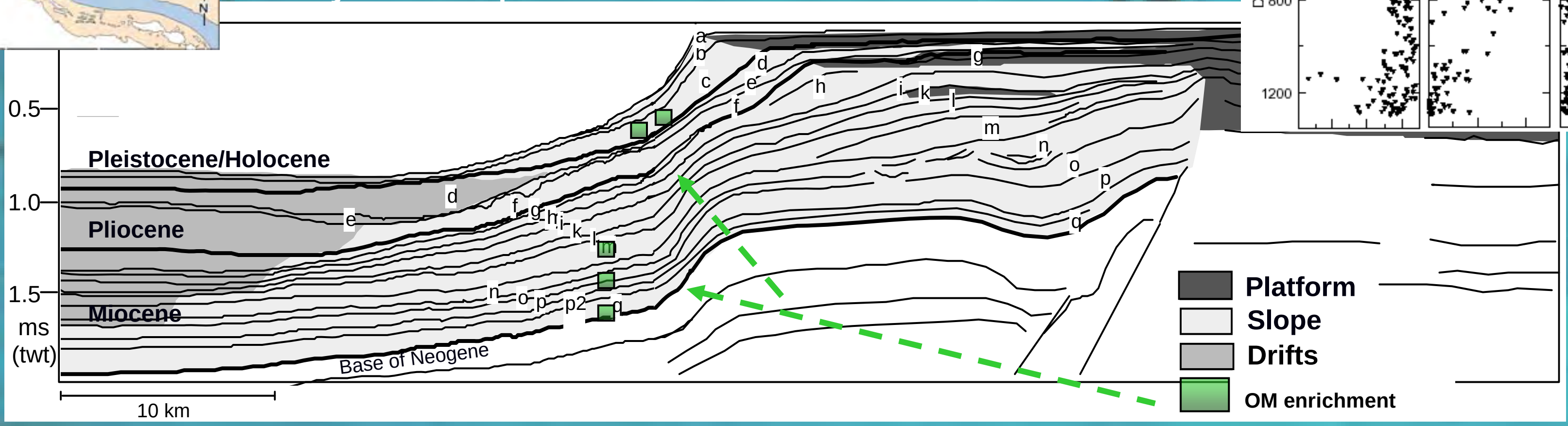
A limitation on source rock deposition is a result of the need for high primary productivity levels and/or elevated organic preservation. In general, bottom sediment and core studies from Great Bahama Bank (GBB) and other modern examples show these prerequisites for a carbonate source rock are not met on the platform top. This is often a combined effect of intermittent exposure and the oxygenated character of the water column.



Tidal Flat Core

Data from periplatform slope deposits of GBB are more encouraging. Sites 1004 & 1005 record a period of Pleistocene marine OM enrichment in a mid to lower slope environment, possibly as a result of an oxygen minimum zone. Site 1003 has fair to good carbonate-rich, immature oil-prone source facies deposited in E to M Miocene lower slope strata. Additional burial is required to mature these potential source rocks, but without reduced circulation and onset of widespread euxinic conditions, regionally extensive world-class source rocks are unlikely to develop.





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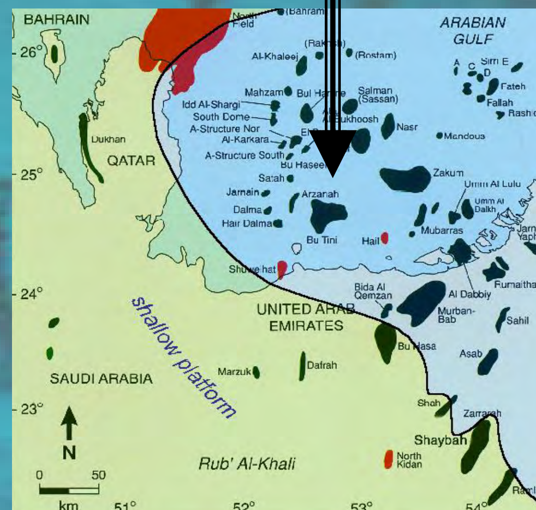
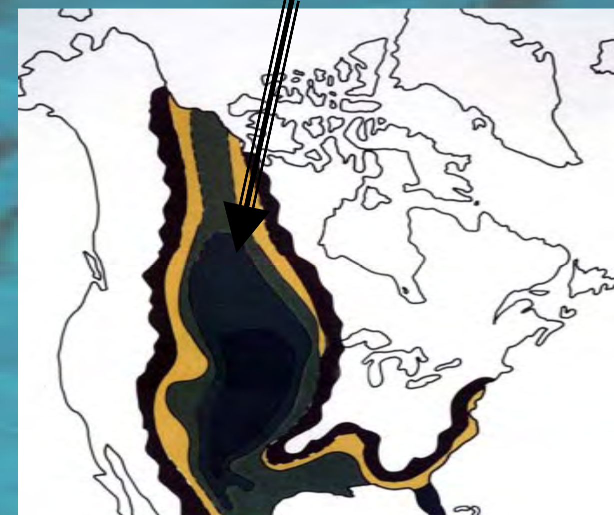
As a result of the preservation potential of varied carbonate mud settings, most carbonate petroleum source rocks tend to be mud/wackestones developed in two geological scenarios: (1) low latitude, embayments or sags where they are interbedded with or underlie evaporates, and (2) shelves during significant periods of rising sea level.

Restricted Embayment

Sag or Intrashelf Basin



Flooded Shelf (in Late Cretaceous)

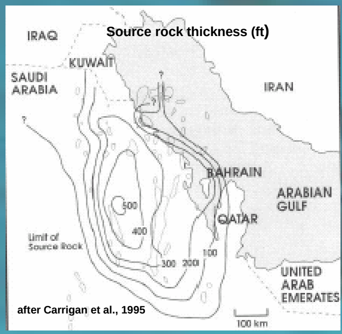


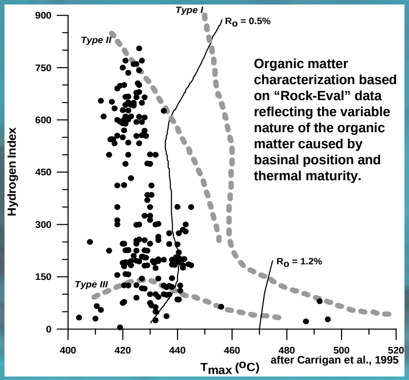
Restricted, low latitude embayments or sags–
Preservation can be promoted by salinity or temperature stratification which reduces resupply of oxygen to the bottom waters and near-surface pore waters. These sources are generally thin and discontinuous due to deposition in shallow fluctuating environments, except where subsidence rates are sufficient to limit exposure and maintain water depths. Examples of this source type are the Permian Bone Spring Limestone of the Delaware Basin, the Jurassic Hanifa/Tuwaiq Mtn. Formations of the Middle East, the Lower Cretaceous Sunniland Formation of South Florida, and the Cretaceous Cobán Formation of Guatemala.

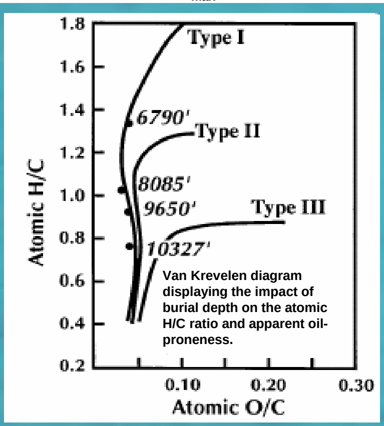
Shelves during periods of rising sea level –
Formation of organic-rich sediment is promoted during major transgressions, which are times of high nutrient supply and poor oceanic ventilation. Carbonate source rocks of this type are often thick and widespread. Upper Devonian – Lower Mississippian examples of this type of source rock are the Duvernay Formation of Alberta, and the Domanik facies of the Timon-Pechora, Volga-Ural, and Caspian Basins. Cretaceous examples of these source rocks include the Sulaiy Formation in the Middle East; La Luna and equivalents in Venezuela, Columbia, Ecuador, and Peru; and the Austin Chalk of Texas.

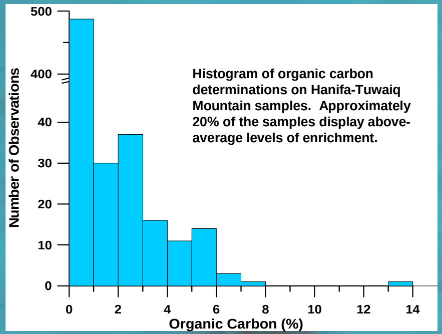
Carbonate Mud and Carbonate Source Rocks

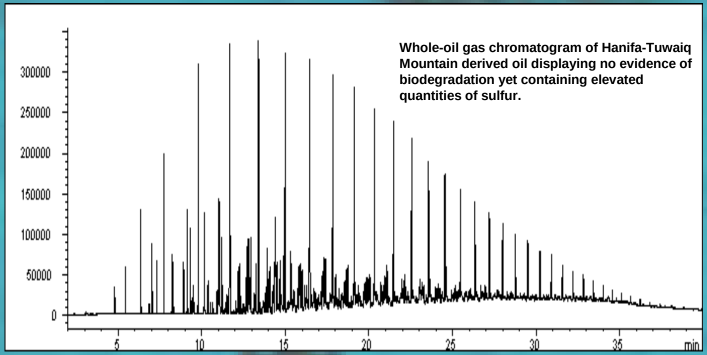
The Hanifa-Tuwaiq Mountain Formations (Callovian-early Kimmeridgian) were deposited within a restricted sag or intrashelf basin. Water depths in the central portion of the basin exceeded wave-base. Sediments along the basin margin tend to be organic-poor, whereas the more basinal sediments appear more typical of an oil-prone source rock. Organic carbon contents can exceed 13%, with generation potentials ranging up to ~90 mg HC/g rock. Although the organic matter varies, the more basinal sediments appear to have been originally more oil-prone. This source interval, which is cyclic in character, can exceed 170 m in thickness. There is strong evidence to support deposition under anoxic conditions. The oils derived from these sediments are sulfur-rich even when they lack evidence of biodegradation.

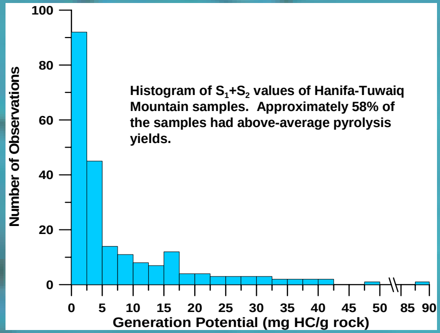


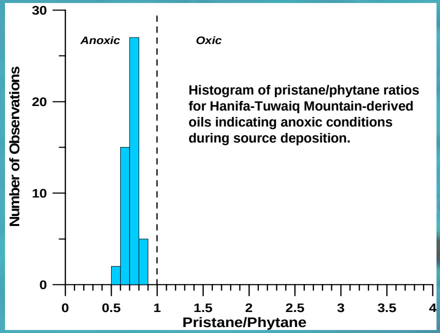


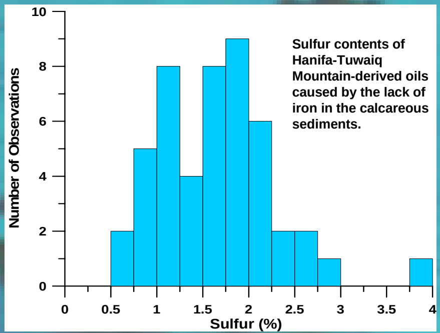


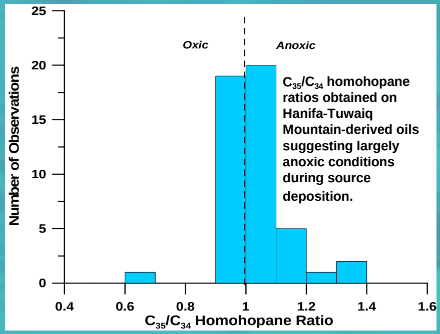












The Cobán Formation is an example of a restricted embayment.
Details of the Cobán are presented in an adjacent poster display by B. J. Katz.

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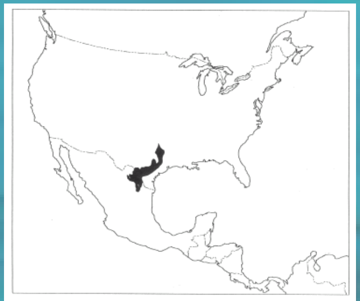
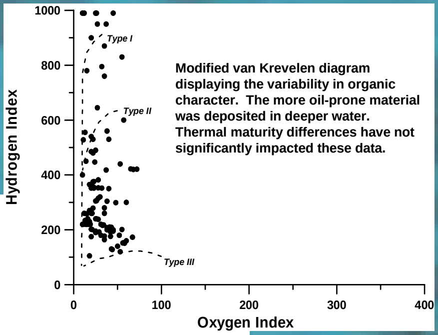
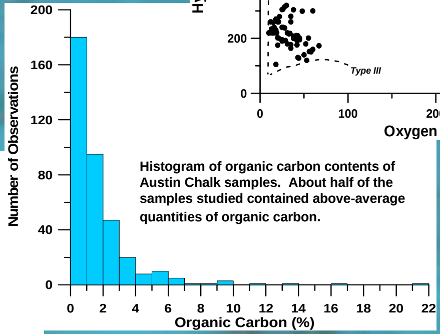
The Austin Chalk (Coniacian-Santonian) is an interstratified chalk and marl deposited during a major transgression. It is thought to have been deposited in water depths ranging up to ~200 m along an open shelf. Shallower water portions are typically light colored, heavily burrowed, and organic-poor, whereas deeper water portions contain increasing abundance of dark, organic-rich sediments. These darker layers are also burrowed but to a lessor degree suggesting that deposition did not occur under anoxic conditions. Deposition within an oxic to dysoxic setting is also suggested by a number of the biomarker indices. The organic carbon contents of darker layers may exceed 20%, with generation potentials reaching almost 50 mg HC/g rock and hydrogen indices exceeding 400 mg HC/g TOC. The available data suggest a gross oil-prone source interval that may exceed 70 m.

The La Luna Fm. (Cenomanian-Campanian) was deposited in a similar geologic setting with one major exception. There is evidence for anoxic conditions during much of its deposition leading to consistently higher organic carbon contents, generation potentials, and more oil-prone material.

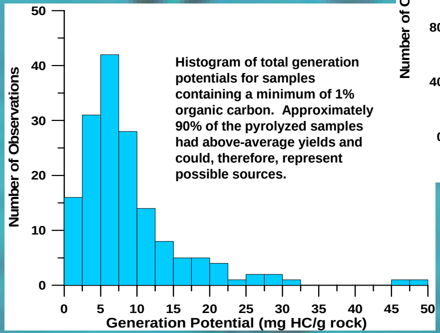




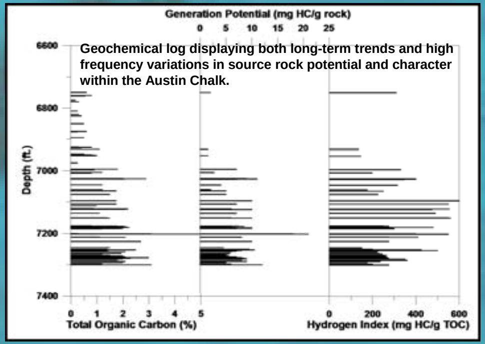
Modified van Krevelen diagram displaying the variability in organic character. The more oil-prone material was deposited in deeper water. Thermal maturity differences have not significantly impacted these data.



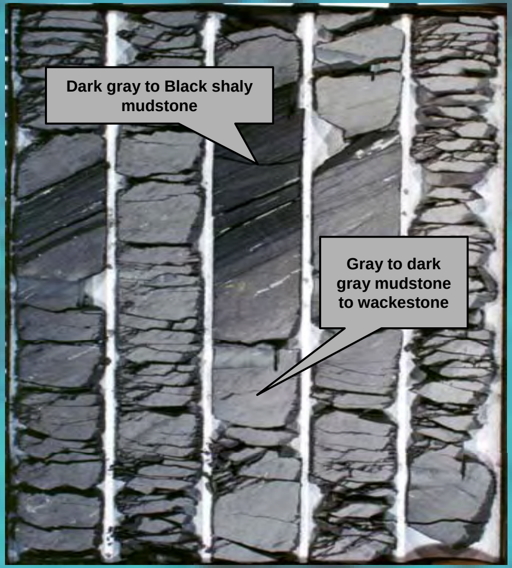
Histogram of organic carbon contents of Austin Chalk samples. About half of the samples studied contained above-average quantities of organic carbon.

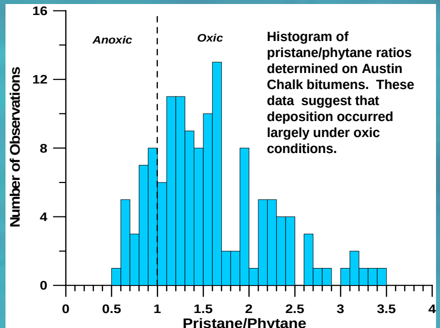


Histogram of total generation potentials for samples containing a minimum of 1% organic carbon. Approximately 90% of the pyrolyzed samples had above-average yields and could, therefore, represent possible sources.

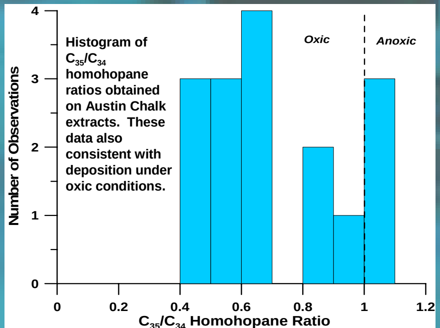


Geochemical log displaying both long-term trends and high frequency variations in source rock potential and character within the Austin Chalk.





Histogram of pristane/phytane ratios determined on Austin Chalk bitumens. These data suggest that deposition occurred largely under oxic conditions.



Histogram of C_{35}/C_{34} homohopane ratios obtained on Austin Chalk extracts. These data also consistent with deposition under oxic conditions.