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Petroleum Origin: Heavy Rains, River Plume, Ocean Stratification

A new model of anoxic facies and petroleum source-bed formation is based on the sapropel control deciphered in the eastern Mediterranean. During the Late Jurassic, the Cretaceous, and other warm periods, formation of black marine sediments occurred near emerged lands, in semi-enclosed deep basins (South Atlantic); shallow basins on carbonate platforms (Saudi Arabia); and the open Equatorial Pacific. The globally warm climates, even at high latitudes, were very rainy. The tropics had a monsoon and a dry season. The small hemispheric temperature gradient weakened the atmospheric circulation, particularly the Hadley cell. Very weak tradewinds annihilated most of the coastal upwelling. Ocean surface currents were sluggish and bottom waters were warm, saline, and hardly circulating. The land drainage resulted in the accumulation of large deltas (Niger, Barreirinhas), but the sediment yield of rivers varied widely, as they do today. The key event for marine stagnation was the spreading on the sea surface of the huge river plumes which accumulated a low-salinity surface layer undisturbed by the weak winds, a process very common today off the tropical river mouths. The strong vertical salinity gradient (2 to 4‰) stratified the upper ocean and interrupted the (thermo) haline convection, so that the bottom waters, isolated in the basins or hardly circulating in the open ocean, became stagnant and oxygen-depleted. Sediments can therefore become organic-rich source beds whatever their lithology. Ocean productivity in the plume was greatly enhanced when rivers drained volcanic areas or swamps.

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Evaporitic Environments and Their Relationship to Porosity of Associated Carbonates in Williston Basin (Mississippian)

Evaporite morphologies, indicative of specific environments of deposition, have been identified in late Cenozoic sediments, and are now recognized in the Williston basin (Mississippian, Little Knife field). The evaporitic environments which are represented include the supratidal (sabkha), the intertidal, and the shallow subaqueous. The development of the sabkha facies exerts a major control on porosity production in associated marine carbonates. Those evaporites forming subaqueously in related lagoons and other water bodies may occlude porosity within similar carbonate sediments. However, subaerial and subaqueous evaporites are now seen in the form of massive to nodular anhydrite and are usually classified together (in cores and well logs), but in fact they contain relic morphologies that permit more precise definition and separation of original facies. Subsequent porosity occlusion and/or creation may also be affected by later deformation of the regional structure and its effect on fluid migration. The recognition of the various evaporitic morphologies leads to a new understanding of porosity development in sediments of varied origins and may aid in distinguishing early from late phases of diagenesis.

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Diagenetic Sequence, Oil Migration, and Reservoir Quality in Peace River Oil Sands, Northwestern Alberta

Extensive deposits of heavy oil occur in updip pinch-out of the Bluesky and Gething Formations (Lower Cretaceous) of northwestern Alberta. In-situ extraction technologies require a detailed knowledge of porosity, permeability, and mineralogy within the reservoir and the effect of diagenesis on these properties.

Marine sands in the upper part of the Gething Formation are composed predominantly of quartz and chert with lesser amounts of clastic carbonate, rock fragments, and feldspar. Emplacement of heavy oil forming the Peace River oil sands effectively stopped or slowed diagenesis. Thin-section petrography and scanning electron microscopy provide the means of establishing a diagenetic sequence and of timing of oil migration. Three wells with abundant core have been chosen to illustrate the relations among diagenesis, hydrocarbon migration, and reservoir quality.

Authigenic minerals, in their probable order of emplacement, include pyrite, quartz overgrowths, feldspar overgrowths, kaolinite, and illite. Kaolinite and illite are most abundant in the water sands. An unusual secondary carbonate mineral, dawsonite. $NaAlCO_3(OH)_2$, occurs in only the richest oil sands but the timing of its deposition is in question. Secondary porosity was formed after feldspar overgrowths but before deposition of kaolinite. Oil migration took place after part of the kaolinite formed.

Diagenesis is an ongoing process and the various stages probably continued until migration of oil into the reservoir. Porosity is better in the good oil sands than in the water sands. Permeability is reduced by the heavy oil.

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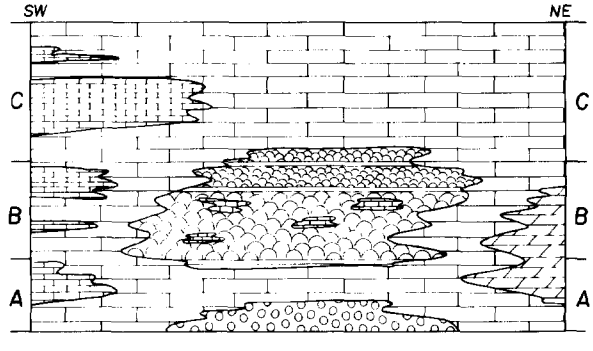
Sedimentation and Depositional Environments Between Mistaya and Survey Peak Formations, Western Alberta, Canada

A regressive-transgressive cycle is recognized within the Mistaya Formation (uppermost Cambrian) and the basal silty member of the Survey Peak Formation (Ordovician) in western Alberta. The regressive cycle consists of shallow-water peritidal carbonates which reflect a gradual shallowing of the carbonate-shoal complex, culminating in a subtidal to supratidal sequence. Lithofacies recognized within this basal sequence A are: (1) interbedded biosparite and millimeter-laminated biomicrite (open platform-subtidal shelf); and (2) interfingering oosparite, intraclastic biosparite, and biosparite (oolitic shoal complex). These lithofacies grade vertically into sequence B of: (1) laminated biosparite and biomicrite (open platform-subtidal shelf); (2) algal



biolithite composed of algal thrombolites, and columnar and polygonal stromatolites (bioherm complex); (3) cross-stratified biosparite and intrasparite (tidal channels); and (4) dolomitic intramicrite, laminated mat algae, and laminated and fenestral dolomite (supratidal flat). The distribution of lithofacies reflects a shallowing of the carbonate complex, culminating in the intertidal stromatolites and supratidal mat algae developing on top of the thrombolitic bioherm.

The transgressive cycle marks the drowning of the thrombolitic bioherm by a rise in sea level. Lithofacies recognized within the transgressive sequence C are: (1) millimeter-laminated micrite and biomicrite (subtidal shelf); and (2) tabular-bedded biosparite (open platform). The lateral expansion of the platform biosparite sands over the thrombolitic bioherm, intertidal, and supratidal environments coincides with the mass trilobite extinction between the deposition of the Mistaya and Survey Peak Formations.

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New Regional Magnetic and Gravity Maps of Central and Western Gulf of Mexico

As part of the regional synthesis phase of the proposed Ocean Margin Drilling Project, magnetic and gravity anomaly maps of the central and western Gulf of Mexico have been prepared from existing data, many of which have not been previously processed or interpreted.

Magnetic anomalies, derived by removal of the modified 1975.5 IGRF and average diurnal variation, are of relatively small amplitude, generally ±50 to 100 gammas, with wavelengths on the order of 50 to 200 km. Free air gravity anomalies have typical amplitudes of ±30 milligals and wavelengths of 50 to 200 km.

Distinctive linear magnetic and gravity anomalies parallel the northwest (Texas) Gulf Coast and the northwest margin of Campeche Bank. Such anomalies are poorly developed along the margins of the Bay of Campeche.

Over the central Gulf, low-amplitude linear magnetic anomalies are present. These anomalies are consistent both in trend and apparent offset with predictions based on hypothetical formation of the Gulf by sea-floor spreading synchronous with early opening of the central North Atlantic. Modeling of these anomalies and calculation of magnetic depth-to-source are in progress and should provide better insight into the origin of the Gulf of Mexico.

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Behavior of Some Common Clays in Response to Various Oil Field Fluids

The marginal or questionably productive nature of some hydrocarbon-bearing zones can be due to clays distributed within rock pores in a manner adversely affecting fluid flow. This research involves laboratory measurement of several clay rheological properties that are not commonly used in evaluating hydrocarbon-bearing reservoirs. Liquid, plastic, and shrinkage limits and plasticity indexes of a kaolinite, bentonite, and an illite are being determined using fresh water, salt water, methanol, xylene, and a non-ionic wetting compound as the moisture components.

Conclusions about the relative merits of each liquid as an oil-recovery enhancer may be drawn directly from the results of their effects on the plastic behavior, or indirectly when these results are applied in conjunction with other data concerning the rate of flow of reservoir fluids in the intergranular environment. When the liquid limit of attached clay particles is exceeded by the introduction of a stimulation fluid, they presumably become transient and change into a blocking phase. An attached clay can be induced to deform into new configurations that alter tortuosity if its plastic limit is exceeded. Differing ranges for the plasticity index would be expected to indicate preferential hydrofracture or stimulation fluids for certain reservoirs depending on type, position, and attachment status of the associated clays.

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Normalization of Well Log Data for Regional Stratigraphic Analysis

The normalization of well logs is a recognized technique for the removal of instrument and sensitivity errors.

This paper describes a project which used logs from 240 wells that penetrated Upper Cretaceous rocks in the Powder River basin of Wyoming. Normalization of the gamma ray, density, and conductivity curves was accomplished by adjusting each curve to a trend surface for the project area. Examples before and after normalization will be shown and alternate methods are discussed.

Processing and problems, data flow, and tabular results of discriminant analysis of the normalized log digits are discussed. The discriminant analysis relates to the evaluation of geologic models established for the Sussex and Shannon formations.

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Hydrogen and Carbon Isotope Analyses of Natural Gases from Candela, Italy—Case History of Mixing Gases of Different Origins

The gases of Candela, south Italy, have been investigated earlier and have been considered as an example of natural gas migration. In a new study, we have performed hydrocarbon and carbon isotope analyses on gases as well as GC-analyses up to the pentanes.

The gases range from -62 to $-42‰$ in the $^{13}C/^{12}C$ ratios and from -200 to $-170‰$ in their D/H ratios of the methane. The $\delta^{13}C$ and δD values are linearly correlated when cross plotted in a $\delta^{13}C/\delta D$ diagram. This relationship is strong evidence for mixing of two gases: (1) bacterial gas and (2) thermogenic gas. The compositional changes in the gases also follow mixing relationships.

These data are evidence that variations in the isotopic composition of gases are not necessarily the result of gas migration. Simple mixing of two sources in various proportions are likely to account for much of the observed variation in natural gases.

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Humid Alluvial Fans

Braided streams dominate environments characterized by high sediment load and flashy discharge. Although coarse-grained braided alluvium is most abundant today in association with semiarid to arid alluvial fans, several authors have speculated about the effects that a lack of terrestrial vegetation may have had on sedimentation prior to the late Paleozoic. It has been suggested that the increased flashiness of discharge and sediment yield associated with the lack of vegetation probably biased the pre-Carboniferous record toward braided alluvial deposits formed in humid areas.

A model for alluvial-fan sedimentation in a humid environment is based on the investigation of six fans formed in response to flooding associated with hurricane passage along the Sierra de