for example, how much oil can a particular source unit be expected to produce?

Organic geochemistry is developing all the signs of a mature discipline with several widely accepted textbooks and journals, increasing numbers of industry-oriented publications, and reputable service companies. An encouraging sign is the increasing number of interlaboratory standards currently being exchanged. I am very optimistic about the future applications of organic geochemistry as an exploration tool.

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Hydrocarbon Accumulation in Pennsylvanian-Age Ten Sleep Sandstone: The Trapper Creek Tar Sand Deposit, Big Horn Basin, Wyoming

Preliminary investigations indicate a potential tar sand accumulation in the Trapper Creek deposit of more than 2.13 million tons of mineralized material with a yield of 0.92 bbl per ton of 5.2° API oil for an approximate resource of 1.96 million bbl of recoverable petroleum. Remote sensing data suggest that the accumulation is in part controlled by two major and four minor lineaments which traverse the area. Stratigraphic and lithologic criteria can be used to infer a Minnelusa-type mode of occurrence. Ancillary stream sediment and outcrop geochemistry data yield locally anomalous but uneconomic concentrations of Mg, Ca, Ti, Mn, Ag, Cu, Mo, V, K, and Si, which may have significance in the identification of similar hydrocarbon accumulations along the west flank of the Bighorn Mountains.

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Distribution of Thermal Maturity in Central Graben, North Sea

The distribution of oil and gas fields in the northern North Sea closely reflects the structural patterns of Mesozoic-graben development. Late Mesozoic–Tertiary basin subsidence in the Central graben has resulted in a very favorable burial history for source rock maturation.

Time-stratigraphic information and present-day average temperature gradients were used from several wells to calculate depths of oil and gas windows in the area. By intersecting this depth-to-generation trend with the Late Jurassic–Cretaceous unconformity surface, the resulting map view reflects thermal maturation at this structural level plus the underlying Kimmeridge Clay. Average depths to the onset of moderate hydrocarbon generation range from 8,000 to 10,000 ft (2.438 to 3,048 m).

A combination of rapid sedimentation and sufficient subsurface temperatures in the Central graben promoted early source rock maturity as compared with the northern North Sea as a whole. The absolute timing of oil generation could in part be dependent on the magnitude of paleotemperature changes possibly associated with thermal subsidence of the basin. Early oil generation and migration may have promoted preservation of high chalk porosities as discussed in published works on the Ekofisk area.

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Numerical Climate Modeling: An Exploration Frontier in Petroleum Source Rock Prediction

Regions of persistent high organic productivity (e.g., coastal upwelling regions) and environmental conditions conducive for organic matter preservation provide a setting for petroleum source bed formation. Both productivity and preservation of organic matter are strongly related to the atmospheric and oceanic circulation. Accurate predictions of ancient circulation patterns will therefore be useful as source rock predictors.

In the past, predictions of ancient circulation patterns and upwelling regions have been based on an analogy with the modern circulation. The approach is essentially one of moving the continents "beneath" the present-day atmospheric circulation. Because topography, continental positions, and sea level almost certainly modify the nature of the circulation, the utility of such a simple research approach is suspect. The most promising approach is through the use of numerical climate models based on the dynamic and thermodynamic equations thought to govern the circulation, given specific geologic boundary conditions.

A mathematical general circulation model of the atmosphere, capable of using realistic geographic surface boundary conditions, has been employed to examine the sensitivity of the circulation to changes in continental position, sea level, topography and land-sea thermal contrast based on mid-Cretaceous geography. Each experiment consisted of a single change in a boundary condition in the following order: (1) a present-day control; (2) the present-day with no topography; (3) rotation of present-day "flat" continents to mid-Cretaceous positions; (4) reduction of Cretaceous land area associated with higher sea level; (5) addition of Cretaceous topography; and (6) addition of a warm Cretaceous ocean. The results are of particular significance because they illustrate (a) the importance of geography as a control on the nature of the circulation and (b) the potential usefulness of numerical climate modeling in petroleum source rock prediction.

(1) Experiments with no topography (flat, sea level continents) are nearly identical, exhibiting only minor differences from a "classical" pattern of atmospheric circulation. This pattern consists of an equatorial low, high pressure centered just equatorward of 30° lat., a low pressure belt centered near 60° and a polar high.

(2) Topography and land-sea thermal contrasts substantially alter the atmospheric circulation patterns in two important aspects. First, these variables reduce the zonality of the surface pressure and wind patterns, resulting in regional convergences and divergences which would not be predicted by a simple qualitative analogy with present-day patterns. Second, the mean latitudinal position of low and high pressure regions (hence easterly and westerly wind patterns) and the intensity of these features were altered by including topography and land-sea thermal contrasts. For example, the Tethyan ocean and the topography of the bordering continents result in a 10° equatorward shift of the Northern Hemisphere subtropical high. Such a shift has considerable implications for the climate of the regions bordering the Tethys ocean. Cretaceous upwelling areas may have been substantially displaced in latitude with respect to present-day patterns.

The model results illustrate the importance of geographic variables as controls on circulation patterns. These results can be compared with the geologic record and evaluated as a petroleum source rock prediction tool.

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Genesis and Preservation of Antidune Stratification in Modern and Ancient Washover Deposits

Antidunes are nearly symmetrical, sinusoidal bed forms formed by near-critical flows, and comprise all bed profiles in phase with surface gravity waves in the overlying flow. This definition applies regardless of bed-form propagation direction or mode of formation. They occur in a wide range of depositional environments but are ubiquitous in the swash zones of fine-grained beaches. Antidunes are a common but little-recognized feature of washover fans, where they generate distinct sedimentary structures that are well preserved in the stratigraphic record.

On washovers at Seabrook Island, South Carolina, antidune trains form at the fan apex, in phase with an undular hydraulic jump. This jump marks the transition within the overwash surge from supercritical flow of the berm crest to subcritical flow on the fan itself. Bed-form distribution on the fan is controlled not only by this transition but also by downfan energy dissipation within subcritical portions of the flow. From berm crest to fan terminus (i.e., downstream) the lateral sequence of bed geometries is: flat, erosional bed; antidunes; flat bed with primary current lineation and rhomboid rill marks; flat, featureless bed; rhomboid to cuspate ripples; undulatory, linear ripples; washed-out ripples; flat bed. Heavy minerals are concentrated near the fan apex owing to selective downfan transport of quartz. Landward fan migration results in a genetic sequence of sedimentary structures in which all of these features are preserved.

Streamwise boundaries of the antidune field are abrupt. Within the field itself, both crest amplitude and crest spacing decrease downfan with decreasing velocity. Bedding geometry is controlled by bed-form scale, by the pulsing nature of the flow (which tends to wash out bed forms at the end of each rock event), and by eolian deflation during neap tides and fair weather. Upstream antidunes produce thin lenses of backset laminae which are commonly truncated by flat beds or superposed backsets. These lenses grade downstream into thinner lenses with lower angle backsets, and finally into zones of very low-angle truncation surfaces.

Orthoquartzitic washovers in the Carboniferous of Kentucky and the Ordovician of South Africa display well-preserved antidune formset geometries. Although the very well-sorted, monomineralic nature of these sandstones renders internal stratification nearly invisible, backset laminae are apparent. Pleistocene washovers in South Africa exhibit antidune bedding types influenced by grain size. Fine to medium-grained sand is organized in en echelon lenses of backset laminae interbedded with flat beds. Coarse sand and granules occur as flow-perpendicular ribbons with lenticular cross sections and spacing similar to antidune spacings on modern fans.

Many published photographs of flat beds contain unrecognized examples of antidune stratification. In many places, the antidune cross-laminae would be impossible to detect without heavy minerals or other markers to accentuate bedding. However, in apparent massive beds, x-ray radiographic techniques have revealed cross-laminae with antidunal affinities. Moreover, antidunes may be responsible for much of the low-angle truncation normally associated with flat-bedded facies.

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History of Development and Depositional Environment and Upper Cherokee Prue Sand, Custer and Roger Mills Counties, Oklahoma

In western Oklahoma the uppermost sand member of the Cherokee Group, the True sand, was first drilled and found productive in two discoveries, completed in 1980, in west-central Custer County and in central Roger Mills County, Oklahoma. For 1½ to 2 years these two discoveries, some 18 mi (29 km) apart, were thought to be stratigraphic equivalents of two separate sand bodies occurring parallel to the classic northwest-southeast-trending systems of the Anadarko basin. Energy Services has drilled eight productive Prue sand wells in this area and has been instrumental in establishing that the 1980 Prue discoveries are actually part of a predominantly east-west-trending system that extends some 40 mi (64 km) across the west-central part of western Oklahoma.

At present, some 40 productive wells will ultimately produce more than 100 bcf of gas and 3 million bbl of condensate from an average depth of 11,500 ft (3,500 m). Sand porosities range from 3 to 18% with most producing wells having porosities in the 12 to 15% range. Because Prue sand is slightly overpressured (a pressure gradient of .53 psi/foot), the reserves are generally better than normal-pressured wells at this depth.

Log and sample data from the 40 producing Prue wells and numerous surrounding nonproductive tests, along with the one core of the sand, give a fairly good picture of the sand geometry and depositional history.

The sand body is over 40 mi (64 km) in length, 1 to 1.5 mi (1.6 to 2.4 km) wide, and 60 ft (18 m) thick. The east-west trend of the sand is parallel to the present-day structure at the top of the Cherokee Group as well as to the interval isopach of the Cherokee Group. The majority of the open-hole logs and samples show a fining-upward sequence, where most of the clean productive interval is at the basal to middle part of the sand. Study of the core shows the interval to grade from a medium to fine-grained sand, highly laminated and cross-bedded with black shale, to a slightly coarser grained nonstructured interval and back into a highly laminated cross-bedded sandy black shale interval. The interval is topped by a 10 ft (3 m) thick black shale layer that is a predominant bed throughout the whole area. We interpret the sand morphology as that of a submarine offshore bar sand that was deposited in shallow water but never emerged above sea level to form a barrier island of beach-type environment.

The existence of a shaly limey interval for 500 ft (152 m) above the Prue sand along with the excellent preservation and consistency of the Prue sand geometry indicate that the Prue was never reworked and was likely deposited in a trangressive or at least a subsiding basin environment.

These conclusions have implications that may assist in the exploration of other Pennsylvanian sands in this area.

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Transverse Structural Styles and Subduction-Related Deformation in Sumatra Fore-Arc Basin, Western Sunda Arc, Indonesia

The western Sunda Arc of Indonesia is a continental-margin arc-trench system characterized by oblique subduction along an irregular crustal edge and by transcurrent faulting within the arc terrane. Offscraping and accretion of material along the base of the landward trench slope have led to formation of a prominent outer-arc ridge that has trapped sediment in basins between the volcanic arc and the trench. Sedimentary strata deposited in these fore-arc basins record the Neogene and Quaternary evolution of the arc-trench system and preserve many of the original structural and stratigraphic relationships.

Along the active Sumatra margin, the combination of compression and transcurrent faulting has led to the development of relatively shallow transverse structures that subdivide the fore-arc region into several discrete sedimentary basins. Multichannel seismic reflection profiles reveal the structural style of two prominent transverse highs that separate Nias basin from the deeper