years. However, recent research indicates that many of the chemical and physical processes which are being modeled deterministically are actually much more complicated than previously believed. Examples include the kinetics of hydrocarbon generation, the mechanisms of hydrocarbon expulsion, and secondary migration. Weaknesses in our conceptual models for these processes will surely translate into more serious weaknesses or even failures of numerical models in actual applications.

Alternatives to purely deterministic modeling include developing models that are based loosely on theoretical foundations but whose details are controlled primarily by empirical data rather than theory; stochastic (probabilistic) models for processes for which either the conceptual model is weak or the input data are variable or uncertain; and models that combine aspects of both deterministic and stochastic approaches.

New theoretical descriptions are being developed for several processes that will permit their mathematical solutions to be rooted more firmly in empirical data. Examples include compaction as a function of time, temperature, lithology, and overburden; vitrinite reflectance as a function of time and temperature based on a chemical-kinetic approach; and shale permeability as a function of compaction rates. These and other phenomena required for basin modeling are incorporated into a combined deterministic/stochastic model.

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Rift Tectonics and Eustatic Overprint, High Atlas of Morocco

The central and eastern High Atlas of Morocco coincide with an east–west aulacogen filled with 5–10 km of Liassic and Dogger limestones and marls, and structurally inverted in the Tertiary.

A mosaic of carbonate environments evolved and migrated within first-order rift subsidence, lasting for 25 m.y., and over individual fault blocks foundering and rotating. Deposition was complicated by synsedimentary transtensional wrenching, but exhibits a pattern of fault blocks representing medial platforms flanked outward by troughs, shelves, and shorelines.

Tests for eustatic vs. tectonic control on deposition include (1) evidence for longer term sea level changes that affect all rift blocks, overriding their independent motions, and (2) evidence for shorter term cyclic deposition within the Milankovitch scale. Because carbonate deposition is sensitive to sea level, stacked facies represent a hierarchy of relative sea level changes.

In the High Atlas, limestone deposition is everywhere overwhelmed by Toarcian marls that overstep the basin margins. These marls are related to a significant second-order circum-Mediterranean or global sea level rise. These marls also separate major lower and upper shallowing-upward sequences of approximately 10 m.y. duration.

Within these major sequences, lower orders of deposition typically are cyclic over all tectono-stratigraphic blocks, and are regarded as controlled by Milankovitch-scale sea level and/or climatic oscillations: shelfal shallowing-upward cycles, turbidite limestone-marl cycles, and midbasin pelagic limestone-marl cycles. These lower order cycles are each up to a few meters thick and commonly are arranged into cycle bundles that internally wax and wane by thickening and thinning, deepening and shallowing, and varying in proportions of limestone and marl.

With the exception of the Toarcian drowning, biostratigraphic control on the High Atlas is not yet refined enough to confidently correlate depositional cycles of any scale with published eustatic sea level histories for the Jurassic.

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Southern Oklahoma Aulacogen: An Integrated Basin Model

A basin model has been developed for the southern Oklahoma aulacogen that includes geochemical data, structural analysis, and regional mapping. This integrated approach has been used to reconstruct the basin's complex history.

Geochemical characterization of over 400 oil samples indicates the presence of four major oil types together with mixtures of these end members. Type A oils have abundant isoprenoids and relatively abundant C_{15+} n-alkanes that show a linear decrease with increasing carbon number. Type B oils have a moderate amount of isoprenoids and an n-alkane profile that decreases exponentially with increasing carbon number. Type C oils have a moderate odd-carbon preference in the nC_{11}-nC_{19} range, moderate isoprenoids, and anomalous concentrations of alkyl-benzenes and alkyl-cyclohexanes. Type D oils have a strong odd-carbon preference in the nC_{11}-nC_{19} range, minor isoprenoids, and limited n-alkanes longer than nC_{19}. These four oil types appear to correlate with Middle Pennsylvanian shales, the Devonian–Mississippian rock units, the Viola Group (tentative), and an unidentified Ordovician unit, respectively.

Because the sedimentation history of a region reflects the tectonic development, burial reconstructions are combined with a thermal model to establish the timing of hydrocarbon generation. The three-dimensional extension of this procedure demonstrates that the major pulse of oil migration from the Ardmore basin was concurrent with the fold development during Early Pennsylvanian deformation, whereas migration from the Marietta basin was affected by fault displacements that were more extensive during Late Pennsylvanian deformation. The distribution of various oil types helps constrain the basin model and demonstrates the application of geochemistry in a mature exploration province.

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Framework for Constructing Clastic Reservoir Simulation Models

Techniques to convert geological information into engineering models have made rapid progress during recent years. In fact, so much is being published on the subject of reservoir characterization that is it timely to provide a framework for modeling as a function of reservoir type and heterogeneities.

The development geologist has to play an active role in data gathering in cooperation with the other disciplines. Early identification of major characteristics influencing fluid flow is required to design optimal data gathering schemes. Already at this stage, good communication between geologists and engineers is essential as well as replacing jargon with practical descriptive terminology.

Every modeling effort is aimed at specific purposes, which, in turn, determine the required degree of detail. In this context, the range of applicability of the various modeling approaches is reviewed. Much depends on the data density relative to reservoir architecture. Schemes indicate the chance of reliable deterministic correlation, and when to turn to alternative solutions such as probabilistic modeling. A database of sand-body geometries for each facies is a basic requirement.

The heterogeneities are treated as a nested system best approached from small to large. This stepwise upscaling to grid-block-size properties with appropriate averaging procedures is demonstrated with a few examples. Verification of the accuracy of the modeling and averaging procedures through timely well test analysis is considered crucial to ensure realistic results.

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Global Petroleum Occurrences in Submarine Fans and Turbidite Systems

Submarine fans and turbidite systems are major petroleum reservoirs in many sedimentary basins in the world. We have identified 60 sedimentary basins that contain major petroleum-producing submarine-fan deposits. These reservoirs produce from structural, stratigraphic, and combined traps. To characterize these reservoir occurrences, tables were compiled for each continent by basin, listing tectonic setting, reservoir age, formation name, reservoir characteristics, and type of trap.

Synrift settings contain both lacustrine and marine turbidite reservoirs. Major synrift lacustrine turbidite reservoirs occur in Tertiary basins in China and Hungary and in the Lower Cretaceous basins of Brazil and western Africa. Synrift marine turbidite reservoirs are best developed in the Upper Jurassic–Lower Cretaceous of the North Sea. The Paleogene postrift sag basins of the North Sea also contain major turbidite reservoirs and are mainly compactional features over older structures and updip stratigraphic traps.

Passive margins contain turbidite reservoirs in a variety of structural