The American Association of Petroleum Geologists
V. 68, No. 11 (November 1984), P. 1836-1838

Association Round Table

DISTINGUISHED LECTURE TOURS, 1984-85

Abstracts

DOTT, ROBERT H., JR., Univ. Wisconsin, Madison, WI

Episodic Sedimentation of Ancient Shelf Sandstones

At casual glance, modern shelves dominated by clastic deposits seem exceedingly dull, especially when compared to carbonate-dominated shelves. During the past 10,000 yr, the Holocene transgression has resulted in modest reworking of relict, pre-Holocene material and only trivial additions of new material. Instead, most new clastic sediment has been trapped in estuaries formed by Holocene drowning of rivers. Thus, clastic shelves appear to be boring because 10,000 yr is too short a time for estuary filling and significant new shelf sedimentation, and also because knowledge of modern shelf processes is biased toward bland, fair-weather conditions. Such a dismal view is dispelled, however, by a second glance at either outcrops or cores of ancient shelf sequences. Abrupt changes of lithology attest to countless changes of process types, magnitudes, and rates. This, coupled with a large share of petroleum reserves trapped in shelf clastics, offers ample reason for a more positive view.

What is needed is a fresh perspective of one of the longest studied of all sedimentary realms. Once the constraints of Lyellian constancy and of the fair-weather bias are broken, we can appreciate the great importance of episodic processes on both modern and ancient shelves. Episodic events are so common on a geologic time scale, in fact, that it is a mistake to refer to them as catastrophic, which has become increasingly popular in recent years. The ancient record provides important insights especially by allowing us to penetrate the 10,000-yr Holocene barrier and to assess the important question of preservation potential; i.e., can everyday processes obliterate the evidence of an episodic event? Episodic sedimentation may result from any event whose magnitude deviates significantly from the norm. Both positive deviations, such as storms and tsunamis, and negative deviations, such as nondeposition, constitute episodes. Of most interest to the sedimentary geologist are events recorded at the spatial scale of cores and outcrops and whose recurrence frequencies range on a temporal scale from decades to millenia. Excluded at one extreme are regular annual processes (such as varve formation), and, at the other extreme, phenomena with time scales on the order of at least a million years (such as Vail curve cycles). Important questions concern assessment of recovery time, preservation potential, and determining whether recurrences are periodic or episodic. Also, we must distinguish instantaneous depositional rates from net accumulation (or preservation) rates.

Some preserved features that attest to episodic sedimentation include conglomerate lenses resedimented by storm surges; intraclast, shell, or glauconite concentrations, as well as rare graded sandstone and shelly beds produced by scour and winnowing; and hummocky stratification resulting from abnormally large waves. All of these reflect positive deviations from normal process intensities. Negative deviations typically result in surfaces of nondeposition, such as mineralized hardgrounds and polygonally cracked emergence surfaces. Bioturbated zones alternating with unburrowed intervals also attest to important episodic deviations, and provide insight into relative process rates. The former reflect fair-weather conditions with slow accumulation, whereas the latter reflect episodic rapid accumulation that outpaced burrowing activity. Both physical and biologic processes can produce complex amalgamation patterns through the overprinting of effects of multiple events, resulting in records that are challenging to decipher.

Association among episodically produced features can provide important tools for basin analysis—for example, clues to relative proximality of shelf clastics analogous to those for deep-water turbidites. Relative proximality diagnosis in turn allows prediction of sandstone thickening and possible permeability trends, which could enhance exploration success. Some puzzling sandstone bodies encased in shale and isolated from any paleoshorelines (i.e., distal) seem explicable only by episodic emplacement; they are ready-made petroleum reservoirs. Thus, ancient shelf deposits are not so boring after all, and sharper tools for basin analysis should enhance our ability to explore for new petroleum reserves trapped within them.

GINSBURG, ROBERT N., Univ. Miami, Miami, FL

Sedimentary Models of Pattern, Process, and Succession Derived from Bahamian Carbonates

Three decades of research on the Cenozoic carbonate platforms of the Bahamas have produced several models of deposition and diagenesis. The models are sufficiently varied and numerous that they can be categorized and their interactions evaluated. The models can be divided into three types: two-dimensional patterns of depositional facies; process models of sediment formation, deposition, and diagenesis; and concepts of facies succession.

Patterns of depositional facies range in scale from a kilometer or less in the bar and channel morphology of ooid sand spreads, to a few kilometers in channeled tidal flats, to as much as 100 km (62 mi) in the platform to basin zonation of reefs and sediments.

The spectrum of process models extends from grain formation (peloids and ooids), to major modes of accumulation (net shoreward movement of lime mud with attendant seaward progradation of shoaling cycles), to sea-floor cementation that yields aggregate grains and hardgrounds.

Vertical facies successions on the scale of several meters are seen in the shoaling deposits of tidal flats and in the coarsening-upward sequences of sand shoals. Larger scale changes in facies, from skeletal to nonskeletal deposits that are tens of meters thick, occur in the subsurface Pliocene-Pleistocene carbonates.

These three kinds of sedimentary models interact in various ways. An example of the influence of pattern on process is seen in the channels between tidal bars of ooid sand. The growth of tidal bars of ooid sand leads to accelerated tidal currents in the intervening channels; the result is a channel lag of coarser sediments that limits traction movement of lime sands and especially the nuclei for continued formation of ooids. Deceleration of ooid formation can in time lead to stabilization of the moving sands with attendant alterations of grains and sedimentary structures. An example of the effect of process on pattern is seen in the formation of extensive hardgrounds on lime sands of the platform interior by submarine cementation. These hardgrounds are rapidly colonized by attached organisms, including reef-building corals; the end result is a major transformation of sediment type and the appearance of the preferred substrate for reefs. An example of the interaction between facies is seen in two aspects of reefal deposits: the preferential development of some reefs seaward of islands or growing sand shoals and the burial of other reefs that fringe leeward margins of the platforms by off-bank transport of lime sands from the interiors.

HILTERMAN, FRED J., Geophysical Development Corp., Houston, TX

Seismic Modeling: Geologic Predictions and Pitfalls

Structural geologists have made tremendous strides in unraveling the architecture of the earth with recent studies of seismic reflection data.

This is true not only for exploration studies, but also for crustal studies. However, the seismic time section is not an undistorted cross section of the earth.

Seismic sections across most geologic structures are distorted by sideswipe and/or lateral velocity changes in the subsurface. Invariably, the distortion on the 2-D migrated section hides the features that are most desired. However, through seismic models of similar geologic structures, the interpretational pitfalls caused by sideswipe and velocity are turned into practical prediction tools.

Migrated seismic lines across domes and anticlines normally exaggerate the size of the anomalies. Migrated seismic lines across synclines and basins are characterized with false expressions that include grabens, contemporaneous deformation, cross-stratification, high amplitudes, and crossing reflections. Geologic areas that have large lateral velocity contrasts, such as reefs, diapirs, or fault blocks, exhibit false seismic expressions. These include relief faults, basement-controlled tectonics, facies changes, and structures that are located in geologically ambiguous positions. Even the polarity of the seismic reflection is 3-D dependent.

Modeling examples show that interpretational pitfalls, such as mapping from migrated sections and interpreting from the basement upward, must be supplemented with pseudo-3-D interpretational techniques. Geologic models and their seismic analyses from salt provinces, reefs, overthrusts, etc, illustrate these pseudo-3-D interpretational tools.

KAUFFMAN, ERLE G., Univ. Colorado, Boulder, CO

Dynamics of Cretaceous Epicontinental Seas

Acceleration of plate spreading and hot spot activity during the Cretaceous produced topographically elevated regions of the sea floor, which episodically displaced global sea level upward as much as 300 m (980 ft), broadly flooding the world's cratons with shallow epicontinental seas. Episodes of relative plate quiescence accompanied destruction of these topographic features and sea level fall. Ten such eustatic rise-fall events, third-order cycles averaging 10 m.y. in duration, are defined from coincident transgressive-regressive strandline migrations and various types of sedimentary cyclothems on many of the world's cratons; epicontinental seas and their sedimentary record comprise the most sensitive tools for defining sea level fluctuations. Precise correlation of these eustatic fluctuations, and determination of rates of sea level change, are possible through a new technique of high-resolution event stratigraphy, integrated through graphic correlation with refined biostratigraphy and geochronology. The best documented record of Cretaceous eustasy, and the most refined system of geologic time and event correlation, is associated with the great Western Interior seaway of North America. This sea occupied a major foreland basin east of the North American Cordillera.

In this basin, strong evidence exists for near-simultaneous response of regional tectonic and volcanic activity, sedimentation patterns, eustatic fluctuation, strandline migration, climate history, and variations in paleobathymetry, temperature, and water chemistry in the Western Interior seaway, with episodes of active vs. passive spreading and subduction. The dynamics of basin history documented in the Western Interior seaway serve as a new model for epicontinental marine history worldwide. Basin analysis suggests that, coincident with active plate spreading and subduction along the Pacific margin of North America, active thrusting, plutonism, and vulcanism characterized the western Cordillera; the foreland basin was subsiding at rates greater than predicted by tectonic/sedimentologic loading; basement block faulting was initiated in the tectonic hinge zone; and the basin reached its deepest phase as sea level rose and marine transgression overprinted regional tectonic and sedimentologic features. Major thermal and chemical fluctuations, including regional and global anoxic events, characterized the seaway at this time, producing extensive source rocks. Subsequent phases of relative plate quiescence were coincident with major reduction in Cordilleran tectonics, vulcanism, and basin subsidence, as well as with eustatic fall and epicontinental regression. Resultant filling of the seaway with sediments allowed extensive eastward progradation of clastic wedges across the basin axis and onto the stable eastern platform, forming the major Cretaceous hydrocarbon reservoirs. Most major coal deposits formed on delta and strand plains during relative eustatic stillstand at peak transgression and peak regression. The integrated study of basin dynamics in epicontinental seas, linked to eustatic history, allows the development of powerful exploration models for fossil fuels.

LELEK, JEFFREY J., Amoco Production Co., Denver, CO

Anschutz Ranch East—Finding and Defining a Giant Oil Field in Thrust Belt

Anschutz Ranch East is the giant oil field of the western United States thrust belt, with over 3/4 billion bbl of oil equivalent in place. The original prospect was not so impressive. Extensive Tertiary cover precluded precise prospecting by surface mapping. An early well penetration of a shallow recumbent fold tied to conventional 2-D seismic reflection lines hinted at a Triassic-Jurassic structure 1,500 acres (600 ha.) in extent. Soon after Amoco discovered Anschutz Ranch East in 1979, production pressure data revealed that the field was very large; but it was development drilling and 3-D seismic that prompted the geologic interpretation of 14,600 acres (5,900 ha.) under closure. Still being delineated nearly 5 yr after its discovery, the current size estimate is near 4,000 acres (1,600 ha.). The field, therefore, serves as a good case example of the difficulties involved in geologic mapping using remote data.

Anschutz Ranch East is part of a prolific oil trend extending more than 40 mi (64 km) along the leading edge of a major regional thrust plate. Situated in the extreme southwest corner of Wyoming and adjacent Utah, the field produces from separate reservoirs in two en echelon structures. The more significant west lobe is a highly overturned, narrow anticline with more than 2,000 ft (610 m) of hydrocarbon column. The producing Triassic-Jurassic Nugget Sandstone, largely eolian in origin, is just over 1,000 ft (305 m) thick, with more than 75% of the rock capable of contributing to production. Geologically, the field has passed through several stages of geometric interpretation: the faulted stage, the concentric fold stage, and the angular stage. Development of these three interpretations was based largely on outcrop examples of fold geometries in thrust belts of both the eastern and western United States.

Production rates in the first half of 1984 averaged approximately 36,000 bbl of condensate, 6,500 bbl of natural gas liquid, and 215 mmcf of gas per day. The reservoir fluid is a rich gas condensate originally about 150 psi (1,034 kPa) above the dew-point pressure. Complexities involving reservoir fluid properties, stratigraphic influences on fluid flow, effects of structural deformation, and fracture systems have required close cooperation between geologists and reservoir engineers in planning for field development. With this cooperation to maximize recovery, the recovery factor for hydrocarbons in place is expected to be about 70%.

More than 90% of the field's recovery will come from the west structure, which is just over 1 mi (1.6 km) wide and probably less than 6 mi (9.7 km) long. Fields of this size might be easily missed in thrust belt exploration.

MUTTI, EMILIANO, Univ. Parma, Parma, Italy

Ancient Turbidite Systems: Models and Problems

An understanding of turbidite depositional systems is important for both geologic reconstructions of ancient margins and for exploration in clastic deep-water basins. In the last 10 yr, ancient turbidites have been interpreted in terms of modern depositional settings such as submarine fans, slope basins, trenches, and basin plains. However, the lack of common ground between models for modern and ancient turbidite deposits has resulted in a nonuniform application of models, facies distinctions, morphologic criteria, and depositional processes. As a consequence, most ancient turbidite systems are still difficult to frame within models derived from modern settings.

Ancient turbidite systems display a variety of sedimentary patterns. Most commonly, these systems consist of channel-fill sediments that are replaced in a downcurrent direction by nonchannelized deposits. Despite this common overall pattern, turbidite depositional systems differ considerably in terms of size, types of facies and facies associations, and geometry and distribution of sandstone bodies. The volume of gravity flows appears to be the main factor in controlling the distribution pattern of sandstone facies within each system.

Substantial accumulations of turbidite sandstone facies are invariably related to periods of lowstand of sea level and are common in those basins where slope instability is enhanced by tectonic uplift. Most predominantly fine-grained systems, and particularly channel-levee complexes, are conversely deposited during periods of highstand and are generally associated with active seaward progradation of deltas on adjacent shelves.