Stratigraphic Traps in Paleocene Sands in Balder Area, North Sea

The Balder oil field in blocks 25/10 and 11 in the Norwegian sector of the North Sea contains 25° API oil in a Paleocene deep-water sandstone reservoir. The sands were deposited from high concentration, high-energy turbidity currents as a complex of channelized sand lobes which formed a small fan. Depositional topography and subsequent submarine erosion created a geometric closure on the upper surface of the fan. Oil is stratigraphically trapped by this closure. Recognition and definition of this mounded surface on seismic records and the development of a sedimentary model has made it possible to drill successful appraisal wells after disappointing initial drilling results.

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Geophysical Characterization of Lithology—Application to Subtle Traps

Traps for oil or gas consist of a geologic material whose physical properties may differ from those above and around it. In its first half century, geophysical exploration by the reflection seismic technique was used to delineate the boundaries between subsurface materials of different properties. The technique could not discriminate between the properties on either side of those boundaries. If geologic information from nearby wells or from outcrop was absent, the wildcatter drilled blindly through trap boundaries in the hope of finding the right kind of material.

Technology has advanced sufficiently that it is now possible to determine from seismic data at least one physical property of subsurface materials. That property is seismic velocity. Because seismic velocity generally decreases with increased porosity and because gas under pressure further decreases that velocity, it is now possible to define some non-structural traps and to identify some hydrocarbon accumulations.

Seismic velocity measurements displayed on computer-plotted cross sections in color, graphically identify a variety of subtle traps in many parts of the world. When applied to 3-D survey data the velocity methods can yield enough information to define all the boundaries of a hydrocarbon accumulation. The characteristic seismic velocites in a 3-dimensional subsurface block can most graphically be displayed as a motion picture depicting passage through the earth in selected directions.

New seismic techniques under investigation should make possible the simultaneous determination of additional physical properties so that even more subtle traps can be found.

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Porosity and Textural Characteristics of Eolian Stratification

An analysis of experimentally formed eolian stratification has shown that processes of deposition are the major factors controlling the primary porosity and texture in the avalanche, grainfall, and ripple-produced types. Avalanche stratification generally exhibits the highest primary porosity (avg 47%) because of loose packing and grain arrangements that occur as a mass of sand shears downslope. Wind ripple-produced stratification has the lowest primary porosity (avg 39%) due to the relatively close packing and the presence of finer grained sublayers developed near the base of each inversely graded ripple stratum during ripple migration. Primary porosity of grainfall stratification (avg 43%) is usually intermediate between that of avalanche and ripple-produced deposits because the packing is between the avalanche and ripple produced types.

Avalanching forms the high-angle, porous, lee-slope stratification commonly observed in eolian deposits. Ripple-produced stratification is formed in two principal localities—on the low-angle windward slope where potential for preservation is poor, and on the lower part of the lee slope where preservation potential is excellent. The ripple deposits, produced by winds moving across the lee slope, form the tangential foreset-to-bottomset stratification common to eolian dunes. The relatively low porosity observed in these deposits is due to the stratification being composed of ripple-produced deposits. Grainfall stratification has a poor preservation potential because of redeposition by avalanching on the upper part of the lee slope. Grainfall on the lower lee slope usually occurs on a rippled surface, and these grains are incorporated into the ripple-produced stratification being formed at that site.

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Bahama Platform Slopes: Carbonate Diagenesis Within and Below Thermocline

Sediments on Bahamian slopes, reef rubble, gully sands, and periplatform carbonate ooze, consist of calcite, magnesian calcite, and aragonite. When not continuously buried by new material, these sediments harden to limestone crusts, 10 cm to several meters thick, on the sea floor. The pathways of sea floor diagenesis vary with depth. (1) Reef wall and talus slope (50 to 400 m) are pervasively cemented by micritic magnesian calcite; botryoidal aragonite fills the large voids. There is no evidence of selective dissolution; primary and diagenetic minerals coexist. (2) On the gullied slopes between 500 and 1,300 m most sediment lithifies to calcite limestone or chalk, with 3 to 7 mol % $MgCO_3$; however, about 20% of the samples are micritic magnesian calcite limestones of 8 to 14% $MgCO_3$. (3) On the gullied slopes from 1,300 to at least 2,500 m, calcite limestones with 2 to 4 mol % $MgCO_3$ prevail.

The downslope trend from aragonite and magnesian calcite to calcite is explained by the decrease in water temperature and carbonate saturation. The magnesian-calcite limestones between 500 and 1,300 m do not follow this trend even though their oxygen isotopes indicate formation in cold bottom water. Micritic ooids of magnesian calcite with globigerinids as nuclei and coccoliths in the cortex are associated with the limestone crusts and obviously form in this current-swept deep-water environment. This suggests that magnesian calcite precipitates from a pore fluid close to, and derived from, sea water. The microenvironment may be controlled by micro-organisms or by inorganic precipitation of calcium carbonate that increases the Mg:Ca ratio in the pore fluid, thus raising the magnesian content of the precipitating calcite.

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Estimate of Displacement in Major Zone of Tear-Thrusting in Fold and Thrust Belt, Southwest Montana

The most pronounced deflection of the marginal fold and thrust belt in Montana occurs in the northern Tobacco Root

Mountains where a zone of imbricated thrusts follows the southern margin of the eastward-trending Helena embayment of the Belt basin.

Movements along major thrusts north and south of this east-trending zone are nearly pure dip-slip. Movements within the zone are demonstrably oblique with nearly equal components of dextral and reverse slip. This suggests that the fault zone may be described as being one of tear-thrusting.

Accumulated net slip along the tear-thrust zone may be estimated by summing estimates of net slip along the individual faults which comprise the zone and by examining displaced isopach lines for rocks deposited prior to faulting. Summing net-slip estimates for individual faults along several sections though the fault zone indicates that the horizontal components of net slip is between 15 and 30 km. Right separation of isopach lines for a limestone member of the Kootenai Formation (Cretaceous) indicates a horizontal displacement which is somewhat larger (between 30 and 60 km). Displacements of this magnitude cannot be accounted for by folding and minor thrusting in the rocks north of the tear-thrust zone and strongly suggests one or more zones of detachment within the section above Archean basement rocks.

Estimates of net horizontal displacement along this fault zone can be very useful in interpreting anomalous isopach trends such as those seen in the Flathead Sandstone (Cambrian) and Maywood Formation (Devonian).

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Depositional Environment of Dry Hollow Member, Upper Cretaceous Frontier Formation, Southwestern Wyoming

The Dry Hollow Member of the Frontier Formation in southwestern Wyoming consists of alluvial deposits that accumulated along part of the western margin of the Western Interior Cretaceous seaway. Typically, the lower part of the Dry Hollow Member contains sandstone bodies 4 to 15 m thick that fine upward and possess basal conglomeratic lenses. These units are interpreted as channel deposits of meandering streams, with the conglomerates having formed as channel-lag deposits. Commonly, silicified wood, plant fragments, freshwater gastropods, and intraformational shale clasts are present in these deposits. Medium-scale trough cross-stratification is dominant and indicates a general west to east paleocurrent direction.

The upper part of the Dry Hollow Member is dominated by interbedded shales, coals, and thin (0.2 to 1 m) fine-grained sandstones. The shales contain abundant carbonaceous plant material, silicified wood, and lignitic layers. Root horizons are commonly preserved within large (0.3 to 1 m) concretions that formed in the shales. The interbedded fine-grained sandstones are typically small-scale trough cross-stratified and contain abundant plant material. These sandstones are interpreted as near-channel overbank deposits that accumulated during periods of stream flooding, while the shales and coals represent vertical accretion deposits of interchannel swamps and lowlands that accumulated farther from the stream channels.

Analysis of these deposits suggests that a wet, poorly-drained fluvial lowland dominated by meandering streams and coal swamps existed along the Western Interior Cretaceous seaway during deposition of the bulk of the Dry Hollow Member of the Frontier Formation.

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Cenozoic Deep-Water Benthic Foraminifers

Cenozoic deep water deposits have yielded rich and diversified faunas of benthic formaminifers. From still limited data, it is clear than these faunas were depth stratified and that most species were cosmopolitan in distribution. The wide distribution and species richness, together with faunal turnover, which in places was very abrupt, points to great biostratigraphic potential. High turnovers delineate distinct Paleocene, Eocene, and Oligocene-early Miocene faunas. A gradual but profound wave of extinction and speciation occurred during the middle Miocene and by late Micene had created the modern deep water faunas.

Superimposed upon these evolutionary developments are strong changes in depth preference, particularly among those species that persist across the turnover periods. During the Paleocene-Eocene transition some species became restricted to the bathyal realm while others preferred the abyss. During the Eocene-Oligocene transition a net downward depth range extension of bathyal species occurred. During the late Miocene the periodic vertical migrations of bathyal and abyssal faunas that so strongly characterize the Quaternary began to appear. In the North Atlantic, such depth range excursions may extend over more than 1,500 m.

The evolutionary and bathymetric changes of benthic faunas are their response to the evolution of the deep water environment, particularly the establishment of the cold water sphere during the late Eocene, and the addition of the North Atlantic as a source of cold water during the middle Miocene. The late Cenozoic depth changes are indicative of periodic rearrangements of the deep ocean circulation in response to climatic change at the earth's surface.

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Surface Features and Geology of Selected Cores from Elizabeth Reef, Tasman Sea, Australia

Elizabeth reef is one of the southernmost coral reefs in the world. Located at approximately 30°S latitude in the Tasman Sea, this atoll is situated near the southern limit of environmental tolerance for reef formation. The atoll has a well-developed outer reef flat encrusted with calcareous red algae and a lagoon consisting of patch reefs, sand flats, and a central mesh reef complex. A relatively small number or coral species occur, and significant coral growth is restricted to the lagoon. Offshore there is a well-developed erosional spur and groove zone (0 to 8 m), a deeper buttress zone (9 to 30 m), and a carbonate sand flat (30 to 40 m) before the steep seaward drop-off. Detailed evaluation of eleven rotary cores from the Elizabeth reef flat indicates that a period of more active coral growth existed in the past. C^{14} age dates on scleractinian corals from the cores indicate a maximum age of about 7,000 years B.P. in the upper 3 to 4 m of the reef flat with maximum accumulation rates of approximately 90 cm per 1,000 years. The atoll has reached equilibrium with sea level, and it is now influenced more by erosion than growth.

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Prediction of Caprock Seal Capacity