and Wyoming have received the most attention by both the Survey and prospective developers. Widespread Survey optimism on oil shale's viable future was emphasized by increased funding in 1981 for Conservation Division's enlarged monitoring and regulatory office in Grand Junction, an expanded research and resource appraisal program for Geologic Division, and for Water Resources Division's hydrologic studies. Deep drilling, coring, and hydrologic testing in the east-central Uinta basin, supported by Geologic, Conservation, and Water Resources Divisions, is currently under way. Environmental investigations related to oil-shale development and production are concentrated in Water Resources and Conservation Divisions along with associated regulatory responsibilities and interagency coordination. In Geologic Division, we are (1) providing basic geologic data to support the government's prototype oil-shale and by-product saline mineral leasing program; (2) continuing stratigraphic, mineralogic, geochemical, and resource appraisal studies; and (3) expanding the computer data base for oil-shale resources and the associated software for more flexible and varied information retrieval and display. We are convinced the enormity of the resource, its occurrence in a relatively small geographic area, and its potential national and international impact require comprehensive basinwide planning and development to achieve maximum recovery of the resource with minimum loss and degradation.

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Deposition and Penecontemporaneous Deformation of Sediments on a Faulted Submarine Slope, Hunters Cove Formation (Campanian-?Maestrichtian), Southwest Oregon

The Hunters Cove Formation is a 300-m thick, fining-upward sequence deposited above and perhaps also contemporaneously with Cape Sebastian Sandstone, a transgressive shelf sequence. Overall, the formation is fine-grained (sand:shale $<1:3$) and consists of thin, T(a)bc(de) turbidites, siltstone, and shale. Distinctive, thick sandstone beds exhibit varied sedimentary structures indicative of rapid sedimentation, soft-sediment deformation, and fluid-escape processes. These sandstones were probably deposited at a break-in-slope or canyon mouth, resulting in unstable-grain-framework sands susceptible to hydroplastic deformation, liquefaction, and fluidization.

The Hunters Cove Formation also contains small-scale slump zones and a thick slump breccia containing clasts of basal Cape Sebastian Sandstone, indicating that Hunters Cove deposition was contemporaneous with, and may have been initiated by, active faulting. This faulting is also suggested by small-scale penecontemporaneous faults and sheet and web structures. Hunters Cove deposition probably occurred on the edge of a small, fault-bounded, borderland-type basin. In particular, submarine-canyon and fan processes in the California Borderland, as described by Shepard, Dill, and others, may be modern analogies for it.

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Depositional Systems in Naknek Formation, Late Jurassic, Lower Cook Inlet, Alaska

The Naknek Formation is a thick wedge-shaped unit of Late Jurassic age. It accumulated along the western edge of a Jurassic fore-arc basin. The formation was examined by BP Alaska geologists along the western shore of Lower Cook Inlet between Chisik Island and Cape Douglas.

Correlation of stratigraphic sections has identified three sandstone/conglomerate sequences separated by two siltstone units. The conglomerate units are thick, lenticular, and occur as both organized and disorganized conglomerate facies. The sandstone units exhibit the following sedimentary structures and bedding types: (1) massive, graded, and amalgamated beds; (2) thickening and coarsening-upward sequences; (3) slump structures; (4) load and flute casts; (5) soft-sediment faulting; (6) rip-up clasts; (7) ripple lamination; and (8) minor cross-bedding. The siltstone units are parallel laminated and have thin sandstone beds with partial and complete density current sequences. Bioturbation is not common although some grazing burrows are present. Ammonites, belemnites, plant debris, and radiolarians are the most common fossils, although forams, gastropods, and pelecypods (dominantly *Buchia* sp.) are also present.

Previous workers have described the Naknet Formation as a shallow-marine deposit, but did not identify specific sedimentary facies. This study indicates that the Naknek Formation was deposited in moderate to deep water as a submarine fan complex.

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East Brentwood Gas Field: A Paleotopographic Trap

The East Brentwood gas field is located about 45 mi (72 km) east of San Francisco, California. The discovery well was drilled in 1978 by Depco, Inc. and completed in the Upper Cretaceous Third Massive sand at a depth of 8,050 ft (2,454 m). The Third Massive sand is a progradational sequence of sands with thin shale interbeds, interpreted to have been deposited in a near-shore, open-sea environment. The reservoir sand is dramatically truncated by the Meganos Gorge, a shale-filled fossil channel of Paleocene age. Faunal assemblages indicate that the cutting and filling of the gorge were submarine rather than subaerial.

The East Brentwood gas field is primarily controlled by the truncation of the basal part of the Third Massive sand by the Meganos Gorge shale fill with lateral closure afforded by several normal faults which divide the field into at least four separate producing blocks. Exploration mapping techniques, including seismic and well control, concentrate on the relation of the Massive sands to the basal Meganos Gorge configuration, the intersection of which essentially represents a buried paleotopographic surface. Exploration for updip sand termination against the shale-filled erosional gorge feature should result in the discovery of additional natural gas accumulations. Nine wells are presently completed in the gas field in which the better wells have over 250 ft (76 m) of net gas sand. The field has produced 19 bcf of 1,080 Btu gas and 50,000 bbl of 46° API gravity condensate since discovery. Field ultimates are expected to be in excess of 40 bcf and 100,000 bbls of condensate.

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Comparison of Wave-Dominated Deltaic Deposits and Associated Sand-Rich Strand Plains, Mesaverde Group, Northwest Colorado

The Mesaverde Group (Campanian) in northwestern Colorado is a thick (>700 m) clastic wedge that prograded eastward into the Western Interior seaway. Models of the main depositional systems in this group were constructed through the study of rock textures and physical and biogenic structures. The geometry of lithofacies was determined from outcrops and analysis of 250 electric logs in the Sand Wash basin. Lithofacies geometry and relations combined with the interpretation of inferred processes from sedimentary structures were used to develop depositional models.

The Mesaverde Group can be subdivided into wave-dominated deltaic deposits and their flanking sand-rich strand-plain, interdeltaic deposits. Deltaic headlands were approximately 20 km wide, while the strand plains extended downdrift for at least 60 km. Near deltaic depositional axes, multiple straight and meandering distributaries replace the upper part of the shoreface sequence. Fluvial plain deposits cap this sequence with point-bar sandstones, splays, overbank mudstones, and coals. In interdeltaic areas, progradational shoreface sandstones were deposited and are overlain by coastal plain brackish and freshwater deposits and coals. Marine flooding of the coastal plain was probably due to a combination of subsidence and formation of flanking lows adjacent to depositional axes due to loading.

The progradational shoreface is a coarsening-upward sequence 30 to 120 m thick. The sequence includes a basal bioturbated mudstone which becomes interbedded vertically with hummocky cross-stratified sandstones that are capped by an 18 to 60 m thick sandstone. The base of the thick sandstone contains hummocky cross-bedding that grades vertically into troughs that are capped with very low angle cross-bed sets.

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Mid-Cretaceous Black Shales: A Result of Excessive Fertility or Global Anoxia?

In Holocene marine environments, organic carbon accumulation rates are high in areas of high productivity, rapid deposition, and in anoxic basins. Heavy metal accumulation rates are high in areas of high bulk sedimentation (resulting from the large detrital component), in areas of high fertility (heavy metal enrichment in organic tissue), and in areas of hydrothermal activity. The various environments can be characterized by the relations between their bulk sedimentation rates, amounts and types of organic carbon in the sediment, organic carbon accumulation rates, primary productivity, preservation factors (fraction of organic carbon fixed in the photic zone that becomes buried in the sediment), and accumulation rates of heavy metals (such as Cu, Ni, Zn). Differences in these relations exist, in particular, between areas where sapropel deposition is due to high supply (i.e., high fertility in localized upwelling areas) and where it is due to anoxic deep waters (such as in the Black Sea).

Application of an improved calcareous nannofossil biochronology to compute accumulation rates in various DSDP sections show that the mid-Cretaceous black shales are characterized by substantially higher accumulation rates of heavy metals relative to organic carbon than is observed in Holocene upwelling settings. The implied widespread deep-water anoxia suggests high organic carbon preservation factors and correspondingly low primary productivity for large parts of the mid-Cretaceous oceans.

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Genetic Stratigraphy and Hydrocarbon Potential of a Combination Progradational-Retreating Barrier Island System

Depositional models and consequent stratigraphic "standards" are among the most valuable tools in scientific hydrocarbon exploration. Such models have been established for barrier-island systems based on extensive study of modern coastal areas. However, concepts of genetic stratigraphy have been developed only for the end members of the barrier-island spectrum, i.e., transgressive barriers (U.S. east coast type) and progradational barriers (Texas Gulf Coast type). Stratigraphic models for these pure types may be inadequate when exploration deals with ancient systems that fall towards the middle of the spectrum. Therefore, a different model must be developed for these intermediate types.

One such intermediate type of barrier-island system along the peninsular Florida west coast has been recognized and modeled by the author. Caladesi and Honeymoon Islands (just north of Clearwater Beach, Florida) formed at the end of the rapid Holocene sea-level rise by upward aggradation of an offshore bar. Subsequent development of the system has been episodic and complex in response to fluctuations in relative rates of sea-level rise and sedimentation. The resulting stratigraphy reflects alternating shoreline progradation (slow sea-level rise) and recession (fast sea-level rise). Laterally adjacent mud and sand environments are repeatedly superimposed on each other, producing an attractive sequence of source and reservoir lithology different from that of previously studied systems.

This stratigraphic framework can be recognized in subsurface cores and electric logs. This model can be used to identify position in a subsurface barrier-island system and to lead to hydrocarbon discovery.

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Geochemical and Mineralogical Analyses, Pennsylvanian Kendrick Fauna, Eastern Kentucky

The Kendrick brachiopods of Pennsylvanian age secreted low-Mg calcite shells with average Sr^{2+} content of 1,140 ppm. The crinoids and rugose corals secreted intermediate-Mg calcite skeletons with average Sr^{2+} contents of 2,140 ppm and 1,770 ppm, respectively. Conversely, the Kendrick mollusks secreted aragonite shells which contain less than 1,000 ppm Mg^{2+}. However, the average Sr^{2+} content (4,040 ppm for the cephalopods, 5,210 ppm for the gastropods, and 4,840 ppm for the pelecypods) is higher by a factor of about 2 over the average Sr^{2+} content of their Holocene counterparts.

The brachiopods, gastropods, and pelecypods precipitated calcium carbonate in oxygen (average −4.5 ppt, $\delta^{18}O$, PDB) and carbon (average +1.7 ppt, $\delta^{13}C$, PDB) isotopic equilibrium with ambient Pennsylvanian seawater. The crinoids and rugose corals are light in both $\delta^{13}C$ and $\delta^{18}O$ by about 5 ppt, relative to isotopic equilibrium values. This isotopic depletion, as in the crinoids' modern counterparts, probably relates to the incorporation of isotopically light metabolic oxygen and carbon at the site of calcification. In contrast, the Kendrick cephalopods apparently precipitated shell aragonite in oxygen isotopic (−4.5 ppt) equilibrium with ambient seawater, whereas their carbon isotopic composition (+0.5 to −5.4 ppt) is controlled possibly by kinetic effects.

The Fe^{2+} and Mn^{2+} contents of the fossil allochems and shale suggest that Kendrick seawater was slightly euxinic. In addition, the Na^{2+} content and oxygen isotopic composition indicate a slightly higher water temperature and hyposalinity for Kendrick seawater. Diagenetic alteration is limited to occlusion of pore spaces in the fossils and to compaction and cementation of the shale. This process probably occurred in the marine and/or submarine environment.

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