and mid-fan facies associations are common within the Yager; however, outer-fan depositional-lobe sequences are both rare and poorly developed, and basin-plain deposits are absent. Sandy mid-fan deposits typically grade into thin-bedded and poorly cyclic fan-fringe turbidites. It is likely that "normal" distal-fan facies associations failed to develop because of restricted basin geometries. (2) The regional distribution of turbidite facies and facies associations indicates that basin-fill sequences generally maintain good continuity along strike (northwest-southeast); the facies changes occur along transverse sections, and are, at least in part, temporally controlled. Thus, the basin-fill sequences appear to be elongate in a northwest-southeast direction, parallel with the dominant structural grain. (3) Thick sections of complexly folded mudrock are common within the Yager. These fine-grained strata, which include both hemipelagic shales and silty or muddy turbidites, are interpreted as slope deposits and are typically cut by lenses of coarse-grained, thick-bedded channel fill. The slope and channel sequences are nearly as prevalent as the sandy basin-fill sequences, which suggests that the Yager basins were not only restricted in size, but probably perched on an inclined, mud-covered slope.

Analogs for the Yager formation can be found along many modern subduction zones, where small, elongate basins typically form on the lower trench slope behind thrust-bounded or anticlinal ridges. Uplift of the ridges causes sediment-transport conduits (submarine canyons and slope channels) to become blocked; coarse detritus is thus trapped behind the ridges in a manner somewhat comparable to the salt diapirs which confine intraslope basins in the Gulf of Mexico.

Mean vitirinite-reflectance values for Yager shales near Garberville, California, are as high as 0.79%. Burial depths of as much as 6,000 m (19,700 ft) are indicated, using a geothermal gradient of 2°C/100 m. However, the depositional overburden associated with Neogene shallow-marine sediments of the Wildcat Group is estimated to be only about one-third the amount required. The additional overburden apparently resulted from mid-Tertiary thrusting along the Garberville thrust, a fault which marks the tectonic contact between Yager strata and melange of the Franciscan central belt terrane.

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Research Trends in Biostratigraphy

Paleontology, as applied in biostratigraphy, has long been an indispensable part of petroleum exploration. However, rapidly improving technology in many disciplines and the limitations of traditional biostratigraphy based on tops and zones dictate the need for an improved technology. In response to this need new approaches have been suggested, including probabilistic stratigraphy, geohistory diagrams, no-space graphs, isotopic and fission track dating, radiometric geochronology, tephrochronology, magnetostratigraphy, paleo-oceanographic geochemistry, and graphic correlation utilizing composite standards.

One example of a research program for the 1990s and beyond includes the development of a paleontologic composite standards and the interactive capability for their use by graphic correlation; the development of computer data bases for morphologic, taxonomic, paleoecologic and paleogeographic research and the interactive capability for synthesis, analysis and display; and, the development of time-based primary sedimentary models for prediction of geologic conditions ahead of the drill. Refined and stable taxonomic data supplied by highly capable paleontologists are a prerequisite for success. Such a program clearly requires management commitment of manpower and resources necessary to develop the technology, and it requires the development of effective technology transfer mechanisms to implement the results in exploration programs. The reward for success will be multifold improvement in our understanding of geologic conditions and history.

As with all exploration sciences, the present and future of biostratigraphy is the intelligent application of good paleontology to the solution of increasingly difficult geologic problems by constantly improving technology.

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Diagenetic Components Within Woodbine Formation, East Texas

The Upper Cretaceous Woodbine Formation contains diagenetic components in the form of cements and clays which can cause problems in drilling, completing, and stimulating a well. These diagenetic components are present in pore systems of the rocks deposited within various Woodbine depositional systems ranging from fluvial to deep marine. Fluvial environments were present in the northeast area of the East Texas basin, and changed to deltaic-marine systems to the south and southwest. Deeper marine sediments are represented by a thickening clastic wedge deposited over the Edwards reef trend as channels, interchannels, and submarine fans. It is necessary to identify mineral types, crystal morphologies, and modes of occurrence of the diagenetic components within pore systems of rocks formed in these various depositional settings so that proper drilling, completing, stimulating, and/or acidizing programs can be conducted.

Calcite, dolomite, ankerite, and quartz are important cements which reduce porosity and affect reservoir quality of the Woodbine Formation. Carbonate minerals occur as isolated patches or extensive cement within the intergranular network. Quartz cement is commonly observed in the form of euhedral overgrowths. The storage capacity of the reservoir and productivity of a well can be hindered where these cements reduce and isolate primary and secondary pores. During completion, stimulation, and possibly acidization, calcite may cause further problems through reaction with hydrofluoric acid and precipitation of formation-damaging calcium fluoride. Iron hydroxide precipitates may also form when iron-rich calcite, dolomite, and ankerite are contacted by HCl, HF, and HCl/HF acids. These precipitated gels can block pores and reduce production.

Important clay components found within the pore network of the Woodbine Formation are kaolinite and chlorite. Kaolinite commonly displays a pseudohexagonal "book" and platelet morphology. It is relatively stable with respect to acids; therefore, acidization should have minimal effect on the kaolinite. A problem of migration of fine particles can arise when these "books" and platelets are loosened from framework grain surfaces. Turbulence within pore networks, caused by fluid movement during stimulation and production, especially near the wellbore or a fracture face, can cause the kaolinite fines to move and block pore throats. This could result in formation damage. Chlorite occurs as well to moderately crystalline platelets which reduce porosity by lining and filling pore areas. If the chlorite is iron-rich and contacted by HCl, HF, and HCl/HF acids, a problem of iron hydroxide precipitation can occur.

Other clays within the Woodbine Formation include illite and smectite. Authigenic illite is found as incipient growths on chlorite platelets. The smectite has a honeycomb morphology and occurs as a grain coating. These components can cause problems if present in significant amounts within Woodbine reservoirs. If relatively fresh water is allowed to contact the formation, illite can "mush" and the smectite can swell, both damaging the formation.

Drilling, completing, stimulating, and acidizing programs can