Trace Fossil Assemblages as Indicators of Shelf-Sandstone Facies, Upper Cretaceous, Northwestern Colorado

Five facies of upper Mancos shelf-sandstones have been identified using sedimentary structures and subsurface data. Microfossil and subsurface studies suggest that all five facies were mid-shelf deposits, yet each of the facies has a distinctive trace fossil assemblage. The Low Energy Shelf Facies is intensely bioturbated by horizontal indistinct forms with some *Helminthoida*, "armored" burrows (*Diopatra*-like), *Terebellina* (plural curving tubes), and "donut" burrows. The intensely bioturbated lower Back Bar Facies contains abundant *Helminthoida* with common donut and some armored burrows, and *Trichichnus*. This grades vertically into the more diverse assemblage of abundant *Teichichnus*, *Terebellina*, "nest structures," and common *Thalassinoides* with some *Ophiomorpha*, armored burrows, and *Helminthoida* near the highly bioturbated top. The overall bioturbation drops dramatically in the Central Bar Facies in which *Teichichnus* and nest structures are the most common. *Ophiomorpha* and *Thalassinoides* are rare. The upper part of the Central Bar contains only rare *Ophiomorpha* and nest structures. The Ramp Facies, seaward of the Central Bar, contains only rare *Thlassinoides* and nest structures. The High Energy Shelf Facies is more diverse than the Low Energy Shelf and is moderately bioturbated with abundant *Ophiomorpha*, *Thalassinoides*, *Teichichnus*, nest structures, *Terebellina*, and armored burrows.

The distinctive trace fossil assemblages found in the five facies that were deposited on the mid-shelf suggest that physical energy and substrata characteristics control trace fossil distribution.

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Models for Deep-Water Sedimentation in Tectonic Basin: Stevens Sandstone, San Joaquin Basin, California

Observed relations between facies associations, sand-body geometries and submarine fan subenvironments commonly appear anomalous when facies interpreted from cores are compared with relations described by some currently popular fan models. Such anomalous relations were observed in cores from several fields producing from the Stevens Sandstone. To explain these inconsistencies an "on-lap" model and a "confinement" model are proposed for some of the observed depositional patterns of the upper Miocene Stevens Sandstones in the San Joaquin basin.

Along the eastern margin of the basin, where deposition occurred on a relatively undeformed homoclinal surface, patterns of turbidite sedimentation and facies associations generally conform to the Mutti and Ricci Lucchi submarine fan model. However, in the central and western parts of the basin the fan model is inappropriate.

The on-lap model describes turbidite deposits which lap onto and stack vertically against rising anticline structures. Internally these sand bodies exhibit distinct sedimentation cycles and facies associations characteristic of fan progradation. Externally these sand bodies pinch out crestward, may or may not be lobe- or fan-shaped, and tend to be abnormally thick. The Paloma field is an example of the on-lap model.

In the confinement model, turbidites are confined to bathymetric lows between adjacent (en echelon) anticlines. These deposits, which accumulated in synclinal lows, tend to have an external channel-like morphology but do not necessarily exhibit facies associations commonly ascribed to channels in fan models. Deep-water sediments from Yowlumne, Tule Elk, and Elk Hills fields are best described by the confinement model.

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Conditions Under Which Fractures Form and Create Conduits for Fluids

The underground occurrence of open extension fractures is important in petroleum exploration because the fractures provide plane conduits for the migration and storage of fluid. Extension fractures are considered to be natural hydraulic fractures that form like the artificial hydraulic fractures produced during well stimulation. Mechanics of natural hydraulic fracturing are discussed, so that the implications of the theory for the migration and accumulation of hydrocarbons are apparent.

Development of open extension fractures in the earth's crust is inhibited by gravitationally induced confining pressures; there should exist a depth above which extension fractures could form and below which faulting would be the dominant mode of failure. Mechanical considerations indicate that for the development of extension fractures on a regional scale this limiting depth is rather shallow—on the order of a few hundred meters to a few kilometers. Alternatively, mechanical considerations indicate that extension fractures could form locally in anomalously stressed regions at much greater depths if the ratio of pore fluid pressure to overburden weight approaches one. Thus, open extension fractures will be most likely to occur at depth in the earth's crust in places where the mean total stress is anomalously low, and where the pore pressure is anomalously high.

Fracture porosity depends critically on fracture aperture, and on degree of infilling with secondary mineral matter. Observed apertures of fractures are usually one to three orders of magnitude larger than that predicted by theory, suggesting that pressure solution is important to the aperture of fractures.

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Application of Biologic Markers in Combination with Stable Carbon Isotopes to Source Rock/Oil Correlations, Prudhoe Bay, Alaska

Novel biologic marker parameters are applied to problems of geochemical correlation of crude oils and source rocks in the area of Prudhoe Bay field, northern Alaska. The molecular structures used for fingerprinting the shale extracts, the kerogen pyrolyzates, and the crude oils are steranes, terpanes, and monoaromatized steranes. The major sources of the principal oil accumulations are shown to be the Shublik (Triassic), Kingak (Jurassic), and the deep post-Neocomian shales. In two of the three (Kingak and Shublik), the indigenous nature of the bitumen was proven by pyrolysis and quantitative biomarker data. Possible source rocks based on geologic reasoning and bulk geochemical data include the deep Kayak (Mississippian) shale, the shallow post-Neocomian, the Neocomian, and the Upper Cretaceous shales. However, all of these are shown by biologic marker techniques not to have generated the petroleum accumulations studied. Of the nine oils investigated, one (Kingak) rises from a single source (Kingak shale). The others have very similar source fingerprints using 10 different molecular and several bulk