Slope-Centered Processes in Santa Barbara Basin, California Borderland

Three basic types of slope-centered processes are responsible for the infilling of Santa Barbara basin: low-concentration suspenate transport, large-scale glides, and small-scale processes which consist of a continuum of slumps to debris flows. Suspensate transport is concentrated on the northeast part of the basin and is perhaps channeled by the Montalvo trough. Large-scale glides extend across the entire northern slope and are most spectacular in the Montalvo trough where higher sedimentation rates due to suspensate transport seem to speed the process. Small-scale slump to debris-flow deposits can be found at six specific sites. These deposits exhibit fluid escape structures, dish structures, a swirled x-radiograph signature, and in some deposits dramatic, matrix-supported, random fabrics with clasts as large as 4 cm. Laminations provide key markers necessary to discern distortion of sediment in areas of mass movement. The deep basin-floor laminated zone is laminated due to low oxygen content of the water column and deposition of gray layers due to suspensate transport during exceptionally rainy winters. Even parts of this laminated zone appear to be involved in gradual glides. In shallow parts of the basin on the northeast side, laminations are of a different type and are produced by years of suspensate transport. This laminated zone is centered along the axis of the Montalvo trough. High sedimentation rates apparently prevented destruction of the laminations due to bioturbation. Only a relatively small part of the deep basin floor, a flat area which slopes very gradually to the south, is somewhat immune to mass movement. However, fluidal flows generated by mass flows upslope could conceivably reach this area and result in unusually thick laminations.

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Shannon Sandstone (Upper Cretaceous) Offshore Bar Facies Distribution, Salt Creek Area, Wyoming

Four major facies are identified in the Upper Cretaceous Shannon Sandstone Member submarine bar complex where it crops out in the Salt Creek anticline area of Wyoming. The Central Bar (trough and laminated) Facies forms the backbone of the bars. This facies is quartzitic and glauconitic, fine to medium grained and is composed of stacked sequences of predominantly trough-bedded sandstones up to 35 ft (10.7 m) thick. A normal vertical (bottom to top) and lateral sequence of facies is Shelf Siltstone, Interbar, Bar Margin, Central Bar, Shelf Siltstone (burrowed). Shelf Silty Shales (bedded and burrowed) surround the bar complex. In general, the outcrop section is sandier than several of the bar complexes that produce in the subsurface about 35 mi (56.3 km) northeast of the outcrop. Two new subfacies are introduced, the Interbar (sandy) Facies and the Bar Margin (interbedded trough and ripple) Facies.

The mean direction of transport in the trough-bedded Central Bar and Bar Margin Facies in south-southwest, except locally in the top foot or two of the bar where westerly transport directions are observed. If the upper few feet are excluded, the spread of transport directions is commonly less than 45° for individual outcrops and for the area as a whole.

Foraminifera control indicates that the bar sands were deposited at middle-shelf depth. Ammonite zonation by Gill and Cobban provides detailed time stratigraphy and documents that the shoreline, at the time these bar complexes were deposited, was as far as 80 mi (129 km) to the west.

The Eagle sandstone delta complex of south-central Montana is a possible initial source for the sands. Nearly unidirectional currents, in part intensified by storms, are inferred to be the main process involved in deposition of the linear bar complexes.

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Early Paleozoic Conodont Biostratigraphy and Paleogeography of Northwestern Canada

Early Paleozoic rocks in northwestern Canada were deposited on a broad Atlantic type shelf and include platform carbonate rocks and transitional and basinal facies that range in composition from calcilutites to cherts. The Paleozoic history of northwestern Canada began with widespread deposition of Lower Cambrian quartzite and carbonate. In the Middle and early Late Cambrian, shales were deposited in deep troughs and continental areas separated by tectonic arches. During the latest Cambrian and Early Ordovician, platform carbonates were deposited on a broad shelf adjacent to a belt of deep water limestone. Middle Ordovician time was characterized by uplift to the north; carbonate deposition changed abruptly basinward into graptolite shales to the south. Late Ordovician-Early Silurian carbonate deposition on the platform graded basinward into shales and limestones.

The phosphatic microfossil *Mellopegma* occurs in Lower to Middle Cambrian basinal strata while conodonts of the Late Cambrian *Proconodontus* Zone are common to both the platform and the basinal strata. A nearly continuous sequence of Early to Middle Ordovician conodont faunas is found in the platform carbonate rocks. These Mid-Continent type faunas include the Early Ordovician faunas A to E of Ethington and Clark and the Middle Ordovician faunas 1 to 9 of Sweet, Ethington, and Barnes. Coeval basinal and transitional facies of Early and Middle Ordovician age are characterized by North Atlantic type conodonts and a few Mid-Continent forms that sharply decline numerically toward the basin. Late Ordovician conodonts are poorly represented in the platform facies; spot samples from transitional and basinal facies yield predominantly North Atlantic taxa.

Lateral and temporal distribution of conodont faunas from northwestern Canada closely resemble those of coeval faunas reported from the Ibex area of western Utah.

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Jurassic Sea-Level Changes From Seismic Stratigraphy

Two areas from the northern North Sea, the inner Moray Firth and the north Viking graben, contain sequences defined by seismic stratigraphic techniques which are indicative of Jurassic fluctuations in sea level. The seismic sequences involve Upper Triassic, Jurassic, and Lower Cretaceous strata. Ten sequences have been identified and their geologic ages are: (1) Rhaetian-Hettangian (198-189 Ma); (2) Sinemurian–early Pliensbachian (189-182 Ma); (3) late Pliensbachian-Toarcian (182-174 Ma); (4) Aalenian-Bajocian (174-165 Ma); (5) Bathonian (165-156 Ma); (6) Callovian (156-149 Ma); (7) Oxfordian-Kimmeridgian (149-141 Ma); (8) Tithonian–early Berriasian (141-133 Ma); (9) late Berriasian (133-131 Ma); and (10) Valanginian (131-126 Ma).

High stands of sea level are represented by the Rhaetian-Hettangian, Bathonian, Oxfordian-Kimmeridgian, and Tithonian–lower Berriasian sequences. Distinctive low stands are indicated by the lower Sinemurian, lower Callovian, upper Berriasian, and Valanginian sequences. The remaining sequences are defined by sea-level fluctuations of intermediate magnitude.

The sea-level fluctuations observed in the North Sea have been partly modified by structural activity. Their chronostratigraphic positioning, however, is thought to be caused by sea-level changes on a global scale. Charts of relative changes of sea level generated for the inner Moray Firth and the north Viking graben in the North Sea compare closely with similar charts from northwest Africa, the Gulf of Mexico, and other areas.

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Characterization of Regularly Interstratified Chlorite/Smectite Mixed-Layered Clay Using Combined Scanning Electron Microscopy/X-Ray Diffraction Techniques

Regularly interstratified chlorite/smectite (corrensite) is rarely found in hydrocarbon-bearing reservoir rocks as a dominant constituent of the clay mineral suite. However, several sandstone core samples, when subject to X-ray diffraction (XRD) analysis, were found to contain 46-100% of this mixed-layered clay mineral. The samples containing 100% corrensite permitted characterization of crystal morphology and mode of occurrence by use of scanning electron microscopy (SEM).

Corrensite was identified by XRD analysis because its characteristic basal reflections as the mixed-layered clay mineral responded to glycolation and heating treatment. This mineral consists of a 14A chlorite in a 1:1 relation with a 15A expandable smectite layer, yielding a total thickness of 29A. Glycolation expands the swelling smectite layer to 32.7A (001), 16.0A (002), 7.97A (003), and 5.91A (004).

The identification of corrensite as the dominant clay mineral of this reservoir rock is significant in that it has permitted: (1) characterization of the crystal morphology of this mixed-layered clay mineral by SEM; (2) the definition of a part of the pore-lining clays in a sandstone reservoir rock as water-sensitive due to the expandable smectite layers; (3) identification of chlorite within this mixed-layered clay so that proper completion fluids could be added to chelate the iron released if hydrocloric acid was used to stimulate the formation; and (4) differentiation of this type of corrensite from chlorite-swelling chlorite and chlorite-vermiculite, and other mixed-layered minerals to insure proper reservoir exploitation.

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Evolution and Stress History of Low-Permeability Upper Cretaceous Gas Reservoirs, Rocky Mountains

The physical properties of the Mesaverde gas reservoirs in Wyoming, Utah, Colorado, and New Mexico are the result of stress-induced changes that modified the sediment's original properties. Consideration of the stress history aids in interpretation of well log data and in understanding the reservoir performance that is controlled by natural or artificial fractures.

The poorly sorted and discontinuous reservoir sands were formed in a shifting nearshore environment in a region of nascent tectonic compression. Rapid sedimentation induced compaction and diagenesis, and later Tertiary burial continued compression and promoted some thermal stress. Laramide wrench-faulting could cause early shear fractures; a later uplift-reburial-uplift sequence, together with episodes of extensional tectonics, could promote tensional fracturing and a re-orientation of fractures and other structures in the well-indurated sediments.

Reservoir style is a result of several aspects of basin history, e.g., the depth of Tertiary burial in the Green River versus the San Juan basin. The regions considered are now generally inactive seismically, and there has been very little igenous activity since Cretaceous time, as contrasted to most nearby areas in the Rocky Mountains.

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Applied Petrophysics—Case History

Although the term "petrophysics" was defined by G. E. Archie in 1949, application of petrophysical approaches and techniques to exploration projects has been minimal during the past 30 years. This paper documents the application of varied petrophysical techniques to a field study and illustrates the integration of data to form a detailed interpretation of the reservoir.

Cut Bank field is a giant oil and gas field located on the west flank of the Sweetgrass arch in north-central Montana. Production is from the Lower Cretaceous Cut Bank Sandstone, which was deposited in a braided fluvial system.

Porosity versus permeability cross-plots of core data indicate a wide range of different rock types within the Cut Bank Sandstone interval. Capillary pressure curves, X-ray diffraction analyses, scanning electron micrographs, and thin section evaluation further define the rock types and document pore geometry differences. An Sw versus height-above-sea-level plot indicates field-wide pressure communication with a common water-oil