Sunbury Shale of Central Appalachian Basin—Depositional Model for Basinal Black Shales

A model for the deposition of basinal black shales and associated base-of-slope turbidites is established in the central Appalachian basin. The model is based on an outcrop and subsurface stratigraphic study of the thin, but extensive Lower Mississippian Sunbury black shale. This model is termed the Sunbury cycle and it provides an explanation for the geometrid relations observed between basinal black shales and laterally adjacent gray/green slope shales and siltstones.

Two genetic types of black shales are recognized—transgressive and regressive. The transgressive black shale is the basal unit that initiates the cycle. Characteristically thin and widespread, it was deposited in the anaerobic zone of a stratified water column. Its sharp basal contact represents the rapid migration of the anaerobic environment over base-of-slope and slope deposits. This is caused by an increase in the subsidence rate of the active basin, decrease of clastic influx, and a minor rise in sea level. The regressive black shale overlies the basal unit. It is thicker, more laterally restricted, and represents the distal facies of base-of-slope turbidites formed by a progressive increase of clastic influx and a decrease in the subsidence rate of the basin floor. The thick regressive black shale and laterally adjacent non-black clastics represent facies of a continuous unit (base-of-slope turbidites) containing varying amounts of preserved organic material. The degree of organic preservation is the result of deposition in zones of varying oxygen content caused by the intersection of the stratified water column with the basin floor.

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Seismic Stratigraphy of Modern Carbonate Slope

Based on analysis of 1,350 km of high resolution, 5 cu in. air-gun and 3.5 kHz seismic reflection profiles, as well as 30 piston cores, the open ocean, windward, deep carbonate bank margin north of Little Bahama Bank has been divided into upper and lower slope facies. The seismic character of the post-Paleocene upper slope unit (200 to 1,000 m water depth) consists of a low-energy slope-front fill facies characterized by parallel to subparallel reflectors that downlap onto a regional unconformity near the Paleocene-Eocene boundary. Sediments of this upper slope facies are interpreted to be primarily fine-grained pelagic carbonates. In contrast, the post-Paleocene unit on the lower slope (1,000 to 1,300 -m water depth) consists of a variable energy chaotic-fill facies characterized by hummocky/discordant to wavy subparallel reflectors. Sediments of this facies are interpreted as coarse, high-energy mass transport deposits such as turbidites and debris flows. Detachment scars on the upper slope and erosional gouge on the lower slope indicate that submarine slides and sediment gravity flows originated on the upper slope. The sediment gravity flows have bypassed the fine-grained upper slope facies via numerous evenly spaced small canyons, which act as a "line source," and were deposited at the base of the slope in a broad "apron" rather than a fan. The seaward transition in the lower slope chaotic fill facies from hummocky/discordant to wavy subparallel reflectors suggests that the sediment gravity flows become thinner and more "distal" seaward. Recurrent faulting and oversteepening of unlithified carbonate slopes are believed to be responsible for the generation of mass movements. Similar facies relations should be recognizable in the rock record. In terms of hydrocarbon exploration, the coarse, lower slope sediment gravity flow facies would appear to have the greatest reservoir potential.

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Geochemical Prospecting for Hydrocarbons in Navarin Basin Province

The Navarin basin province, which lies beneath the northwestern Bering Sea shelf, is a large (45,000 sq km) frontier area for petroleum exploration. Our preliminary geochemical survey of this province measured hydrocarbon gases in near-surface sediments in search of evidence for the possible occurrence of petroleum. Hydrocarbons (methane through butanes) were analyzed from sediment samples taken at a depth of 1 m from cores collected during the summer of 1980 at 32 stations spaced approximately 50 km apart. In addition, samples at the same depth were analyzed from five stations spaced about 5 km apart over a shallow acoustic anomaly. All samples analyzed contained hydrocarbon gases, but none had significant amounts of hydrocarbons of obvious thermogenic (petroleum-related) origin. At only two stations on the shelf and one on the slope were concentrations of methane and ethane significantly above background values, whereas those of propane and the butanes were not. Concentrations of methane and ethane were 5 to 9 and 10 to 20 times, respectively, higher than background values, and ratios of ethane to ethene of 6, 30, and 25 were unusually large relative to background values of about 1. The ratios of methane to ethane + propane of 100, 140, and 180, and the large ratios of ethane to ethene, suggest that some thermogenic hydrocarbons are present. Although petroleum is potentially present at depth in the Navarin basin province, our preliminary survey did not detect surface hydrocarbon-gas anomalies that would unequivocally signal its presence.

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Subduction-Related Structure Along Eastern Aleutian Trench

Along the eastern Aleutian Trench between Kayak and Sanak Islands, the trench, magmatic arc, and active Benioff zone define a modern convergent margin 13,000 km long. The structures developed during the past 10 to 15 m.y. show the deformation associated with subduction. Fore-arc basins have been formed on pre-Neogene rock that was presumably accreted, uplifted, and then locally depressed. Structures in the basins are compressional near the shelf edge and extensional farther toward the arc. The trench lower slope is underlain by rocks that are coeval with those in the fore-arc basin, but are deformed as a result of subduction. Despite a uniform convergence history, the margin has marked structural variations along strike that reflect local non-tectonic influences on structural style. The structure could be influenced by a variety of geologic variables such as sediment volumes on the slope, in the trench, and on the ocean crust, and perhaps by the morphology of the igneous ocean crust. Although we have not yet successfully reconciled all the effects of local variation on structural style, a comparative study of these styles and local features can help define kinematic processes associated with plate convergence.

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Environments and Dynamics of Clastic Sediment Dispersal Across Cambrian of Grand Canyon

The transgressive Grand Canyon Cambrian contains basal fluvial sands (Tapeats Sandstone) and overlying shallow marine sands and shales (Bright Angel Shale) in which textures and structures permit a detailed reconstruction of clastic sediment dispersal across a broad cratonic margin.

Dominantly trough cross-bedded basal Tapeats Sandstone, containing buried regolith in bed-rock depressions, a low-variance, unimodal paleocurrent trend down the regional paleoslope, and well to moderately sorted medium to coarse-grained sands, records pre-vegetation bed-load fluvial sedimentation. Bed-load sands (>200 mμ) mature from arkosic to orthoquartzitic within 5 to 10 m of the base. Finer, suspension-transported sands remain subarkosic through the entire 250 to 500 m of Cambrian section implying rapid dispersal.

The Bright Angel Shale is composed of shallowing upward sedimentary cycles 1 to 6 m thick. Lower parts of the cycles are thinly interbedded fine sand and shale layers whose sedimentary structures and textures record level-bottom storm resuspension, dispersal, and deposition (sand layers) alternating with quiescent periods of finer silt and clay dispersal and accumulation. Bed-load transported sands are absent. Sand bed thickness up to a maximum (5 to 20 cm) represents variation in storm intensities with maximum thicknesses controlled by water depth, which limits volume in suspension.

Upper parts of cycles are cross-laminated fine sands with glauconite and U-shaped or vertical burrows. These represent shoaling phases with increased bottom agitation, decreased sedimentation rate, and winnowing bypass of silts and clays. Organism structures, tadpole ripples, and rare mud cracks record shallowing.

Cycle caps are 1 to 20-cm thick layers of medium to very coarse quartz sand, hematitic ooids, phosphatic, and dolomite cemented clasts that record phases of emergence and complete bypass of all suspension load.

Recently recognized dunes 3 to 5 m in height provided bed load dispersal at the close of sedimentation cycles. Structures and textures suggest dunes are eolian.

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Holocene Tepees and Stromatolites from Southern Australia and Their Paleohydrologic Significance

Along the southern coastline of South Australia, coastal salinas were created by the stabilization of the late Pleistocene-Holocene sea approximately 6,000 y.b.p. In these isolated seepage depressions stromatolites (millimeter laminated), algal tufas, tepees, and other fenestral crusts and mounds constitute a marginal aragonite facies. The fenestral limestone crusts 10 to 30 cm thick) are underlain by a highly porous, open boxwork limestone.

During late winter and spring the water table is high in the calcreted, Pleistocene calcarenite dunes which surround and underlie the salinas. Consequently the hydraulic gradient between the dune and the salina is steep; meteoric-influenced ground water seeps into the salina margin. Waters driven by this ground water head seep into the boxwork beneath the crusts and are confined by this crust aquitard. The pressure causes the crust to expand and become slightly concave. During the late summer and autumn, the dune water table and associated hydraulic gradient are lower by the processes of evapotranspiration. Concentration of the salina waters and lowering of the salina water level causes a lowering of the

crust. This lowering is coincident with passive and neomorphic precipitation of aragonite on and within the crust. The alternate lifting and falling of the crust in conjunction with aragonite deposition during the falling stage cause a seasonal increment in crust size. As the crust is laterally confined by the calcreted dunes, overthrusting of the crust occurs and tepees are formed.

Millimeter layered indurated stromatolites, growing millimeter laminated algal mats and poorly laminated algal tufas (including *Conophyton*-like tufas) all form in this schizohaline zone. The breaking of the crust along megapolygonal overthrust zones creates zones of pressured ground water upwelling that commonly control the three-dimensional distribution of stromatolites and tufas. In some marginal zones of Marion Lake stromatolites are only found atop tepee crests. All finely laminated stromatolites probably grew up to the ambient water level.

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Casablanca Field, Offshore Spain—Paleogeomorphic Trap

The Casablanca field, the largest of four producing fields in the Spanish Mediterranean, is located about 50 km south of Tarragona. Using the Halbouty classification in AAPG *Memoir 16,* the field is a "paleogeomorphic trap."

The field is producing 18,000 BOPD from two wells in an "early production phase." The crude has an API gravity of 33.7°, sulfur content of 0.2%, and a GOR of 155 cf/bbl. Full field production of about 35,000 to 40,000 BOPD will start in 1983 after a platform is installed.

The reservoir is a weathered and fractured Upper Jurassic