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.

WARREN, JOHN, Univ. Texas at Dallas, Richardson, TX

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.

WATSON, HILREY J., Chevron Oil Co. of Spain, Madrid, Spain

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 carbonate rock. The primary matrix porosity averages about 3%. However, weathering during the early Tertiary enlarged fractures and previously existing porous zones to a depth of 100 to 150 m below the top of the carbonate rocks. This secondary porosity, in combination with an extensive fracture network, has converted the otherwise dense carbonate rock into a commercially exploitable reservoir.

A contour map on the top of the eroded Mesozoic carbonate reservoir defines a closure 11 by 2.5 km. The field is elongated parallel to and bounded by Miocene faults with an overall configuration of a rounded limestone ridge.

The ridge is covered by middle Miocene organic rich shales, the oil source. These and younger shales cap the accumulation.

The use of a paleogeomorphic model aids the interpreter in mapping data in the Casablanca area which otherwise would seem uninterpretable, or at least difficult to interpret. The model may be of use in other carbonate areas.

WEAVER, FRED M., Exxon Production Research Co., Houston, TX, and RICHARD E. CASEY and ANNA MARIA PEREZ, Rice Univ., Houston, TX

Stratigraphic and Paleo-Oceanographic Significance of Early Pliocene to Middle Miocene Radiolarian Assemblages from California to Baja California

Comprehensive studies of radiolarian faunal assemblages recovered from outcrop sections at Centerville Beach, Newport Back Bay, Palos Verdes Hills, and Chalk Hills in California and at Bahia Tortugas and Maria Madre Island, Baja California, provide the data base for regional paleo-oceanographic and stratigraphic analyses of Monterey and associated siliceous sediments of middle Miocene to early pliocene age within Neogene California marginal basins.

The sequential succession and development of characteristic radiolarian assemblages and the temporal and spatial variance in environmentally sensitive species in Luisian, lower and lupper Mohnian, and "Delmontian" sediments provide significant insight to regional paleo-oceanographic evolution. Documentation is provided by interpretation of paleoclimatic trends, variation in sediment accumulations rates, changes in water-mass interaction and distribution, and upwelling and productivity events.

Stratigraphically important species of radiolarian genera such as *Theocorys, Lamprocyrtis, Stichocorys, Diartus, Eucyrtidium, Cyrtocapsella,* and *Botryocyrtis* are used to differentiate potential biohorizons which are useful for inter- and intra-basinal and broad regional correlations. Within key intervals, radiolarians provide accurate identification of the low latitude *Dorcadospyris alata* and *Diartus petterssoni* Zones in lower Monterey formation sediments.

WEIMER, ROBERT J., Colorado School Mines, Golden, CO

Relation of Unconformities, Tectonics, and Sea Level Changes, Cretaceous of Western Interior, United States and Canada

Intrabasin tectonics have influenced patterns of deposition and geographic distribution of major unconformities within the Cretaceous of the Western Interior. Eight major regional to subregional unconformities have been identified. Five of these have been related by previous workers to sea level changes and to well-documented regressive-transgressive cycles.

New studies of recurrent movement on basement-controlled fault blocks suggest a synchronous relation among fault block movement, sea level changes, and unconformities. Which fault blocks moved on the basin floor, and when, can be explained by stress fields generated by direction and rates of plate motion. Unconformities associated with north-northwest fault trends are caused by more westerly movement, and those associated with east-northeast trends by more northerly plate motion. Expansion of the Gulf of Mexico, the Atlantic Ocean, or the Arctic Ocean during these plate motions may account for associated sea level changes. The 81 to 82 m.y. unconformity and shoreline regression in the Western Interior and synchronous volcanic events on the northern margin of the Gulf of Mexico illustrate the relations.

Uncertainty exists in dating many of the unconformities. However, by use of the time scale of Obradovich and Cobban, the approximate dates for unconformities are estimated as follows: (1) late Neocomian to early Aptain, >100 m.y.; (2) late Aptian–early Albian, 100 m.y. ±; (3) Albian, 96 to 97 m.y.; (4) early Cenomanian, 93 m.y. ±; (5) Turonian to early Coniacian, 87 to 88 m.y.; (6) late Coniacian–early Santonian, 81 to 82 m.y.; (7) late Campanian 71 to 74 m.y.; and (8) late Maestrichtian, 64 to 69 m.y.

Several billion barrels of oil have been found in sandstones associated with unconformities in the Cretaceous. Future stratigraphic trap exploration will be guided by a knowledge of tectonic influence on sedimentation during sea level changes and how these factors controlled distribution of source rock, migration patterns, reservoir rock, and seal.

WELDER, FRANK A., U.S. Geol. Survey, Meeker, CO

Ground-Water Potential for Oil Shale Development in Northwestern Colorado

Rocks in northwestern Colorado contain large amounts of oil shale which constitutes perhaps the richest hydrocarbon resource in the United States. Efforts to develop oil shale will increase demand for water in a region where surface water is fully appropriated. To meet additional water needs associated with industrial and population growth, sources of ground water need to be investigated.

It has been 15 years since investigators determined that large quantities of ground water occur above, within, and below rich oil shale deposits in the Eocene Green River Formation in the Piceance basin of northwestern Colorado. Estimates of the amount of ground water stored in the Piceance basin are as much as 25 million acre-ft. The specific conductance of ground water discharged during the drilling of 24 test holes ranged from 100 to 50,000 micromhos per cm at 25°C.

Another potential major source of ground water in northwestern Colorado may be the Leadville Limestone of Mississippian age. Solution cavities in the outcrop of the Leadville Limestone in northwestern Colorado indicate that the formation may store and transmit large quantities of water. Where fractured and near the surface, the Leadville Limestone has been exposed to ground-water movement, resulting in the development of solution cavities that have enhanced the hydraulic conductivity and storage capacity of the aquifer. Where the Leadville is exposed on or near various structural uplifts in northwestern Colorado, the opportunity for ground-water recharge, movement, and storage may be extensive. Other potential aquifers such as the Dakota Sandstone and the Entrada Sandstone are also under consideration.

WELTE, D. H., and A. YUKLER, Kernforschungsanlage Julich GmbH, Julich, West Germany