chlorite in red beds. Reduction and dissolution of hematite pigment in red beds may have supplied the necessary iron.

ALAN THOMSON, Shell Development Co., Houston, Tex.

SOFT-SEDIMENT FAULTS AS INDICATORS OF PALEOSLOPE ORIENTATION

The Tesnus Formation in the Marathon region, Texas, consists of interbedded sandstone turbidite and shale of a late geosynclinal filling phase. Deposition was on an unstable slope as indicated by the occurrence of deformational features of preconsolidation origin including rolled sandstone bodies (tens of feet long), sandstone dikes (up to 1 in. wide and 5 ft long), diapiric structures, and numerous normal faults of small displacement.

Throw on these microfaults is less than 1 in. and averages 0.25 in. The displacement is seen only on the undersides of sandstone beds and cannot be traced through the beds in which they occur. The faults intersect the base of beds at an average angle of 55° from the base, whereas most fractures of postconsolidation origin are oriented normal to the base. The measured intersections with the base of beds of 100 faults show that their mean orientation is 97° to the direction of paleoslope as indicated by flute casts. The standard deviation is 15°. Hence, the faults generally parallel paleoslope contours. Of hundreds of faults examined, more than 95% were downthrown down the paleoslope.

Each individual fault has a fault zone less than 1 mm wide. Petrographic evidence for a soft-sediment origin includes (1) boundaries between fault zones and country rock are not sharp, (2) fractured grains are not present in the fault zones, and (3) all healed fractures of postconsolidation origin cut the fault zones.

Soft-sediment faults have been found useful for providing current directions for sole markings, such as groove casts, which normally give only orientation. If used carefully, the faults also can provide paleoslope information where sole markings are absent.

DONALD C. THORSTENSON, Dept. Geology, Northwestern Univ., Evanston, Ill.

PORE-WATER CHEMISTRY OF CARBONATE SEDIMENTS FROM HARRINGTON SOUND, BERMUDA

The interstitial waters of some anaerobic carbonate mud from Harrington Sound, Bermuda, have been analyzed for several organic and inorganic chemical species. The pore-water chemistry is controlled by production of these species because of the action of anaerobic bacteria on organic matter in the sediment.

Interstitial waters from a series of shallow cores (approximately 1 m) were analyzed for the following aqueous species: pH, HCO_3^-, $SO_4^=$, NH_4^+, HS^-, CH_4, N_2, Ca^{+2}, Mg^{+2}, and SiO_2. The insoluble organic matter was analyzed for organic C and N. Some observed concentration ranges are NH_4^+:O to 1 meq/l; HS^-:O to 1 meq/l; HCO_3^-:2.7 to 8.0 meq/l. The decrease in $SO_4^=$ concentration varies from 0 to 2 meq/l. The abundance of all the dissolved organic species consistently increases with depth, with concurrent decreases in pH, $SO_4^=$, Ca^{+2}, and Mg^{+2}. The C:N ratio in the metabolized organic matter is approximately 8. The ratio of CO_2/H_2S introduced into the pore waters is 5. This cannot be explained solely by the action of sulfate-reducing bacteria.

The data are consistent with a theoretical model of organic decay in a closed chemical system, in which the components of the aqueous phase maintain near-equilibrium with the minerals present.

RODERICK W. TILLMAN, Sinclair Oil Corp., Tulsa, Okla.

CARBONATE FACIES AND PALEOGEOGRAPHY OF ROBINSON MEMBER, MINTURN FORMATION, EAGLE BASIN, COLORADO

The Robinson Limestone Member is one of eight carbonate members of the 5,000 ft thick, predominantly sandstone, Minturn Formation (Desmoinesian) in the study area west of the Gore Range in Central Colorado. The Robinson Limestone Member consists of three limestone units (lower, middle, and upper) interstratified with marine and nonmarine sandstone beds. Total thickness of the Robinson ranges from 200 to 400 ft.

The areal distribution and the thicknesses of four time-transgressive facies which make up each of the Robinson limestone units imply an asymmetrical deposition basin with a relatively deep marginal trough along the east side.

From east to west the facies are (1) an oölite facies composed of superficial oölites, pseudo-öolites and oncolites in micro-spar or micrite; it is interpreted to be a shallow-water, high-energy deposit on the east edge of the marginal trough; (2) a tubular foraminiferal facies composed mainly of tubular Foraminifera micrite; (3) a phylloid algae facies of biomicrite containing abundant *Archaeolithophyllum*, *Eugonophyllum*, fusulinids, and *Komia;* the phylloid algae facies is interpreted to be a deeper water deposit near the middle of the trough; (4) a stromatolite facies of stromatolites, laminated micrite, and vuggy ostracod-bearing intramicrudite, which indicate quiet-water deposition near the western margin of the trough. The overall patterns of the limestone facies and sandstone beds indicate intervals of rapid marine transgression followed by relatively slow depositional regression.

Bioherms as thick as 80 ft are in the areas of phylloid algae and stromatolite facies. Nonphylloid algae appear to be the major components of these bioherms. However, recrystallization and dolomitization make recognition of the algae types difficult.

ELAZAR UCHUPI, K. O. EMERY, S. T. KNOTT, C. O. BOWIN, JOSEPH PHILLIPS, K. E. PRADA, and E. T. BUNCE, Woods Hole Oceanographic Inst., Woods Hole, Mass.

CONTINENTAL RISE OFF EAST COAST OF NORTH AMERICA: SHALLOW STRUCTURE

The continental rise off the east coast of North America is a broad sedimentary apron 200–500 km wide, 1,200–5,200 m below sea level, with an average gradient of less than 1°. Continuous seismic-profiler recordings indicate that the rise is a prism of sediments lying on a strong and nearly level reflecting layer known as Horizon A. This horizon is believed to be the top of a turbidite sequence delineating an abyssal plain that covered most of the North American basin near the end of the Cretaceous Period. Progradation of the overlying Cenozoic sediments of the continental rise has decreased the width of this Cretaceous abyssal plain by as much as 200 km.

Sediments of the continental rise range in thickness from about 3 km at the base of the continental slope to several hundred meters along the seaward edge of the rise where it joins abyssal plains. Through most of its length the sedimentary sequence is separated from the continental slope by an unconformity. Seismic-profiler data reveal many examples of deformation within the rise due to slumping and gravitational sliding. The lower continental rise hills located at or near the rise-abyssal plain contact probably are the toes of these structures.

LOUIS O. VIDRINE, Louisiana Land and Exploration Co., New Orleans, La.

DEEP MIOCENE IN SOUTHEAST LOUISIANA

Deep Miocene sediments strike east-west across southeast Louisiana. Generally, regional dip and total thickness of sediments increase southward. Deep Miocene hydrocarbon traps include deep-seated and piercement salt domes, faultline closures, and combination structural-stratigraphic phenomena. Drilling below 15,000 ft indicates two major, distinct east-west trends in the southern parts of Terrebonne and Lafourche Parishes. The northern trend is essentially an alignment of faultline structures with upthrown and downthrown production; the deep producing sediments are in the strata of the *Cibides carstensi* zone. The southerly trend is a series of salt domes and related down-to-the-north faulting; deep production is downthrown and from the *Textularia* "L" zone. Recognition of these trends will become more difficult as they are extended.

Some deep tests have been disappointing failures because they were located on young structures. Others have found buried faults and related deep sandstone which encourage additional drilling. Production possibilities from stratigraphic pinchout traps have been indicated in several areas, but economic factors of deep drilling inhibit this type of hydrocarbon exploration.

The limits of deep Miocene prospecting and production are imposed by technological and economic considerations. Production has been found below 21,000 ft and sandstones capable of producing may be projected to 30,000 ft and deeper. Prospecting above 17,000 ft has proved to be profitable, but at greater depths the economic potential is reduced by greater risks and costs.

GLENN S. VISHER, Univ. Tulsa, Tulsa, Okla.

PHYSICAL CHARACTERISTICS OF FLUVIAL DEPOSITS

The physical processes of sediment transport and deposition by confined unidirectional flow are produced only in a fluvial environment. The physical properties resulting from these processes provide unique criteria for recognition of fluvial deposits. Characteristic physical properties include (1) surface texture, (2) particle shape, (3) texture, (4) fabric, (5) sedimentary structures, (6) bedding, (7) sequence of structures, bedding, and textures, (8) scour surfaces, and (9) local and regional geometric patterns. Other aspects, including mineralogy, detrital clasts and fragments, physical character of the associated sediments, and fauna and flora, may aid in the identification of fluvial environments.

Point-bar deposits resulting from channel migration are the most commonly preserved type of fluvial sandstone bodies. These geomorphic features are nearly universal in all meandering streams, and they control clastic deposition. The commonly developed sequence of festoon, current-laminated, and ripple cross-bedded sedimentary units is developed in response to flow across point bars. Other types of fluvial sand bodies, such as those deposited in alluvial fans, braided streams, and deltaic distributaries, exhibit many fluvial characteristics, but they lack the sequence of sedimentary structures related to point-bar deposition.

Unidirectional currents produce characteristic grain-size distributions, which suggest a predominance of saltation and suspension modes of particle transport. Current transport produces elliptical-shaped particles with smooth surfaces. Detrital clay clasts commonly are preserved, many altered to clay-ironstone concretions. Minerals chemically stable in fresh, oxidizing, slightly acid water are commonly characteristic, such as kaolinite, feldspar, and ferric iron. The absence of other minerals such as calcite, glauconite, and ferrous iron compounds is significant.

The external geometry of fluvial deposits is probably the least characteristic physical attribute. Individual outcrops may not show channeling, and fluvial sand bodies may be of a blanket type. Boundaries of channels, however, show abrupt pinchouts, commonly within a few hundred feet. Trends of sand bodies in connection with paleocurrent and slope indicators provide strong supporting evidence for identifying fluvial environments.

ROLAND E. VON HUENE and DAVID W. SCHOLL, Office of Marine Geology and Hydrology, U.S. Geol. Survey, Menlo Park, Calif.

TECTONIC IMPLICATIONS OF STRUCTURES IN STRATIFIED SEQUENCES AT BASE OF PACIFIC CONTINENTAL MARGINS[1]

During the past decade many geo-scientific discoveries suggest that continental margins are regions of extensive thrusting. Seismologic data establish that earthquake hypocenters are contained in a tabular volume of rocks that plunges steeply landward below the seaward edges of continents. First-motion studies of these earthquakes indicate a convergence of continental and oceanic crusts. On land, coastal areas of extensive thrust faulting are becoming known. These data support the hypothesis of ocean-floor spreading which requires extensive thrusting of oceanic crust beneath the continents. This hypothesis and the seismologically defined thrust zone imply that profound compressional deformation should take place at the base of continental slopes.

Structures produced by compressional forces are not observed in seismic-reflection records of the sediments filling marginal trenches or in sediments tilted against the continental slope during development of the trenches. Continental rises also consist of undeformed strata. Only deformation from subsidence and slumping has been seen at the foot of the continental slope from southern Chile to the outer Aleutian Islands. The observations of little or no thrusting at the juncture of the upper continental and oceanic crusts are now numerous and well established. These data must also be

[1] Publication authorized by the Director, U.S. Geol. Survey.