GORTER, J. D., Pancontinental Petroleum Ltd., Sydney, New South Wales, Australia, and ROBERT S. NICOLL, Bur. Mineral Resources, Canberra City, ACT, Australia

Interpretation of Conodont Color Alteration and Thermal Maturation in Amadeus Basin, Central Australia

The Amadeus basin of central Australia contains about 11,500 m (38,000 ft) of late Proterozoic to middle Paleozoic (Late Devonian) sediment, generally thickening northward across the basin toward the MacDonnell Range. A complex series of anticlinal structures, some of them fault-bounded, in the north-central part of the basin contains accumulations of hydrocarbons in sediments of Early Ordovician, Cambrian, and late Proterozoic ages. Hydrocarbons have been produced from the Ordovician in two fields, the Palm Valley gas field and the Mereenie gas and oil field.

Study of conodont color alteration to define organic maturation levels and trends is based principally on samples collected from the Early Ordovician (Arenig) Horn Valley Siltstone from both outcrop and subsurface localities. Additional faunas have been recovered from the overlying Early-Middle Ordovician Stairway Sandstone and Stokes Formation.

The conodont color alteration isograds in the Amadeus basin appear to be primarily related to events of the Alice Springs orogeny, when the thick mass of molasse sediments (Pertnjara Group) resulting from erosion of the uplifted Arunta Block was deposited. Anomalies to the conodont color isograds appear to be related to erosion associated with the Rodingan orogeny and also possibly to the effects of salt structures.

GRADSTEIN, F. M., Geol. Survey Canada, Dartmouth, Nova Scotia, Canada, and W. A. BERGGREN*, M. J. KAMINSKI, and K. G. MILLER, Woods Hole Oceanographic Inst., Woods Hole, MA

Paleobathymetry of Late Cretaceous-Paleogene Agglutinated ("Flysch Type") Benthic Foraminiferal Faunas and a Modern Analog

A diverse (~ 30 genera, >50 taxa) fauna—the so-called "flysch type," or A assemblage-with definite taxonomic affinities to contemporaneous assemblages from the Alpine-Carpathian flysch basin, has been recognized in Upper Cretaceous to Paleogene deposits in geologic trench and graben type basins and in the deep sea from lat. 65°N to 65°S. This assemblage consists of (predominantly) coarse-grained, larger sized tests, in which simple (*Rhabdammina, Bathysiphon, Ammodiscus*) forms predominate over biserial (*Spiroplectammina, Textularia*), multiserial (*Gaudryina, Dorothia*), trochospiral (*Recurvoides, Trochammina*), and planispiral (*Cyclammina, Cribrostomoides, Haplophragmoides*) forms. Paleobathymetric interpretations of these assemblages range from continental (lacustrine, paludal, tidal flat, fluviatile lagoonal) to marine (neritic, upper bathyal, middle to lower bathyal, abyssal; i.e., 0 to 5,000 m, 0 to 16,404 ft). Several lines of evidence now converge to place constraints upon, and realistic estimates of, the paleobathymetric range of this assemblage: (1) backtracking DSDP sites on oceanic crust leads to paleodepth estimates ranging from >2.5 km to >4 km; Cenozoic shallow ridges in the Norwegian-Greenland Sea yield upper values of >0.7 km; (2) the association of several components of these assemblages (*Trochammina, Cyclammina, Bathysiphon*, etc) in various stratigraphic sections (such as the Lodo Formation, California) with other, clearly "shallow" faunal indicators (*Cibicides, Nonion, Eponides*, etc) indicates upper depth limits near the shelf/slope break at least, in some cases; (3) seismic stratigraphy indicates updip extension of this biofacies close to, if not contiguous with, the distal parts of deltaic wedges in the North Sea.

Modern day distribution patterns of open-ocean agglutinated taxa show a rather clearly defined upper limit at about 500 m (1,640 ft) (in general agreement with our estimate of the upper depth limit of "flysch type" faunas based on geologic evidence).

There is a taxonomic resemblance of modern Newfoundland slope faunas to the flysch-type assemblages from basins situated on the Newfoundland shelf and slope at the family and generic level, with the notable exception of a greater variety (diversity) in the Astrorhizidae and Saccamminidae in the Holocene assemblages, a function, no doubt, of differential preservation. A qualitative generic communality of over 50% between the two assemblages with the same genera tending to dominate the two (with the notable and unexplained exception of the rarity of *Cyclammina* in the modern assemblage) and a tendency toward an increase in species diversity and absolute abundance between 1,500 to 3,000 m (4,920 to 9,840 ft) (similar to that seen in the flysch faunas between the margins and center of the Labrador-Newfoundland and North Sea Basins) support the interpretations of the "flysch-type" fauna as being predominantly a slope fauna. Low species communality is probably due to evolutionary turnover and/or differential preservation.

Studies of 37 HEBBLE area box cores (4,800 m; 15,748 ft) from the lower Nova Scotian Rise show that in addition to sharing certain physical and chemical parameters, the two environments experience(d) short term catastrophic events affecting the benthic fauna. While turbidites characterize the flysch basin, the HEBBLE area is subject to periodic high velocity boundary currents capable of resuspending and transporting bottom sediments. In both environments the epibenthic foraminiferal population is presumably locally destroyed by turbidity associated with a high energy event and repopulated during times of relative quiescence, which in the HEBBLE area lasts on the order of a few weeks or months.

Flysch-type assemblages have generally been linked with high organic carbon and various, associated, hydrographic limitations, as low O_2, high CO_2, low pH, low Eh, and poor circulation. However, data on Holocene and fossil assemblages suggest that, at least in some circumstances, high organic carbon may not be a controlling factor.

The flysch type fauna is clearly not related to depth per se; while predominantly a slope fauna its paleodepth distribution probably extended from <500 m ($<1,640$ ft) to over 4 km (2.5 mi). Its distribution is linked with a complex set of interrelated factors that may differ under different geologic settings. These different factors may be ultimately related to a single, unifying cause but we do not yet understand this relationship.

GRAMMER, G. MICHAEL, Southern Methodist Univ., Dallas, TX

Diagenesis of Viola Limestone (Middle and Upper Ordovician), Southeastern Arbuckle Mountains, Oklahoma

The Viola Limestone in the Arbuckle Mountains was deposited on a carbonate ramp within the southern Oklahoma aulacogen. Depositional environments within the Viola ranged from anaerobic deep-ramp, through dysaerobic mid-ramp, to fully oxygenated shallow-ramp conditions. Corresponding microfacies in the southeastern Arbuckles include, respectively, nonbioturbated, spiculitic pelletal packstones; thoroughly bioturbated fossilferous wackestones and packstones; and pelmatozoan packstones and grainstones.

A complex diagenetic history has occluded virtually all primary porosity within the Viola. Petrographic evidence suggests that the following approximate sequence of diagenetic events has occurred; (1) microboring and subsequent micritization of bioclasts to form micrite envelopes; (2) very early submarine cementation that bound the loosely sorted allochems and partly occluded porosity, characterized by drusy overgrowths on trilobite and brachiopod fragments, bladed, void-filling cement, and turbid, inclusion-rich syntaxial overgrowths on pelmatozoan fragments; (3) initial compaction evidenced by local fracturing of elongate bioclasts; (4) neomorphism, including the inversion of aragonitic allochems to calcite and the recrystallization of micrite to microspar and pseudospar in the presence of low-salinity pore fluids; (5) freshwater cementation dominated by clear syntxial overgrowths on pelmatozoan fragments and pore-filling mosaic calcite that filled virtually all remaining pore space; (6) selective dolomitization; (7) silicification, including the formation of chert nodules and the replacement of bioclasts and calcite cements by microgranular quartz and/or lutecite; (8) compaction and pressure solution, probably due to deep burial, characterized by nonsutured seam stylolites, sutured seam stylolites oriented subparallel to bedding, and sutured grain boundaries; and (9) tectonically imposed pressure solution indicated by sutured seam stylolites oriented at high angles to bedding that developed during the late Paleozoic deformation of the Arbuckle Mountain.

The Viola Limestone is known as a reservoir rock and possible source unit for hydrocarbons throughout much of south-central Oklahoma. Thorough understanding of the nature and timing of diagenetic events is important for the further economic development of the Viola Limestone and other similar carbonate ramp deposits.

GRANTZ, ARTHUR, and STEVEN D. MAY, U.S. Geol. Survey, Menlo Park, CA

Geologic Framework and Petroleum Potential of United States Chukchi Shelf North of Point Hope, Alaska

A reconnaissance grid of 24-channel seismic-reflection data indicates that most of the United States Chukchi shelf north of Point Hope, Alaska, is prospective for petroleum. The prospective rocks, which consist of four stratigraphic sequences, rest on the Arctic platform, a regional erosional surface cut across mildly metamorphosed lower Paleozoic rocks in Late Devonian time. The Eo-Ellesmerian sequence, interpreted to contain mainly Mississippian nonmarine deposits, is 5+ km (16,500 ft) thick and fills local sags and faulted depressions in the Arctic platform. Mississippian to Neocomian stable shelf clastic and carbonate beds of the Ellesmerian sequence, 0 to 7.7+ km (25,000 ft) thick, underlie most of the shelf but are absent from Barrow arch and the outer shelf of the northeastern Chukchi Sea. Albian and Upper Cretaceous intradelta and prodelta deposits of the lower Brookian sequence, which thicken from 250 m (800 ft) on Barrow arch to 7.5+ km (24,500 ft) to the southwest, northwest, and north, underlie most of the shelf. The upper Brookian sequence, inferred to consist of marine and nonmarine clastic deposits of mainly or entirely Tertiary age, is 0 to 5.6+ km (18,500 ft) thick. It occurs only in Nuwuk and North Chukchi basins and locally as canyon fill beneath the central Chukchi shelf.

The northern Chukchi shelf contains seven provinces of contrasting tectonic origin and structural style. Nuwuk basin, a progradational clastic prism containing 12+ km (39,500 ft) of lower and upper Brookian strata and numerous growth faults, overlies a rifted margin of Neocomian age beneath the outer shelf and slope of the northeastern Chukchi Sea. North Chukchi basin, which underlies the outer shelf west of Nuwuk basin, contains Ellesmerian beds and 12+ km (39,500 ft) of lower and upper Brookian strata. It may also overlie a Neocomian rifted margin, but was deepened by Laramide extensional rifting. South of these basins, shelf structure is controlled by the geometry of the Arctic platform, which slopes gently southwest from a depth of 0.25 km (800 ft) on Barrow arch to about 13 km (42,650 ft) off Point Lay. In the central part of the shelf, the platform is somewhat faulted and folded and descends to a depth of 10+ km (33,000 ft) to form the north-trending Hanna trough. West of the trough the platform rises to within 1 km (3,300 ft) of the seabed and is broken by numerous normal faults. The southern part of the platform contains a thick lower Brookian section with numerous northwest-striking, northeast-verging detachment folds. The fold province is bounded on the southwest, off Cape Lisburne, by the northwest-striking Herald arch overthrust belt at which one or more southwestward-dipping thrusts brought Ellesmerian and older strata to the seabed.

The seismic and extrapolated onshore data suggest that Nuwuk and North Chukchi basins, Hanna trough, and the Arctic platform east and west of the trough could contain significant deposits of oil or gas. The potential of the fold belt, however, is modest, and of Herald arch slight. Small areas on Barrow arch and the Arctic platform west of Hanna trough lack potential because they are underlain by less than 1 km (3,300 ft) of prospective section.

GREGG, WILLIAM J., Michigan Technological Univ., Houghton, MI, and T. H. MROZ, Morgantown Energy Technology Center, U.S. Dept. Energy, Morgantown, WV

Mechanical Factors Affecting Stimulation Design in Devonian Gas Shale

Oriented core samples from 23 Devonian gas shale wells in the Appalachian basin were used to determine microscopic and mesoscopic fracture patterns. The specific objectives were to note the preferred direction and nature of natural microcracks, to determine the preferred fracture propagation direction in laboratory mechanical testing, and to outline areas in the basin that are characterized by a high natural fracture density in the gas shales. This information provides a necessary background for the development of the in-situ stimulation technology which would most effectively connect natural fracture systems to a single well bore.

Mechanical tests under zero confining pressure conditions included point load, indirect tensile, laboratory hydrofracturing, and directional ultrasonic testing. Natural fractures were measured prior to testing. The preferred orientation of both induced and natural fractures throughout the basin was generally parallel to the trend of Paleozoic tectonic structure. This parallelism, as well as the details of the microfabric, suggests an "incipient cleavage" origin for the natural crack arrays. It thus appears that the residual effects of in-situ stresses do not influence the orientation of the induced fractures in laboratory tests. Tests under zero confining pressure are therefore not useful for determining the orientation of σ_{Hmax} as other workers have previously suggested, nor is the orientation of the fractures produced in these tests necessarily the same as that of an induced hydrofracture in the field.

The trajectory maps for in-situ stresses in the basin clearly illustrate the lack of parallelism with the mechanical fabric of the shale. However, analysis of the two patterns has been used to outline local areas in the basin where σ_{Hmax} is parallel to the natural microcrack system. In these areas the natural crack array would