The Lower Cretaceous Grand Rapids Formation in the Wabasca Oil Sand Deposit of north-central Alberta contains approximately 10.5 billion cu m (66 × 10^9 bbl) of viscous, low gravity bitumen in the subsurface. It represents a progradational clastic sequence building northwest into the Boreal Sea during early Albian time. The formation measures up to 90 m thick and consists of three progradational sandstone units (C, B, and A members in ascending order), separated by two marine shale/siltstone units, indicative of marine transgression.

Sequences of lithologies, sandstone geometry, and sedimentary structures indicate that each sandstone member represents a variety of depositional environments. Each shows a shallowing-upward trend from nearshore marine below effective wave base to lower and upper shoreface facies. Tidal inlet, beach, and possibly coastal dune environments are found in the upper parts of the A and B sandstones. Variations between localities indicate that upper shoreface to ?dune environments laterally grade into lagoonal and/or terrestrial environments. Coals, which locally cap the A and B sandstones, indicate back-barrier lagoon or interchannel marsh deposits. Local chert pebble beds found in the upper shale/siltstone sequence and in the basal part of the A sand are interpreted as possible major storm deposits.

On a regional scale, the Grand Rapids Formation of the Wabasca area appears to represent a barrier island coastal complex possibly adjacent to deltaic or delta plain sequences.

KRAUSE, F. F., Petroleum Recovery Inst., Calgary, Alberta, Canada

Evolution of a Mixed Carbonate/Terrigenous Platform: Lower Cambrian Continental Terrace Wedge of Mackenzie Mountains, Northwest Territories, Canada

Rocks of the Sekwi Formation and underlying siltstones of G.S.C. units 10A and 13 exposed in the western Mackenzie Mountains define a continental terrace wedge that evolved during the Early Cambrian on the northwestern flanks of the North American continent. Growth of the continental terrace wedge can be categorized by three phases of platform up-, out- and in-building. *Phase 1*—Continuous out- and up-building, and evolution from a ramp to a platform configuration. Growth culminated in middle and upper *Nevadella* zone rocks with prominent karst surfaces, abundant intraclast pebbles in oolite shoal deposits and a switch in composition of slope and fan deposits from carbonates to terrigenous clastics. *Phase 2*—Coincided with transgression of the shelf near the *Nevadella* and *Bonnia-Olenellus* zone boundary. Maximum platform out-building occurred at this time and climaxed with subaerial exposure of mid-*Bonnia-Olenellus* zone rock. Slope deposits changed from carbonate to terrigenous sedimentation. *Phase 3*—Renewed slow up- and in-building that led to eventual drowning of the platform by latest *Bonnia-Olenellus* zone time. Sedimentation patterns on this platform are reciprocal. Periods of sea-level highstand are characterized by abundant limestones, whereas periods of sea-level lowstand are marked by terrigenous influxes. These two stages of sea-level stand are highlighted in compositional differences of carbonate breccia deposits. During sea-level highstands, breccias contain predominantly ribbon and nodular limestone clasts. They reflect conditions of early lithification of the sea floor and non-equilibrium compaction of these deposits with subsequent sliding and downslope transport. In contrast during sea-level lowstands breccias consist preferentially of shelf and shelf-margin derived clasts.

KROHN, M. DENNIS, and JEFFREY D. PHILLIPS, U.S. Geol. Survey, Reston, VA

A Principal Component Enhancement for Landsat Images: Possible Structural Applications in Vegetated Virginia Piedmont

Digital processing algorithms that specifically display spectral differences are needed for better use of Landsat images in vegetated areas. A modified principal-component (PC) enhancement was applied to a Landsat scene of eastern Virginia: a second inverse rotation was applied to the uncorrelated axes, so that the image presentation of the PC data resembles the color relationships in a false color composite. Fieldwork showed that several types of coniferous and deciduous oak forests could be readily distinguished on the image.

An E-W elongate zone, 45 km long by 20 km wide along the James River west of Richmond, was defined on the image based on the distribution of a chestnut oak (*Quercus prinus*) forest. In this area, chestnut oak has a strong affinity for weathered coarse upland gravel deposits. Although such Miocene(?) gravel deposits are scattered throughout the image area, nowhere else are they concentrated into a linear zone. In addition, several other structural features coincide with the linear segments of the James River drainage: (1) a series of offsets in the gravity gradient map, (2) an inland extension of the offshore Norfolk fracture zone, and (3) a zone of seismicity near the James River. Such cross-strike features had an important role in the thin-skinned tectonics of the Valley and Ridge and may have important applications for the extension of the Eastern Overthrust belt postulated beneath the Piedmont.

KUEHL, STEVEN A., CHARLES A. NITTROUER, and DAVID J. DEMASTER, North Carolina State Univ., Raleigh, NC

Regional and Fine-Scale Strata Formation in a Major Accretionary Environment: Amazon Continental Shelf

Investigation of Amazon shelf sedimentation demonstrates that strata is presently accumulating on the inner shelf ($<$60 m water depth) in the form of a subaqueous delta (composed primarily of silt and clay) which is prograding over relict basal sands. Seismic reflection records (3.5 kHz) reveal regions of topset, foreset, and bottomset stratigraphy. The formation of fine-scale ($<$ 50 cm) strata was examined using x-radiographic and radiochemical (e.g., ^{210}Pb, ^{137}Cs, ^{234}Th) techniques on more than 60 box cores from the deltaic deposit. On the basis of sedimentary structure, three distinct sedimentary environments have been delineated within the topset region: (1) interbedded mud and sand in a corridor extending from the river mouth across the inner shelf, (2) faintly laminated muds to both flanks of this corridor, and (3) bioturbated muds comprising the remainder of the deltaic deposit. The interbedding of mud and sand may result from short-term fluctuations in a turbulent jet emanating from the Amazon River mouth. Faintly laminated muds are deposited from suspension on the flanks of the turbulent jet and have the highest accumulation rates found on the inner shelf ($>$2 cm/year). Where accumulation rates are reduced, bioturbated muds are present. ^{234}Th data from the bioturbated muds indicate rapid mixing down to 5 cm with a mixing coefficient of about 30 cm^2/year. Observations of sedimentation on the foreset and bottomset regions are not as comprehensive because of their relatively small areal extent. However, accumulation rates are found to decrease from topset ($>$2 cm/year) to bottomset ($<$0.5 cm/year) regions. With decreasing sediment accumulation rate the effects of biological mixing on preserved strata become more pronounced.

KUMAR, MADHURENDU BHUSHAN, Louisiana State Univ., Baton Rouge, LA

Geothermal Patterns and Petroleum Traps, Louisiana

Published literature documents varying degrees of correlation between geologic structures and geothermal highs (halos) of several petroleum fields. In conjunction with these fields, additional structures and associated productive trends have been evaluated in order to develop certain predictive criteria. The studies attempted in this regard include structural and stratigraphic traps, rollover anticlines, and salt domes with productive horizons of various ages in Louisiana.

As part of the characterization of the subsurface temperature regime of the regions studied, the following broad generalizations seem to be in order. (1) Geothermal halos observed near faults appear astride the fault, or clearly confined to one fault block or the other. (2) A single geothermal halo in a deep section may be overlain by multiple halos, generally of lower relief, in shallow sections. (3) Geothermal halos associated with deep-seated salt domes are located in the sedimentary section on or near the top of the dome, near the perimeter or on the flanks. Such halos are not discernible on shallow domes. (4) In the interior basin, a salt dome with productive horizons appears to have a geothermal halo of higher relief than those in the vicinity with no petroleum accumulations. (5) Even some petroleum traps, created by sedimentary facies changes with no distinct structural closures, are marked with geothermal halos.

The observed characteristics of the subsurface thermal regimes are generally explicable in terms of thermal properties of rocks and pore fluids and by hydrodynamics.

KUMAR, NARESH, ARCO Exploration Co., Denver, CO, and ROGER M. SLATT, ARCO Oil and Gas Co., Dallas, TX (present address: Cities Service Research, Tulsa, OK)

Deep-Water Stratigraphic Traps in Interior Basins: Examples from Anadarko Basin, Oklahoma

As in modern oceans, there is ample evidence that sands bypassed shelf-edges of ancient interior basins and accumulated in deeper parts of the basins. Although water depths in these basins were never in the abyssal zone, these deposits are today recognizable as "deep-water" sands.

Based on a seismic, subsurface, and sedimentologic study of the Tonkawa Sandstone (Missourian), we have developed a seismic-stratigraphic model for Pennsylvanian sands in the Anadarko basin. Typically, the Tonkawa and other sands are regressive and cyclic and are bounded at the base and top by transgressive limestones. The sands consist of three facies: (1) an upper shallow-water shelf facies, (2) a middle submarine slope-channel facies, and (3) a lower submarine fan-lobe facies. Each sandstone unit exhibits characteristic electric log and seismic signatures and distinctive sedimentary structures and textures. For each depositional cycle, the shelf edge may be formed by a contemporaneous reef, and the break in bathymetric gradient at the base-of-slope may be marked by an older reef. Besides the Tonkawa Sandstone, this model is applicable to the following formations: (1) Springer/Morrow (Springeran/Morrowan); (2) Red Fork (Desmoinesian); and (3) Cleveland and Cottage Grove (both Missourian).

The model predicts that both individual slope sands and submarine fan lobes are potential stratigraphic traps. Associated carbonate banks may also form traps. We suggest that many deep-water traps remain to be found in the Anadarko basin.

KUMATI, SUGAIER M., Mobil Oil Libya Ltd., Tripoli, Libya (S.P.L.A.J.), and JOSEPH M. ANKETELL, Univ. Manchester, Manchester, England

Structural Analysis of Western Sirte Basin, Libya (S.P.L.A.J.)

Examination of surface sediments and tectonic features in the oil-rich Hofra area, western Sirte basin, Libya (S.P.L.A.J.), demonstrates that this area was subject to periodic movement of blocks due to faulting and probably also eperiogenic uplift.

It is here proposed that the faults are the major structures in that it is possible to interpret some, if not all, of the folds as having formed in relation to reactivation of the fault systems. The fault systems may be interpreted in terms of a major "bull-nose" Riedel P Shear structure related to a deep-seated fault along which there was left-handed movement. The faults making up the major bull-nose structure and in particular the Abu Shush fault system display Riedel Shears in patterns indicative of left-handed movement. Abu Shush fault system appears to display a northerly change from styles ranging from those typical of a pre-residual to a peak structural situation. In addition, the post-peak to pre-residual styles typical of the southern part of the Abu Shush fault zone are associated with reversal of stress patterns along a major P zone in the southern part of the Gedari fault zone.

The complexities in stratigraphic relationships resulting from such events may often not be easily recognized in boreholes without exhaustive paleontologic studies, particularly when one considers that most of the unconformities display little variation in dip across the unconformable surface.

KURESHY, A. A., Staten Island, NY

Large Tertiary Foraminiferal Biostratigraphy, Kirthar Province, Sind, Pakistan

Large foraminifera of Pakistan are chronostratigraphically diagnostic and are the basis for stratigraphic correlation of marine Tertiary carbonate deposits. The sedimentary deposits of Pakistan are divided into three basins, among which the carbonate deposits of the lower Indus basin are very rich in large foraminifera. The lower Indus basin is divided into Sulaiman and Kirthar provinces. The Tertiary deposits of Kirthar province are mainly carbonate with intercalation of argillaceous sediments, designated to Lakhra, Laki, Kirthar, Nari, and Gaj formations, and range in age from Paleocene to early Miocene. The large foraminifera of these deposits are divided into ten distinct foraminiferal zones. These are: (1) Lakra Formation, characterized by *Nummulites muttalii* zone of late Paleocene age; (2) Laki Formation, characterized by *Assilina granulosa* zone of early Eocene age; (3) Kirthar Formation (4) zone, characterized by *Nummulites beaumonti* zone (middle Eocene), *N. pengaroensis* zone (late Eocene), *N. fichteli* zone (early Oligocene), and *N. fichteli/Lepidocyclina* (E) *dilatata* zone (middle Oligocene); (4) Nari Formation (3 zones), *N. fichteli*, *N. fichteli/Lepidocyclina* (E) *dilatata* zone, and *L.* (E) *dilatata* zone (of early, middle, late Oligocene respectively); and (5) Gaj Formation, characterized by *Miogypsina gunteri* and *M. thecideaeformis* zones (Aquitanian and Burdigalian, early Miocene). The foraminifera are mostly restricted to their respective zones. Post-early Miocene rocks of Kirthar province, Sind, Pakistan, are nonmarine and devoid of foraminifera.

LAMBERT, MICHAEL W., Chevron U.S.A., Inc., New Orleans, LA

Vitrinite Reflectance of Woodford Shale in Anadarko Basin, Oklahoma

The Woodford Shale (Upper Devonian-Lower Mississippian) is a black shale thought to be an important oil-source bed in the Anadarko basin of western Oklahoma. The reflectance in immersion oil (R_0) of first-generation vitrinite particles found in this stratigraphic unit is related to temperature history and thus