very easy to use. In addition, several separate models for each well were generated and the results compared statistically in a very short span of time.

Results from several formations, including the Mancos "B" in western Colorado, are presented in detail to illustrate the advantage of the use of interactive graphics software.

The degree of success achieved in solving these problems indicates that the use of an interactive computer system in this manner is not only valid, but merits more widespread application.

KOHM, J. A.,* The Exploration Co., Denver, CO, and R. O. LOUDEN,* Buckhorn Petroleum Co., Denver, CO

Ordovician Red River Formation, Eastern Montana and Western North Dakota: Relationships Between Lithofacies and Production

Ordovician Red River cores were examined from 16 wells across western North Dakota and eastern Montana plus core from 8 wells in Brush Lake field area, Sheridan County, Montana. Several distinctive basinwide carbonate lithofacies record at least three cycles of upward shoaling or restricted conditions. The oldest and best developed of these cycles consists of a fossiliferous burrowed carbonate mudstone member overlain by a non-fossiliferous, finely laminated micro- or crypto-crystalline dolomite member. The cycle is completed by an anhydrite of regional extent. The thickest development of porous dolomite is in the lowest cycle of the Red River. This cycle contains most of the Red River oil reserves of the study area.

Porosity distribution is directly related to patterns of dolomitization in the carbonate members of each cycle. In northeast Richland County, Montana, an area of dense well control, net porosity isopach maps of each member of the lowest cycle show alternating bands of porous and nonporous carbonates. These bands are oriented northeast-southwest. Bands of good porosity development in the burrowed member occur between bands of good porosity in the overlying laminated member. A classification system based upon these patterns of dolomitization is used to analyze statistically the occurrence of porosity in the lowest cycle.

Regional anhydrites, nonporous carbonate rocks and kerogenites within these cycles have formed adequate seals for the trapping of Red River oil.

Fifty percent of Red River structural growth occurred during upper Interlake time in northeast Montana. Rejuvenation of this growth occurred through Cretaceous time.

Black kerogenous limestones in the burrowed member of the lowest cycle may be the source of Red River oil.

KOLLA, V., Lamont-Doherty Geol. Observatory, Palisades, NY, R. T. BUFFLER, Inst. Geophysics, Univ. Texas at Austin, Galveston, TX, and J. W. LADD, Lamont-Doherty Geol. Observatory, Palisades, NY

Seismic Stratigraphy and Sedimentation, Magdalena Fan, Southern Caribbean Sea

Multi- and single-channel seismic records from the Magdalena Fan reveal six seismic sequences in the entire sediment column (with thickness from >5.5 to 2.5 secs two-way traveltime). Although sediments were deposited in the Magdalena Fan since about the Late Cretaceous, terrigenous sedimentation became important only in later Cenozoic time during the deposition of the upper three units following the Andean uplifts. However, the uppermost seismic sequence is the fan unit, most influenced by influx of terrigenous sediments and deposited subsequent to the major uplift of Andes in Pliocene time. The morphologic and shallow acoustic (3.5 kHz) characteristics of this fan unit are: (1) upper fan, 1/50 to 1/100 gradients, with channels having well-developed levees and with several subbottom reflectors; (2) middle fan, 1/100 to 1/200 gradients, occurrence of numerous channels with very subdued levees and several subbottom reflectors; and (3) lower fan, $<1/200$ gradients having small channels and relatively smooth sea floor with few or no subbottom reflectors. Large irregular to regular hyperbolic echoes and sediment waves are very common in the upper, middle, and to some extent the lower fan, and have resulted from slumping and other downslope mass movements. On multichannel seismic records, the upper fan exhibits conspicuous channel-levee migration and onlapping and coalescing wedge-shaped reflection patterns (from levee deposits). The middle fan is characterized by the presence of chaotic and discontinuous reflection patterns which resulted from the presence of numerous channels and the hyperbolae and sediment waves of the type recorded on 3.5 kHz records. The lower fan region has continuous and smooth reflection patterns. Within the topmost seismic unit, several episodes of increased terrigenous sediment influx have resulted in a seaward progradation of different fan regions in Pliocene-Pleistocene times.

KRAFT, JOHN C., and H. FLETCHER BROWN, Univ. Delaware, Newark, DE

Terrigenous and Carbonate Clastic Facies in a Transgressive Sequence Over Volcanic Terrain

The Kawainui marsh in Hawaii and its adjacent broad barrier accretion plain has been deposited over a former coralline algal-coral reef embayment surrounded by high slope volcanic hills. In late Holocene time, littoral transport formed a beach accretion plain which cut off the former marine embayment leading to deposition of lagoonal and deltaic facies which were eventually covered by a dense salt marsh formed of *Scirpus* sp. and "California" grass. A core program was used to obtain data for a three dimensional analysis of the resultant transgressive coastal environmental lithosomes. By use of a large number of radiocarbon dates and three relatively important archeological sites surrounding the marsh, the late Holocene settings and times of deposition of the various sedimentary environmental units were determined. This transgressive sequence began at least 5,000 years before present and continues to build landward and upward. The vertical stratigraphic sequence from top to bottom includes salt marsh peats, lagoonal marine muds or terrigenous deltaic deposits, in some areas a basal marsh peat, and a coralline algal-coral reef tract, underlain by basalts. The adjacent barrier accretion sands overlie a coralline algal-coral reef tract underlain by basalts. Preservation potential of such a sequence in a volcanic terrain appears to be fairly high as deposits of many previous high sea stands have been identified in the Hawaiian Island chain. Final burial under deep marine muds or oozes will eventually occur as the islands subside as evidenced by the previous history of the Hawaii-Midway Island chain. Buried similar sequences of transgressive coastal sedimentary facies should be anticipated along other volcanic terrains such as the Kelvin chain (Mytilus seamount) off the eastern Atlantic coast of North America, the Jordan Knoll in the southeast Gulf of Mexico, the Tonga-Fiji volcanic arc, and other similar geologic settings.

KRAMERS, JOHN W., Alberta Geol. Survey, Edmonton, Alberta, Canada

Grand Rapids Formation, North-Central Alberta: An Example of Nearshore Sedimentation in a High Energy, Shallow, Inland Sea

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