fills.

Deposits in the lower Saskatchewan River valley (120 × 80 km), a much wider basin with much slower aggradation rates (± 15 cm/100 years), occur as channel sands flanked by laterally extensive (1 km) sheets of overbank levee deposits of fine sandy silt, which grade into even more laterally extensive thick deposits of mud or peat. With time, dominant channels become sinuous, thus causing increased flow resistance, major avulsions upriver, and eventual channel filling and abandonment. Many channel sand-fill deposits form cross-section geometries, ranging up to 15 cm thick by 120 m wide.

Facies differences of the two anastomosed river systems are believed to be caused by both the rate of sedimentation and width of the sedimentary basin. Other than size differences of similar sedimentary environments, Columbia River channels are less sinuous, avulse more frequently, and contain coarser grained sand. In the Saskatchewan, some crevasse-splay (sheet sands) and associated avulsions are laterally extensive (10 × 30 km) and very complex. Wetlands in the Columbia are dominated by marsh (organic-rich mud) and lacustrine silt, whereas thick (up to 3 m) laterally extensive peat bogs dominate in the Saskatchewan system.

Within the upper Mannville Group of the Lloydminster area there exists a large-scale mappable complex of fluvial channel-fill sandstones that exhibit an anastomosed pattern. The complex has areal dimensions of 250 km (width) by 700 km (length).

Channel sandstones are thick (up to 35 m), narrow (300 m), can be traced for several kilometers, and are stratigraphically variable. The channel fills are multistoried, with the predominant sedimentary structures consisting of plane beds, cross-beds, and climbing current ripples. Interchannel sediments consist of interbedded sheet sandstones, siltstones, mudstones, and coals. The predominant sedimentary structures of the interchannel sandstones are the same as those found within channel sandstones.

From a compare-and-contrast approach, it is concluded that meandering, sandy braided, valley-fill, deltaic, or tidal origins cannot account for the observed sand-body geometries and facies distribution.

The modern model that best explains the sediment and facies distributions within the upper Mannville is the anastomosed fluvial model in which narrow, vertically accreting channels are bordered by extensive aggrading interchannel wetland deposits with interbedded crevasse-splay sands.

Hydrocarbon distributions within the upper Mannville are stratigraphically controlled and oil quality can be directly related to depositional facies. Common trapping mechanisms consist of updip shale-filled channels, structural closure formed by differential compaction, and lateral sandstone pinchouts.

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Sedimentation Within Southern Oklahoma Aulacogen: Viola Limestone

The Viola Limestone (Middle Ordovician) was deposited within the southern Oklahoma aulacogen in the Arbuckle Mountains of Oklahoma. The northwest-trending aulacogen is a basement rift which opened in the Late Cambrian (535 to 525 m.y.a). During the early history of the aulacogen, the thick Cambro-Ordovician Arbuckle Group (2,050 m) was deposited as a predominantly peritidal complex. The conformably overlying Early Ordovician Simpson Group (700 m) shows more variation in water depth but still is dominated by shallow-water deposits. The Viola Limestone rests disconformably on a hardground which was developed at the top of the Simpson Group. Early Viola deposition was below wavebase probably with continental slope bathymetry; this time thus represents the deepest carbonate sedimentation within the aulacogen. Initial results show that the oldest microfacies of the Viola Limestone is a laminated calcisiltite deposited within anoxic bottom conditions by weak traction currents. Progressively increasing oxygenation and wave energy resulted in deposition of a bioturbated wackestone which then grades upward into a washed grainstone. These microfacies indicate a general upward shallowing along the axis of the aulacogen. Early workers, however, suggested that the more cratonward Viola microfacies may deepen slightly upward. As noted in earlier studies, the carbonate ramp model seems to fit best the depositional setting of the Viola. The ramp model can deal with the conflicting water depth trend by having a subsidence hinge axis upslope from the upward-deepening and upward-shallowing sections. In addition, sedimentation rates would have been greater in the aulacogen axis than on the marginal platforms. Shallow subtidal deposits cap the Viola of both the aulacogen and platform. In both areas these shallow-water carbonates were subjected to early diagenesis by meteoric water, confirming their proximity to sea level.

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Computer Applications by Geologists Using Micropaleontologic Data

The role of computers in petroleum exploration is increasing. The large volume of micropaleontologic data in company files is much more efficiently utilized with the aid of computers. In the Gulf Coast, micropaleontology is especially helpful in correlating the very thick Cenozoic section of alternating sands and shales. Micropaleontology is also essential in the interpretation of depositional environments.

Computer applications to micropaleontologic data most commonly requested by geologists are: (1) indexes, listing wells containing paleontologic data, (2) biostratigraphic and paleoecologic summary reports for the wells, (3) base maps illustrating paleo control, (4) structure maps contoured on paleo-marker horizons, (5) isopachous maps on intervals between two paleo-marker horizons, and (6) paleoecologic maps illustrating depositional environments at the time of extinction of a paleo-marker species.

The applications quickly provide the geologist with a structural, stratigraphic, and paleoecologic framework.

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Use of Stand-Alone Computer "Work Stations" for Mapping and Engineering Management of Mineral Fuel Resources

Low-cost microcomputers will be widely used in the future to assemble, evaluate, and map the geologic information and engineering data required to explore and develop oil and gas prospects and mining operations.

Because of recent developments in hardware and software design, exploration geologists and mining engineers can now use low-cost stand-alone computer work stations based around a microcomputer interfaced to a digitizer, plotter, and interactive color graphics display, to reduce the time and cost of planning and design work required to prepare project feasibility and design maps and reports.

Stand-alone computer work stations in the $20,000 to $30,000 range are now available. There is, however, a great need for the development of more and better user-oriented, menu-driven, software that will make it possible for geologists, mining engineers, and many others to enter data and interactively manipulate and edit them through interactive computer graphics systems and prepare plotted maps at a work station that can easily be fitted into an average size office.

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Sedimentary Fabrics of Debris Flow-Dominated, Stream-Modified Alluvial Fan, Saline Valley, California

Although depositional sequences in alluvial-fan deposits may reflect tectonic activity, they are difficult to distinguish from those produced by changes of climate or by local aggradation. This presentation deals with an alluvial fan depositional style that occurs in arid conditions in which rare, large-scale debris flows are modified by more frequent, but small-scale, stream floods. Recognition of this type of deposition in an alluvial-fan succession could indicate change of climate and aggradational sequences may be seen by changes in its fabric.

A small alluvial fan in Saline valley, California, was described from apex to toe to determine the types of fabrics produced and their relative distributions. Debris flows produce levees and lobes which appear as 1 to 3 m high mounds of poorly sorted, matrix-supported conglomerates. These mounds become lower, less regularly distributed downfan and disappear before the fan toe. The tops and outer edges of levees and lobes have the largest boulders, which are tightly packed in a near-vertical, imbricatelike pattern. Fan-toe debris-flow fabric is 1 to 10-cm thick pebbly mud sheets with irregular lines of isolated cobbles. The small streams are deeply incised between levees at the fan apex, shallow and anastomosing around levees and lobes at mid-fan, and braided at the fan toe. Deep channels are floored by step patterns produced by partly or completely exhumed debris-flow boulders with fine gravel or sand deposited on the upstream side. Shallow channels have two major fabrics: (1) 5 to 20-cm high hummocks of poorly sorted, muddy gravel surrounded by fine gravel and sand with better sorting, and (2) muddy, moderately well-sorted gravel in which the long axes are horizontal and oriented parallel with flow. The braided channels at the fan toe are dominated by horizontally discontinuous lamination and abundant mud intraclasts. Windblown sand commonly accumulates in channels, preserving mud curls and mud drapes from the last flood.

All fabrics observed in the small fan in Saline valley were also seen in larger fans there and in several other Mojave basins. These fabrics were also found in some Triassic alluvial-fan deposits in New Jersey.

SNEIDER, R. M., Robert Sneider Exploration, Inc., Houston, TX, and H. R. KING, H. E. HAWKES, and T. B. DAVIS, Canadian Hunter Exploration Ltd., Calgary, Alberta, Canada

Detection and Characterization of Reservoir Rock, Deep Basin Gas Area, Western Canada

Major gas reserves have been discovered in the past 6 years in Cretaceous sandstones and conglomerates at depths of 3,000 to 10,000 ft (915 to 3,045 m) within Alberta and British Columbia, Canada. Discovery of these new reserves resulted from a joint geologic and petroleum engineering effort which used rock-fluid data from cuttings, cores, well logs, and drill-stem and production tests. A key element in the exploration search is the rapid detection and characterization of reservoir-rock properties from well cuttings, especially of the low-permeability rocks.

Rock studies of over 10,000 ft (3,045 m) of conventional cores integrated with petrophysical studies of well logs and core analyses, which were compared with drill-stem and production tests in over 200 wells, provide the basis for establishing reservoir-rock potential. Porous rocks are subdivided into three categories: type I, capable of gas production without natural and/or artificial fracturing (subdivided on basis of air permeability), type II, capable of gas production when interbedded with type I rocks or with natural and/or artificial fracturing, and type III, too tight to produce at commercial rates even with natural or artificial fracturing.

Criteria to identify a rock's reservoir potential from well cuttings or conventional and sidewall cores are based on examination of dry, freshly broken fragments with a binocular microscope. Estimates of the following parameters form the basis of establishing a rock's reservoir potential: (1) size, (2) volume and distribution of visible pores, (3) particle size and distribution, (4) type and amount of cements and pore-filling material, and (5) degree of consolidation. Geologists and engineers can make rapid, accurate estimates of reservoir-rock potential of unknown porous intervals with the help of several visual aids. These include plastic trays of cuttings-size rock chips crushed from conventional cores of known rock and pore types, porosity, and permeability; colored photographs of freshly broken rock surfaces; and thin-section microphotographs and scanning electron photomicrographs of rock chips and their pore casts.

The methods and procedures described continue to be used in Western Canada and the United States for delineation of exploration opportunities, identification of bypassed pays in old wells, for well-log interpretation, and in evaluating intervals for completion.

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Productivity Gradients for Paleo-Oceans: A New Application of Isotopes of C-13 and O-18

Based on the coincident relationship between the $\delta^{13}C$ and $\delta^{18}O$ of modern ocean water, above the O_2 minimum, I have constructed a series of ocean-specific models designed to calculate open-ocean values of PO_4 for paleo-oceans. Inherent in these models are the assumptions that the $\delta^{18}O$ and $\delta^{13}C$ of ocean water vary as functions of temperature and dissolved O_2 (or AOU), respectively. In the Atlantic, for example, the derived model is:

$$PO_4 = 4.95 - 2.54\,[\log 16.9 - 4.206(\delta^{18}O_c - \delta^{18}O_w) + (\delta^{18}O_c - \delta^{18}O_w)^2] - 0.32\,[O_2 \text{ saturation} - (e^{7.15} - 3.45\,\delta^{13}C_w/43.5)].$$

Above the O_2 minimum, foraminiferally derived values of $\delta^{13}C$ and $\delta^{18}O$ can be used to calculate PO_4 concentrations at the levels at which the tests were secreted, resulting in a restratification of the PO_4 concentration with depth for paleo-oceans. A more powerful application of these models is the construction of productivity (ΔPO_4) gradients using average concentrations of PO_4 obtained from the sedimented tests of surface (0 to 50 m) and deep-dwelling (below 150 m) planktonic Foraminifera. The higher the value of ΔPO_4, the greater the productivity. Preliminary results for the Sargasso Sea suggest that plots of ΔPO_4 values are very effective in delineating water masses, and possibly strong surface currents. Calculated ΔPO_4 gradients are in agreement with observed ΔPO_4 gradients. Calculated concentrations of PO_4 with depth in the Atlantic compare well with observed trends. Concentrations of PO_4, derived from Holocene planktonic Foraminifera from the Indian Ocean, are noticeably similar to observed PO_4 concentrations in the overlying water in which the tests were secreted. These results, although preliminary, suggest that ΔPO_4 gradients can be calculated and used to delineate water masses for paleo-oceans throughout the Cenozoic.