Geologic Controls of In-Situ Processing of Tar Sands, N.W. Asphalt Ridge, Utah

The Laramie Energy Technology Center completed three in-situ oil-recovery experiments from tar sands at N.W. Asphalt Ridge, Utah. The 10-acre (4 ha.) tract is part of the Sohio Shale Oil Co. "D" tract located west of Vernal, in Uintah County. Asphalt Ridge, lying on the northern boundary of the Uinta basin, is a northwest-southeast-trending ridge. The area on the northwest is structurally a monocline dipping southwest. The 3.28 to 14.75 m thick experimental tar-sand zones are in the Rim Rock Sandstone Member of the Mesaverde Formation of Cretaceous age. The beds dip 28°SW, and overburden thicknesses range from 89 to 164 m. Two known faults, with throws up to 66 m, bound the tract.

Three experiments were performed at the tract on varying partial acreages from 1975 to 1980. Two combustion tests using reverse combustion and a combination reverse and forward combustion were completed in a tar-sand bed 3.28 to 3.93 m thick. Recovered oil and water for the experiments ranged from 65 to 580 bbl and 167 to 600 bbl, respectively. The third test used steam injection on a 14.75 m thick bed. Production was 1,150 bbl of oil and 6,250 bbl of water. Tar-sand analyses yielded the following range of data for the three tests: extracted porosity, 26.1 to 31.1%; absolute air permeability, 651 to 2,175 md; oil saturation, 62 to 75% pore volume; water saturation, 2.4 to 7.9% pore volume. Various geologic controls can determine the effectiveness of the extraction process. These include the dip of the beds, reservoir thickness, water and oil saturation, porosity, permeability, vertical and horizontal continuity of section, confinement of zone, and potential fractures and faulting in area.

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Early Cretaceous Depositional and Structural Development of Wyoming-Idaho-Utah Foreland Basin

Early Cretaceous deposition in the western Wyoming, eastern Idaho, and northeastern Utah region reflects the interplay of tectonic and eustatic controls during the early development of the thrust belt in this area. A major marine withdrawal at the close of the Jurassic was closely preceded by initial movement of the Paris-Willard thrust. Two subsequent pulses of eastward movement along this thrust occurred: a poorly dated event in Early Cretaceous time and a final movement during Late Cretaceous (Turonian). These periods of uplift on the western margin of the foreland basin are reflected by the eastward progradation of coarse fluvial clastic wedges into the Cretaceous seaway.

Between pulses of thrust movement, tectonic quiescence was coupled with a decrease of clastic influx into the subsiding basin. During periods of marine regression, broad marl-dominated lacustrine depositional systems developed in the foreland basin. In contrast, during transgressive periods, depositional environments were characterized by mixed fluvial and lacustrine systems bordered down paleoslope by extensive marsh-dominated systems. Basin subsidence, instigated by tectonic loading of the Paris-Willard thrust allochthon and further enhanced by sediment loading of the coarse clastic wedges, controlled the distribution of lacustrine systems during periods of marine regression.

The Paris-Willard thrust allochthon throughout the Early Cretaceous was dominated by upper Paleozoic strata. Subsequent to the final movement of the thrust, the allochthon was carried passively eastward and uplifted by ramping along steps of the more eastern Absaroka thrust. This uplift resulted in the exposure of upper Precambrian and lower Paleozoic strata which dominate the allochthon today.

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Geometry of Modern Anastomosed Channel Deposits and Potential Hydrocarbon Traps

The anastomosed fluvial model, interpreted from modern deposits in the upper Columbia River valley between Radium and Golden, British Columbia, consists of aggrading, multiple, low-gradient, low-sinuosity, thick, sand-filled channels laterally contained by levees, crevasse splays, and various wetland deposits. While active aggrading cross-valley alluvial fans controlled sedimentation in the upper Columbia valley, basin subsidence and/or regional tilting were controls for probable ancient anastomosed fluvial rocks, such as in the Cretaceous Western Interior molasse basin. The uniqueness of anastomosed fluvial style compared to that of meandering rivers is attributed to regional rapid aggradation, which subsequently favors anastomosed deposits for deep burial and preservation.

In the Columbia valley, the cross-valley profile of anastomosed channel deposits consists of vertically and laterally multiple stringers of channel sand, longitudinally interconnected at different stratigraphic levels. Individual channel cross sections consist of mud-contained, thick channel fills with multistoried textural cycles dominated by planar, tabular cross-bed structures. The upper ¼ to ⅓ of each channel fill consists of either mud or sandy point bar, contained laterally by mud resulting from waning river discharge.

Several different trapping processes may account for hydrocarbon accumulations in ancient anastomosed fluvial sandstones, based on core observations from modern deposits in the Columbia valley. The most common trap occurs in upper channel fill point-bar sands contained laterally and above by mud. A less common trap is a sand-filled channel segment plugged at both ends with a mud-filled master channel and capped with lacustrine mud. Two other traps result from differential compaction of mud versus sand: (1) deep scour holes at the downstream confluence of two channels allow the thicker sand-filled scour to form a domelike "compaction high" when capped with mud; and (2) a cross overlap of two stratigraphically different channels results in an anticline of the upper channel where it crosses over the lower channel.

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Anastomosed River Deposits—Modern and Ancient Examples in Western Canada

Depositional facies of two Canadian modern anastomosed river systems, the upper Columbia River and lower Saskatchewan River, occur in intermontane and plains settings, respectively. Both systems contain low-gradient, multiple, interconnected, laterally stable sand-bed channels, with adjacent splay, levee, and shallow wetland deposits, all aggrading in accordance with channel sedimentation. While aggrading cross-valley alluvial fans or subsidence tend to control sedimentation rates in intermontane valleys, basin subsidence and/or regional tilting controls deposition rates in plains settings.

Deposits in the upper Columbia River valley (120 × 1.5 km) consist of low-sinuosity multistoried stringers (textural cycles) with planar tabular cross-bed sets of channel sands and numerous sandy crevasse-splay deposits. Channel deposits are laterally contained by deposits of levee silt and lacustrine mud, and when buried are vertically mud encased. Aggrading at an average rate of 60 cm/100 years over the past 2,500 years, the anastomosed system is very dynamic, exhibiting many avulsions and channel 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