CARRIGY, MAURICE A., Research Council of Alberta, Edmonton, Alta.

DELTAIC SEDIMENTATION IN ATHABASCA TAR SANDS

The Athabasca tar sands of northern Alberta underlie an area greater than 26,000 sq km and contain in excess of $700 \times 10^9$ bbl of heavy oil. Excellent outcrops of the oil-impregnated Lower Cretaceous strata (McMurray and Clearwater Formations) are present in the valley of the Athabasca River and its tributaries in the vicinity of Fort McMurray. The middle and upper members of the reservoir consist of many small deltas of modest thickness (less than 30 m) built by rivers flowing north into a lake or lagoon which occupied an elongated depression formed by extensive salt removal from evaporite beds beneath the Devonian limestone that underlies the tar sands. Lithofacies associated with the changing environments of deposition during the infilling of this depression include successively fluvial sand; delta-front sand and silt; delta-platform sand; and silt, clay, and nearshore marine sand.

*Fluvial sand.*—This medium- to coarse-grained, well-sorted sand, composed of quartz, k-feldspar, and muscovite, is present in the basal part of the McMurray Formation where it forms lenticular sand bodies (2–7 m thick) containing sets of medium-scale (25 cm), high-angle, cross-beds. Included in these sand bodies are shale chips, mummified logs, and abundant comminuted carbon. Grain size is uniform throughout and the upper and the lower contacts are sharp. There is little mineral cement, and there is little evidence of animal activity.

*Delta-front sand.*—This fine-grained, well-sorted, sand, composed of quartz, k-feldspar, and muscovite, is present in the middle McMurray Formation as a large, low-angle (5–7°), cross-stratified unit 20–30 m thick. Individual beds 10–20 cm thick are separated by discontinuous, thin (5–100-mm) silt layers. Internal structures include micro-cross-laminations, burrows, and "castings." No megafossils are present but silt beds contain an abundant microflora of pollen and spores. The lower contact is usually sharp and the upper contact is transitional. Within this unit there is a gradual and uniform increase in "shaliness" from base to top and mineral cement is rare.

*Delta-platform sand.*—This fine-grained sand and silt unit, composed of quartz, muscovite, and k-feldspar, is present in the upper part of the McMurray Formation forming a widespread unit, 7–10 m thick, composed of horizontally bedded silt and sand laminae. The lower contact is transitional with the underlying delta-front unit but the upper contact with the nearshore marine sand of the Clearwater Formation is sharp. Siderite and calcite-cemented beds are common within this unit which also contains lenticular beds of brackish-water mollusks. Also present in this unit is a sparse fauna of agglutinated foraminifers together with fish teeth, and a microflora of spores, pollen, and microplankton.

*Nearshore marine sand.*—This medium-grained sand is clean in places but mainly is a poorly-sorted mixture of sand, silt, and clay composed of quartz, chert, and glauconite. This sand forms a widespread marker bed, 5–10 m thick at the base of the Clearwater Formation, and is known as the Wabiskaw Member. Bedding in this unit has been virtually destroyed by animal activity and the most conspicuous internal features are burrowing structures filled with clean sand. A rich microfauna is found in this unit consisting inter alia of calcareous Foraminifera, Radiolaria, sponge spicules, and hystrichospherids. Lower and upper contacts are sharp with a uniform upward increase in the sand to matrix ratio.

The distribution of oil within the tar-sands reservoir is controlled by the original porosity and permeability of the sediments. Thus the maximum amount of oil (18–20% by weight) is present in well-sorted, clean sands which are most commonly of fluvial origin. No oil is present in the poorly-sorted, argillaceous parts of the nearshore marine sand, or in the silt beds within the deltaic complex.

CHENOWETH, PHILIP A., Consulting Geologist, Tulsa, Okla.

GEOLOGY OF OIL AND GAS OCCURRENCE IN PENNSYLVANIAN ROCKS, MID-CONTINENT REGION

Oil production in the Mid-Continent began in 1860 with a discovery near Kansas City. The initial find was in rocks of Pennsylvanian age, and reservoirs in that system are still the most important in the region. Hundreds of pools produce from it at depths which range from the surface "tar sands" of western Missouri and southern Oklahoma to sandstones 3 mi or more deep. Several major fields produce mainly from Pennsylvanian rocks.

The geologic history which accounts for this prolific production is punctuated by 3 distinct orogenic episodes: the widespread post-Morrowan Wichita orogeny, the early Desmoinesian Ouachita orogeny, and the Late Pennsylvanian Arbuckle uplift. Activity centered in a belt extending from southern Arkansas across Oklahoma and into the Texas panhandle. Between the major orogenic pulses there were lesser and somewhat more localized movements. Repeated folding is common in the area.

Orogeny actually began in Late Mississippian time with the uplift of an area in northern Texas and southern Oklahoma and the development of a foredeep on the north. Earliest Pennsylvanian rocks are a flysch laid down in this southern Oklahoma geosyncline. In the beginning of the Pennsylvanian most of the Mid-Continent was above sea level and subject to erosion, but by Desmoinesian time shallow seas had spread across the shelf as far north as central Nebraska. Two large topographic highs in Kansas were the last to be submerged.

Cyclic sedimentation characterized the entire period so that alternating marine and nonmarine rocks occupy most of the region north of the geosyncline. Relatively thin and persistent carbonate rocks and shale are most abundant on the north, siliceous clastic rocks predominate and attain great thicknesses on the south. A shelf-edge zone of marine banks and algal reefs occupies the boundary between the two regions. Redbeds and some evaporites are present in Upper Pennsylvanian strata.

Oil and gas are produced from all types of stratigraphic and structural traps. Reservoirs include conglomerate, arkose, sandstone, siltstone, limestone, dolomite, and shale. To date, only dry gas has been found in the southeast Oklahoma-western Arkansas part of the province; elsewhere gas and oil generally are found in close association. Liquids range from nearly solid hydrocarbons to very light naturally refined oils.

Prospecting in the region uses all the conventional techniques but subsurface geology is the most popular and most effective in the more densely drilled parts. Success for exploratory wells in recent years has been as high as 26% in Oklahoma and Kansas where virtually all wildcat drilling is based on geologic advice.