Sedimentation and Depositional Environment of Mannville (Lower Cretaceous) Sediments in the Tangleflags Area, West-Central Saskatchewan

by Malcolm Wilson

Tangleflags Field is located north and east of Lloydminster within the area of Townships 50, 51 and 52 and Ranges 24 and 25 West of the 3rd Meridian.

Within the Mannville Group, the subdivisions followed are those of Fuglem (1970) and Vigrass (1977). It was proposed by Lorsong (1980) that these subdivisions be given formation status and here they will be considered formations for convenience. Figure 1 shows the stratigraphic subdivision of the Mannville. It should be kept in mind that they are lithostratigraphic units and, therefore, undoubtedly diachronous.

The Tangleflags Field yields oil and gas from a number of units within the Mannville, the most consistent of these being the Lloydminster and General Petroleums (GP), but also from the McLaren, Sparky, Waseca, Colony and possibly Cummings.

Subdivision of the Mannville into formations is based almost exclusively on wireline logs. Only in a few enhanced oil recovery pilot projects, such as the Celtic Field (Lorsong, 1979, 1980), is it possible to correlate from core alone, and even in those the correlation is only possible for a portion of the entire Mannville sequence. Basic correlations are made using electric logs (Spontaneous Potential and Resistivity), with further definition being provided by Gamma Ray and Compensated Neutron Porosity - Formation Density logs. Unfortunately, the latter log suite is not available for many of the wells drilled within the Tangleflags area. While it is obvious that core provides the most accurate and reliable data, it must be pointed out that core is taken only in approximately 10 to 15 percent of the wells drilled in the Lloydminster heavy oil area as a whole, Tangleflags being no exception, and that much of this core is discontinuous and in poor condition. All the core within the boundaries of Tangleflags Field and some outside the boundaries has, however, been examined and the data recorded.

Lithostratigraphic Units and Depositional Environment

In the Tangleflags area, all the wells penetrate at least to the Lloydminster Formation and some deeper. Few, however, reach the Paleozoic unconformity, making any detailed picture of the pre-Mannville erosion surface impossible. In addition, it is rarely possible to determine the thickness of the Cummings or to distinguish the presence or absence of the Dina.

The Lloydminster sand is apparently consistent across the entire area. Extensive cross-sections through the Tangleflags area and computer-plotted contour maps of the central part of the Tangleflags Field suggest only gradual changes in thickness. Whether or not this sand is the same sand body across the entire area is not possible to determine from the log signatures and available core data; however, the lateral continuity of the sand is strongly suggested by the generally even thickness and similarity of log character within the area. In addition, the Lloydminster sand is consistently oil saturated indicating, at the very least, hydrodynamic continuity. A number of the density logs show the presence of coal or carbonaceous shale at the top of the Lloydminster, again pointing to lateral continuity.

Where core data are available, they suggest a shoaling (coarsening upwards) sequence with the sands dominated by facies L (lithologic terminology after Lorsong, 1979, 1980), a low angle, cross-laminated sand indicative of upper shoreface or swash-zone sands. The presence of coals and carbonaceous shales above the sands reinforces the interpretation as a shoaling sequence. Underlying the sands are interlayered silts and shales of Lorsong's facies B (generally bioturbated) and shales forming the base of the formation. The general picture provided by the logs and core data is, therefore, one of a shallow marine (coastal) environment with the deposition of an extensive sand sheet as the shoreline progrades. At present, it is not possible to ascertain the direction of this progradation.

Where the core extends across the Lloydminster/Rex boundary, there is clearly a cemented sand present near the base of the Rex Formation. While this sand is not extensively burrowed, it does contain a characteristic type of ichnofossil (Plate 1 gen. et sp. indet.) which, in light of McLane's (1982) work, would appear to indicate the lower to middle shoreface. This concept suggests a

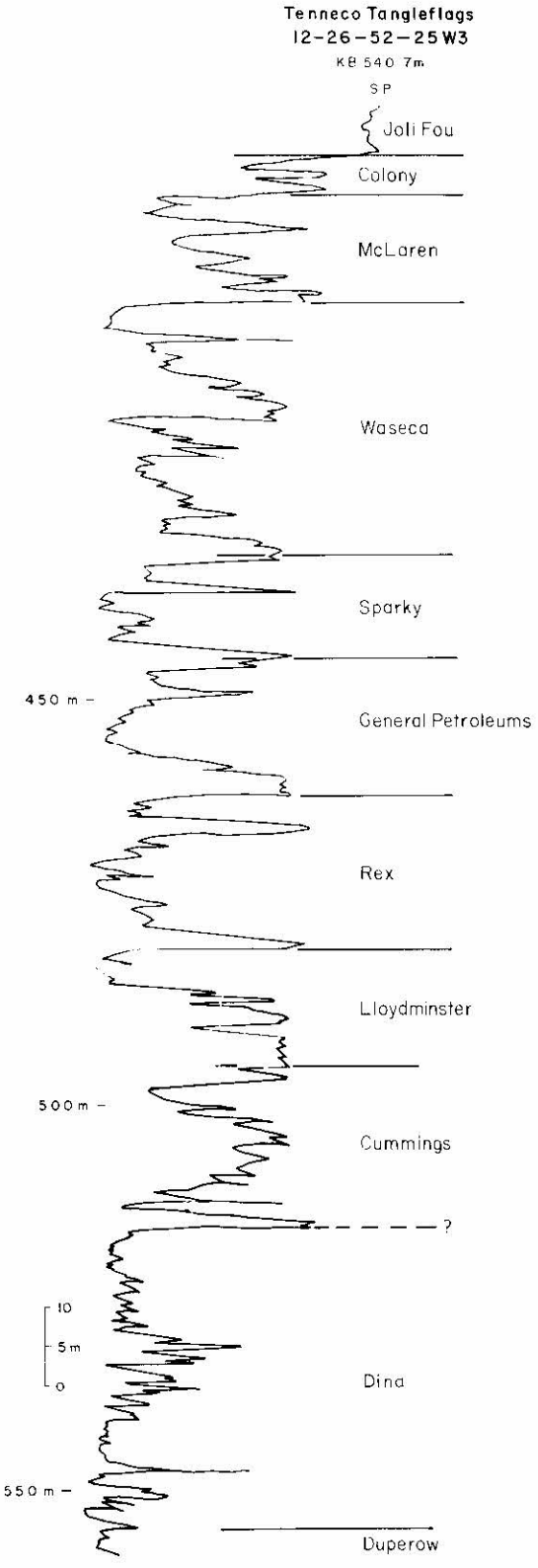

Figure 1—Log 12-26-52-25W3, illustrating stratigraphic subdivision of the Mannville.

post-Lloydminster trangression and a laterally continuous lower Rex sand body. It also lends credence to the above suggestion of an extensive Lloydminster sand sheet.

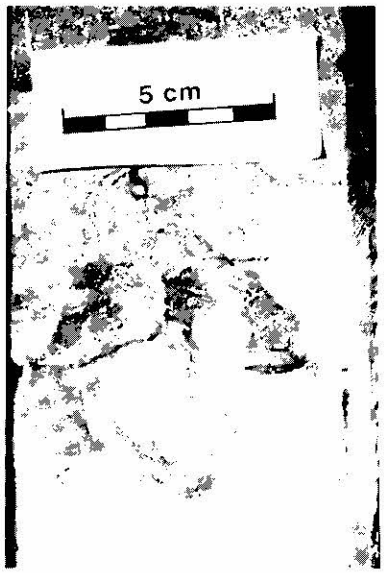

Plate 1—Characteristic trace fossil from cemented sand, lower Rex Formation.

In the Tangleflags area the Rex is almost entirely water filled and therefore of little economic interest to the oil industry. For this reason there is virtually no core taken except at the base and any interpretation must, of necessity, be made from the available log suites. There is, however, a consistent break (log signature for a shale) at the top of the Rex. This break appears to form a good lithologic marker throughout the Tangleflags area. The logs also suggest that in this area the Rex Formation is a series of stacked sand sheets.

Following the Rex are the GP and Sparky Formations, often difficult to differentiate on the log suites. The available information suggests a shallow marine (shoreface/ nearshore) environment becoming terrestrial at the top. Typically, a coal or carbonaceous shale exists at the top of the Sparky. Vigrass' (1977) definition of the top of the Sparky Formation is problematic when there are only logs to consider: just where in the superjacent shale is the hiatus and, therefore, the formational boundary? Since a coal commonly exists at the top of the Sparky/base of the Waseca and is clearly visible on the Neutron and Sonic logs in the Tangleflags area, as well as in the Pike's Peak area (MacEachern, 1982), it would appear to be a convenient marker. Where the coal is absent or only electric logs are available,

the location of the boundary must be estimated based on the probable location of the coal.

Above the Sparky lies the Waseca Formation. Unlike Celtic and many other fields in the Lloydminster area, the Waseca is of minor economic importance in the Tangleflags Field, with the result that there is little information available besides the log suites. The log suites do, however, suggest two, or occasionally more, coarsening upwards sequences culminating in a coal or carbonaceous shale at the top of the formation. Again, the coal represents a convenient lithological marker to define the top of the Waseca.

The McLaren Formation, overlying the Waseca, again typified by a coarsening upwards sequence culminating in a coal, appears to be one more pulse similar to the Waseca in sediment character and log signature.

The Colony Formation, the youngest lithostratigraphic unit in the Mannville, is of minor economic significance with little core data available. The Colony, in the Tangleflags area, is generally a relatively thin, fining upwards sequence capping the Mannville. In places the Colony sand becomes considerably thicker and is coincident with a structural high containing gas or gas and oil. The coincidence of thick sand and structural high suggests compaction rather than tectonic or salt-related feature. In fact, much of the subtle structure in a localized area of the Mannville such as Tangleflags Field may well be a result of differential compaction of the sediments.

Marine Versus Non-Marine Origin for the Mannville

Within the Tangleflags area the sediments of the Mannville, at least from the Lloydminster up, have apparently been deposited in a coastal environment. Each unit (not necessarily formation) represents a transgressive/regressive event frequently culminating in terrestrial sedimentation (the coals and carbonaceous shales). There is little evidence, even in logs where thicker sands exist, of any extensive terrestrial (i.e. fluvial or deltaic) channel deposits, although there are insufficient core data to confirm this.

In the North Tangleflags Field a number of wells display a log signature (Fig. 2) in the Lloydminster or Cummings Formations very similar to that found in the Pike's Peak Waseca 'channel' sands, where some core is available. In Husky Tangleflags North A14-15-52-25W3, the oil-saturated sands display imbricated clay clasts (Plate 2), possibly formed as clay fragments were ripped up and deposited in a channel sand. Samples

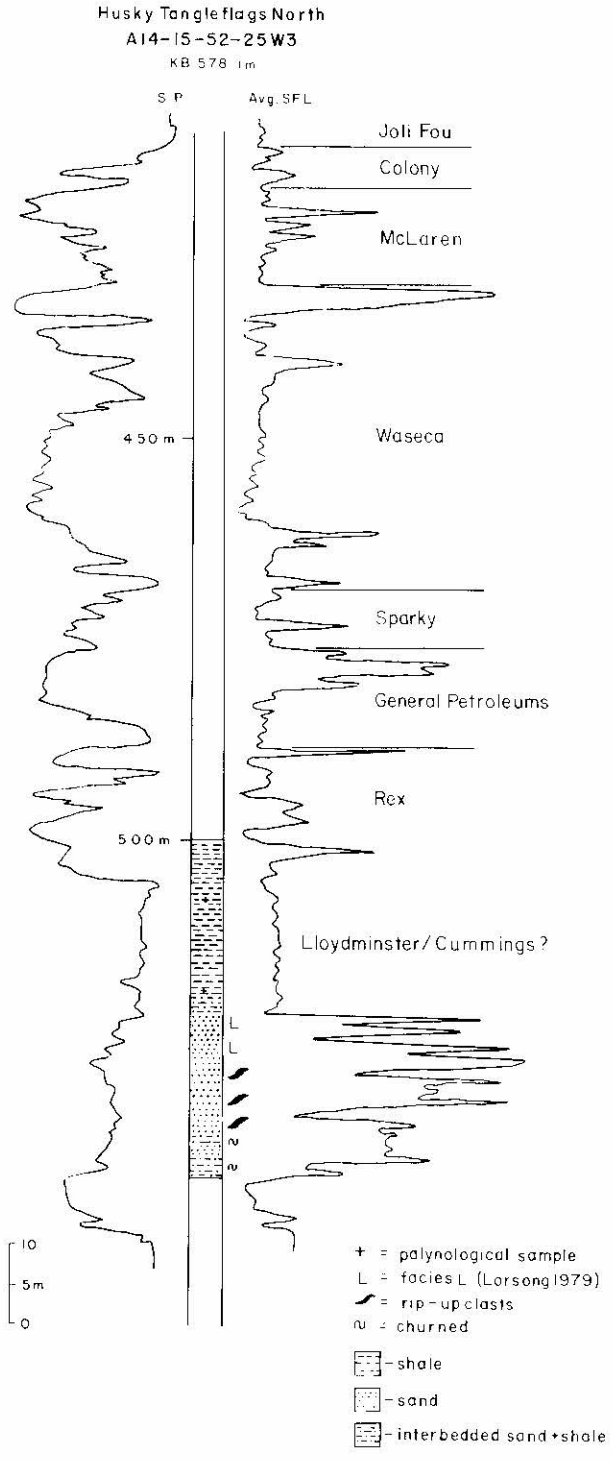

Figure 2 – Spontaneous Potential/Resistivity log of Lloydminster/Cummings 'channel' in Husky Tangleflags North A14-15-52-25W3. Note the subdued response of the Spontaneous Potential curve to the sand (shown by core).

from the overlying shale, however, show the presence of dinoflagellates, the higher sample showing increasing marine influence. To further confuse the 'channel' theory, Francana Murphy Tangleflags A6-10-52-25W3 has a similar log signature but the shaley response on the Spontaneous Potential curve is due to shale laminations in the sand rather than clay clasts. A third well, Imperial Tangleflags 13-23-52- 25W3, despite the extremely poor condition of the core, shows no shale at all. Given this conflicting evidence, in Tangleflags at least, there is no concrete evidence for channel sedimentation.

Plate 2 – Imbricate shale clasts in oil-saturated sand matrix.

In an attempt to gain a better stratigraphic control over the Mannville sediments, Shell Oil Co. has drilled a number of wells with core taken through most of the Mannville. A study of the northerly three wells (A13-1-52-27W3, A13-19-52-23W3 and A7-3-54-25W3) shows non-marine sediments, primarily sands, in the Dina and lower part of the Cummings. In the upper Cummings, marine sediments occur and dominate Mannville sedimentation to the top of the McLaren. Because of their locations away from centres of drilling, it is difficult to correlate these wells with field data; however, in general terms, they do provide strong corroborative evidence for the environmental picture envisioned for the Tangleflags Field.

Conclusions

1. The Mannville is dominated by marine sediments.

2. Lloydminster and younger Mannville sediments represent a series of transgressive/regressive marine pulses, with each pulse terminating in shoreface or coastal terrestrial sediments.

3. The marine sedimentation took place in shallow (shoreface to nearshore to quiet lagoon or embayment) water.

4. The coals and carbonaceous shales, where present, provide convenient lithostratigraphic markers within the Tangleflags area.

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