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Source Rock Intervals within the Tyler Formation, North Dakota

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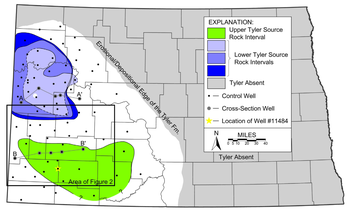


Figure 1. Preliminary map showing the approximate distribution of source rocks within the Tyler Formation. The source rocks depicted in Figure 1 correlate with the source rocks interpreted in cross-sections A-A' (lower Tyler source rocks 1-3) and B-B' (upper Tyler source rock). Source rocks were mapped using gamma ray logs, Passey's Δ log R method (sonic and deep resistivity logs), and/or TOC analysis of Tyler cuttings and core.

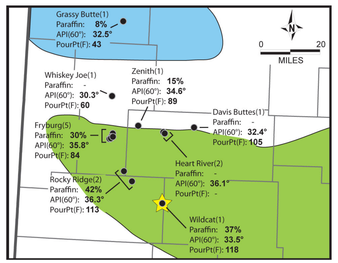


Figure 2. Map showing oil analysis data for Tyler oils. The oil analyzes were completed prior to this study. The wells from which Tyler oil samples were collected for analysis are shown by black circles. The field name and number of oil samples analyzed are posted along with the field's average paraffin percentage, API gravity, and pour point. The blue and green shaded areas correlate with the source rocks depicted in Fig. 1 and cross-sections A-A' and B-B'. Note how the Tyler oil sample from the Grassy Butte field has significantly lower Paraffin content (8%) and pour point (43) than all of the other Tyler oil samples analyzed.

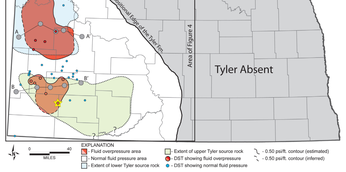


Figure 3. Fluid pressure map of the Tyler Formation modified from Nesheim and Nordeng (2011b) showing the locations of A-A' and B-B'. Fluid overpressure in the Tyler Formation is likely the result of intense oil generation by the source rocks depicted in Figure 1 and cross-sections A-A' and B-B'. The darker red, northern region of fluid overpressure was approximated using the 5650 ft. subsea level Tyler Formation top structure contour. The lighter red, southern region of fluid overpressure was approximated using well control.

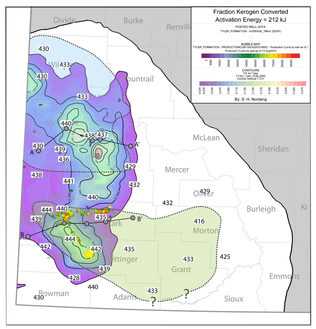
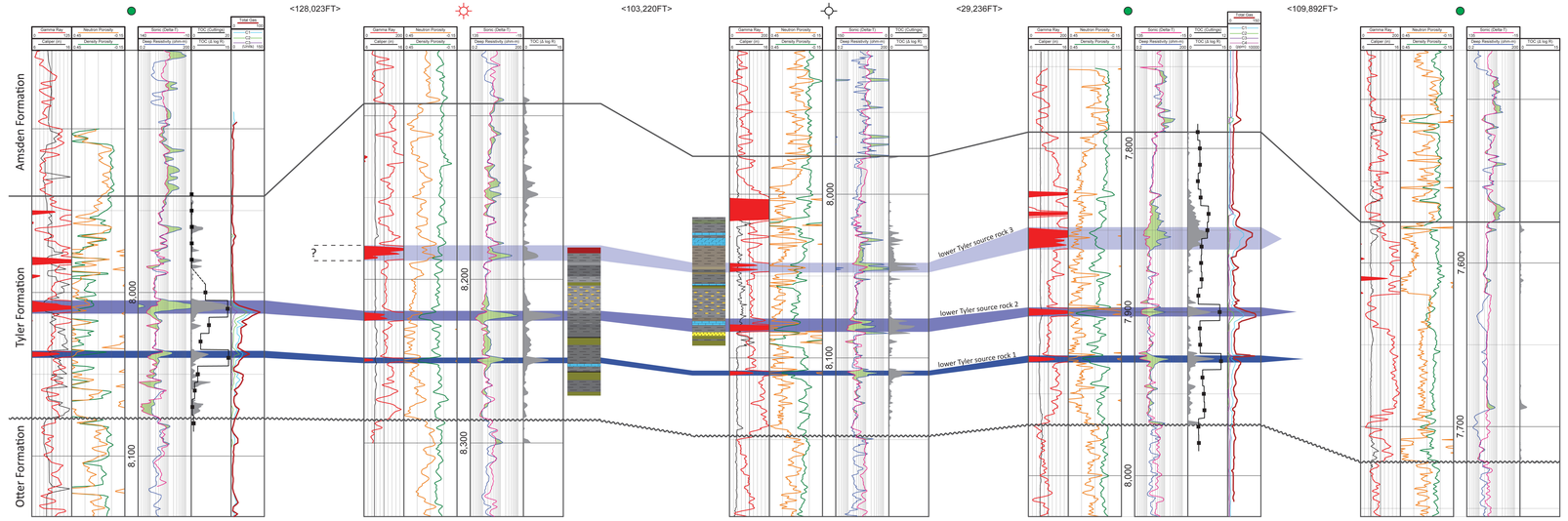
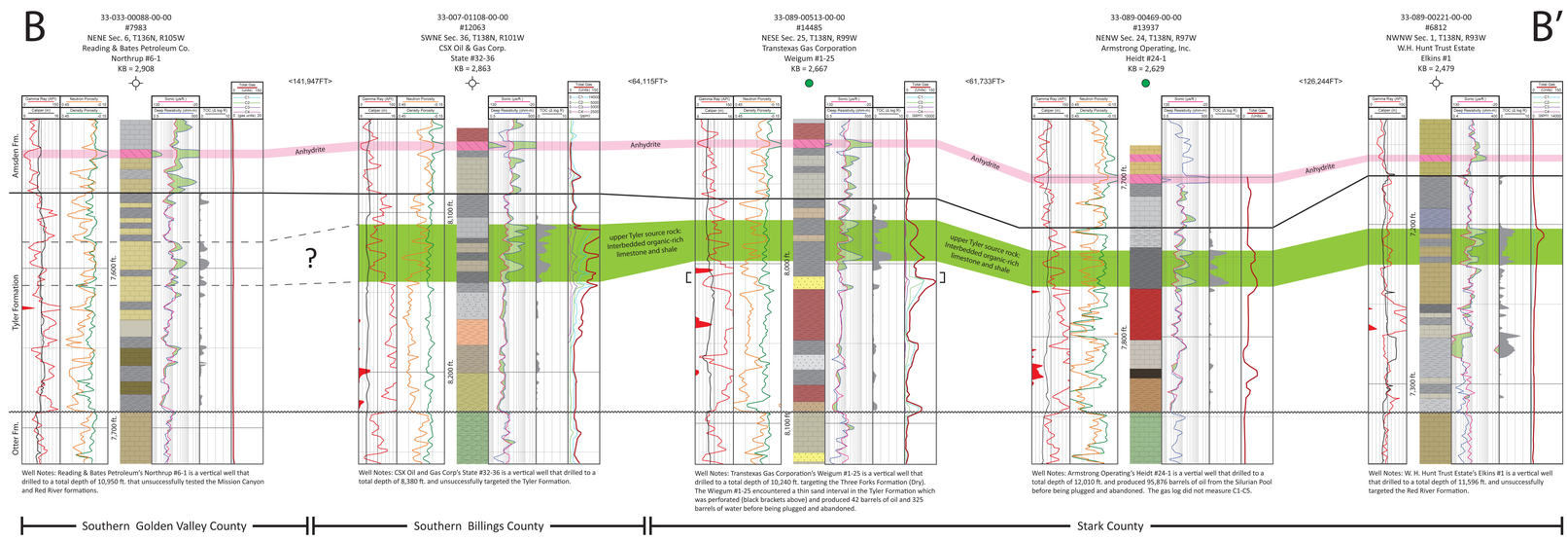


Figure 4. Time-Temperature Index and production map of the Tyler Formation modified from Nordeng and Nesheim (2012) with measured Tmax values. A-A' and B-B' wells are shown by the larger grey circles. The purple to red shaded area depicts where the Tyler Formation is modeled to be thermally mature and in the oil window. Note how the TTI thermal maturity zone correlates with the regions of fluid overpressure in Figure 2. Tmax values equal to or greater than 435 indicate the sampled formation has likely reached a maturation level of intense oil generation. Tmax values of 435 extend beyond the TTI modeled oil window in the southwestern part of the state. The high Tmax values in the southwest indicate that the upper Tyler source rock interval may have generated oil throughout most of western Hettinger and part of northwestern Adams counties.





DISCUSSION

The Tyler Formation is currently being re-evaluated as a potential resource play by the North Dakota Geological Survey. A fundamental component of resource plays is thermally mature source rock (organic-rich rock intervals). Organic-rich shales have been previously noted within the Tyler Formation by Dow (1974), Williams (1974), and Nesheim and Nordeng (2011a), but have not been thoroughly examined or mapped. The primary purpose of this study is to identify potential source rock intervals within the Tyler Formation using well log interpretation in combination with Total Organic Carbon (TOC) analysis of drill cuttings (A-A' and B-B'). In addition, a preliminary source rock map (Fig. 1) was compared to oil analyzes (Fig. 2), fluid pressures (Fig. 3), and thermal maturation data (Fig. 4).

In the absence of analytical data, wirelogs can be used to interpret organic-rich, source rock intervals. For example, the Δ log R method developed by Passey et al. (1990) uses a crossplot of porosity (e.g. sonic log) and deep resistivity logs to calculate TOC weight percentage (TOC wt. %). Immature source rocks tend to have a lower sonic velocity than surrounding non-source rocks, while mature source rocks have higher resistivity due to the presence of hydrocarbons. Using Passey's Δ log R method, the lower portion of the Tyler Formation contains three organic-rich intervals in west-central North Dakota (Fig. 1 and A-A') and another organic-rich interval in the upper Tyler further to the south (Fig. 1 and B-B').

TOC analytical results from Tyler drill cuttings validate organic-rich intervals identified by Passey's Δ log R method. Drilling cuttings from the entire Tyler section were analyzed for TOC wt. % from over thirty wells to date (Nordeng and Nesheim, 2012). In west-central North Dakota, the lower two organic-rich intervals measured 8-19% TOC (e.g. Burlington Northern 13-5 and Jane Federal 11X-20 in A-A'). In southwestern North Dakota, the upper Tyler source rock interval measured 3-6% TOC (e.g. Fig. 5).

Several factors indicate that the organic-rich Tyler intervals are thermally mature in parts of western North Dakota. Gas kicks, including spikes in C1-C4, are encountered while drilling through the organic-rich intervals ("Total Gas" in A-A' and B-B'). Fluid overpressure, thought to be caused by intense hydrocarbon generation (Nesheim and Nordeng 2011b), occurs in two separate regions (Fig. 3) which overlap with the Tyler source rock distribution (Fig. 1). Time-Temperature modeling and Tmax values measured from drilled cutting also indicate the Tyler Formation is within the oil window (Fig. 4).

The type of oil generated in the Tyler Formation may vary between the upper and lower source rock intervals. Numerous Tyler oil samples analyzed from southwestern North Dakota nearly all consist of 30-40% paraffin and have a pour point above 80° F, which is thick and viscous oil. One oil sample collected from west-central North Dakota, in the vicinity of the lower Tyler source rock intervals, had much lower paraffin content (8%) and a lower pour point (43° F). This is likely due to a difference in kerogen within the source rocks which may be a function of varying depositional environments.

REFERENCES:

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#11484
NENW 24-135-98
Milestone Petroleum, Inc.
Kirschman #21-24
KB = 2,733

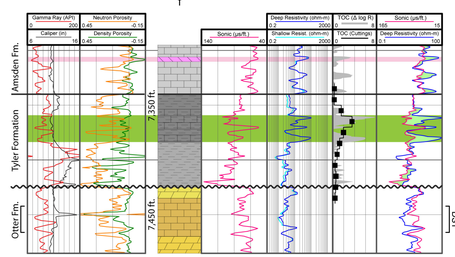

Figure 5. Single well cross-section of Milestone Petroleum's Kirschman #21-24. Lithologies were determined from drill cuttings. Note how the organic-rich intervals in the upper Tyler indicated by the Passey method (TOC-Log) overlap with the high measured TOC drill cutting samples (TOC-Cuttings). A Drill Stem Test (DST) was run on the underlying Otter Formation (indicated by brackets above). The DST produced 0.48 barrels of water and 0.03 barrels of oil and had an extrapolated fluid pressure gradient of 0.51 psi/ft (Nesheim and Nordeng, 2011b). This suggests the upper Tyler source rock interval may have generated oil that migrated downwards at least 50 ft. into the underlying Otter Fm. The yellow star in figures 2-4 shows the location of Kirschman #21-24.