The Montney Formation: Mineralogy, What Shall It Be?

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Summary

Application of the scientific method can be a tedious and time-consuming task. Consequently, it is only human to take advantage of expeditious short cuts, to ease this process. As a result sometimes we rely heavily on tool-derived technological interpretations without crosschecking this evidence against that available from more labour intensive tools. In this study of the Montney Fm., an unconventional oil and gas reservoir in the Western Canadian Sedimentary Basin, we examine the responses of total gamma ray (TγR), photoelectric (P_e) and spectral gamma ray (SγR) logs and cross-reference the interpretations based on these logs with those obtained from thin-sections and drill cores from the Sturgeon South Lake area in west-central Alberta (Figure 1). Notably, the interpretations from the logging tool responses suggest that the formation is a shale. On the other hand, evaluation of the petrographic analyses from rock samples indicate that the Montney Fm. is a mixed carbonate-siliciclastic deposit, specifically a crystalline dolostone with quartz, feldspars (K-feldspar and albite), muscovite and pyrite minerals. This study demonstrates that geology is a multidisciplinary endeavour and that remote sensing tool records, like ones from total gamma ray, photoelectric factor and spectral gamma ray logs provide detailed information regarding rock properties but require flexible interpretations and should be regularly ground truthed.

Introduction

TγR logs and P_e logs of the Montney Fm. collected in the Sturgeon Lake South area typically have radioactivity responses that range from 60º-150º API and 2.3-3.8 barns/e, respectively **(**Figure 2**)**. While this log response quintessentially is attributed to shale, explorationists working in the WCSB have learned that in the Montney Fm. this logging record is not as it seems and instead is a function of carbonate and non-clay radioactive minerals. In this study with the aid of SγR and P_e logs, optical thin section microscopy, microprobe chemical element maps and point analyses, and X-Ray diffractometry, we document the nonradioactive and radioactive minerals characteristic of the formation. With the use of these tools we conclude that the rock is not a clay-rich shale, but instead is a siliciclastic dolostone or dolarenite.

Theory and/or Method

Logging Tool Response:

As is customary, SγR logs are plotted against depth on 3 separate tracts to illustrate the concentrations of the 3 most common naturally occurring radioactive elements in rocks, namely potassium (K %), thorium (Th ppm) and uranium (U ppm). In TγR logs radioactivity is presented in a single tract in API units as the 3 tracts of the SγR logs are summed after applying vendor specific API unit multipliers to each radioactive element. As is apparent in SγR logs of the Montney Fm. bulk U concentrations average between 2-4 ppm, Th concentrations are higher and range between 3-8 ppm, and K concentrations are higher still and range between 1.2 – 4%. Using the Schlumberger chart (CP-19) the high Th and K concentrations plot within the illite field, and would be used to indicate that there is a significant contribution from illite to the TγR.

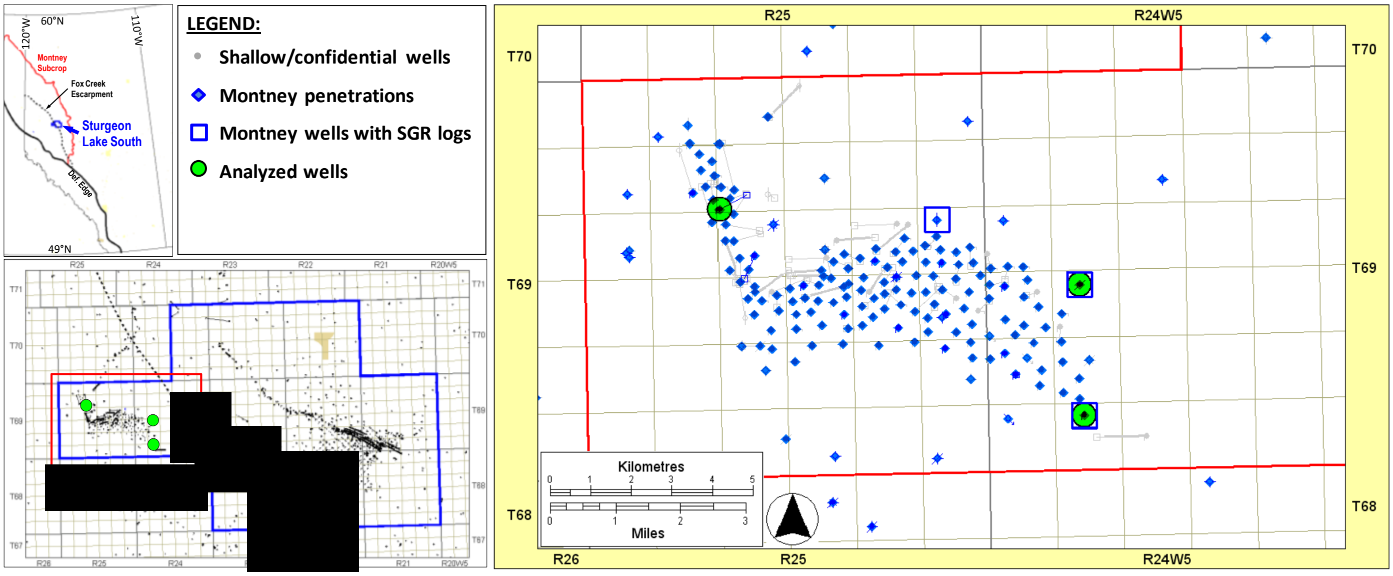

Figure 1 – Location of the analyzed wells in the west portion of the Sturgeon Lake South field, west central Alberta.

Petrologic Tool Response:

Predictions supported by SγR analyses indicate that illite is the source of the bulk radioactive mineral response in the Montney Fm. This prediction is not supported by petrological examinations, including thin section observations, microprobe chemical element mapping, and XRD analyses. Instead the minerals observed, in order of abundance, are dolomite, quartz, orthoclase, muscovite, albite and iron sulfides. Assessments of XRD analyses of whole rock and clay-size fractions confirm the presence of these same minerals, but in addition illite is observed in trace amounts. As a consequence, the dominant K sourcing minerals are K- feldspars, which include both orthoclase, and sanidine, and muscovite. Chemical element abundances in these minerals are for quartz 2 ppm Th, 0.7 ppm U, 0.08%; K-feldspar 5 (3-7) ppm Th, 0.2-3 ppm U; 14 (10.9-16) %K; albite 0.5-3 ppm Th, 0.2-5 ppm U; dolomite 0.07 % K; muscovite 7.9-9.8 % K, K-feldspar are ± 10-11% for muscovite and illite 10-25 ppm Th, 1.5-12.4 ppm U, 6.7 (3.5-8.3) % K (Rider (1996); Luthi (2000)). Our microprobe chemical analyses for K within the formation are ± 7 – 9% for muscovite and ±13-17 wt% for K-feldspar. Accordingly the K-feldspars contribute the greatest proportion of K to the formation, while illite contribution is much less significant because it only occurs in trace amounts.

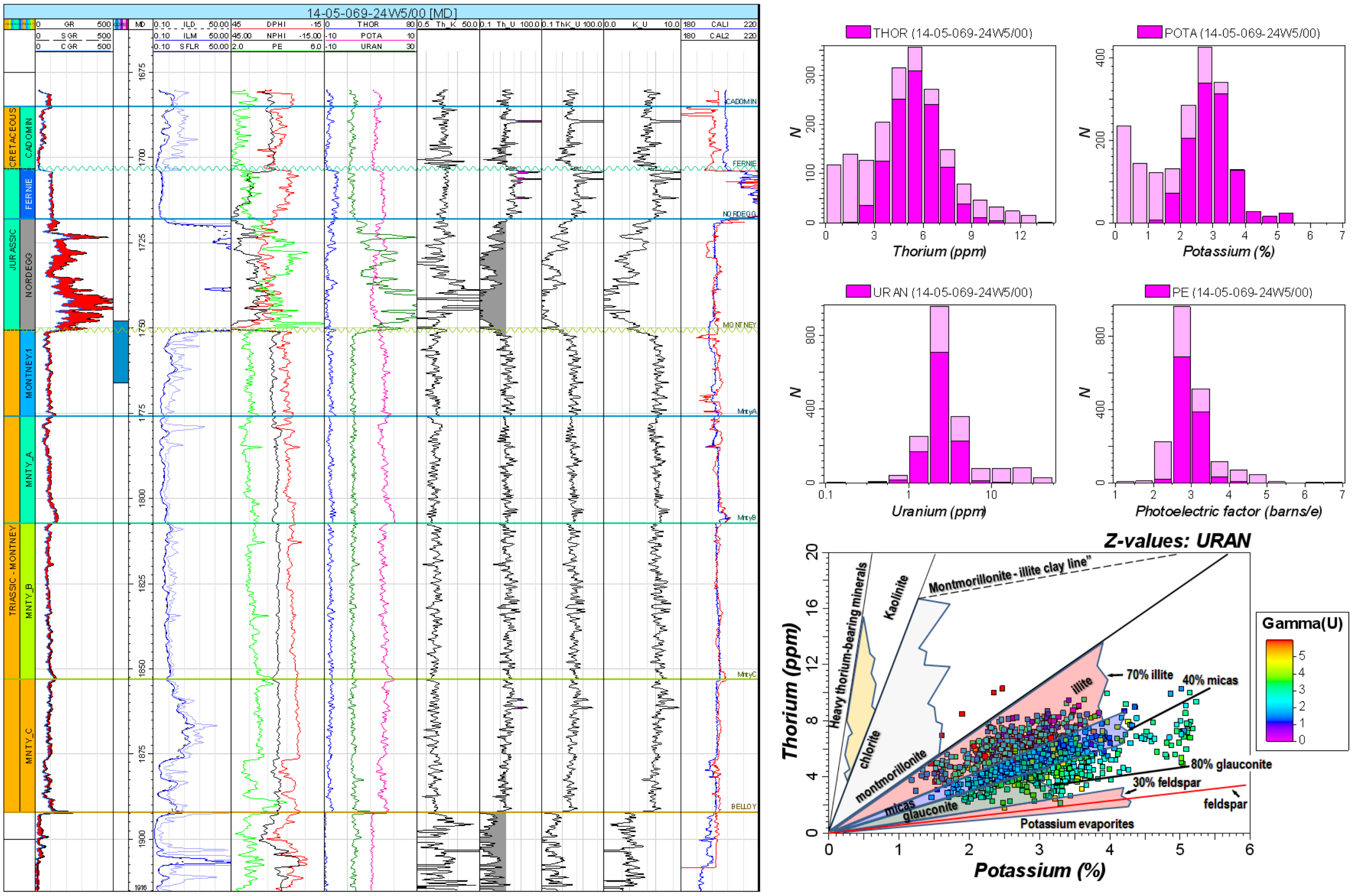

Figure 2 – Example of spectral gamma ray and conventional well logs suite displayed for the well 14-05-069-24W5. The data shown in the Thorium vs. Potassium plot, and highlighted in the histograms above refers only to the total Montney Formation interval.

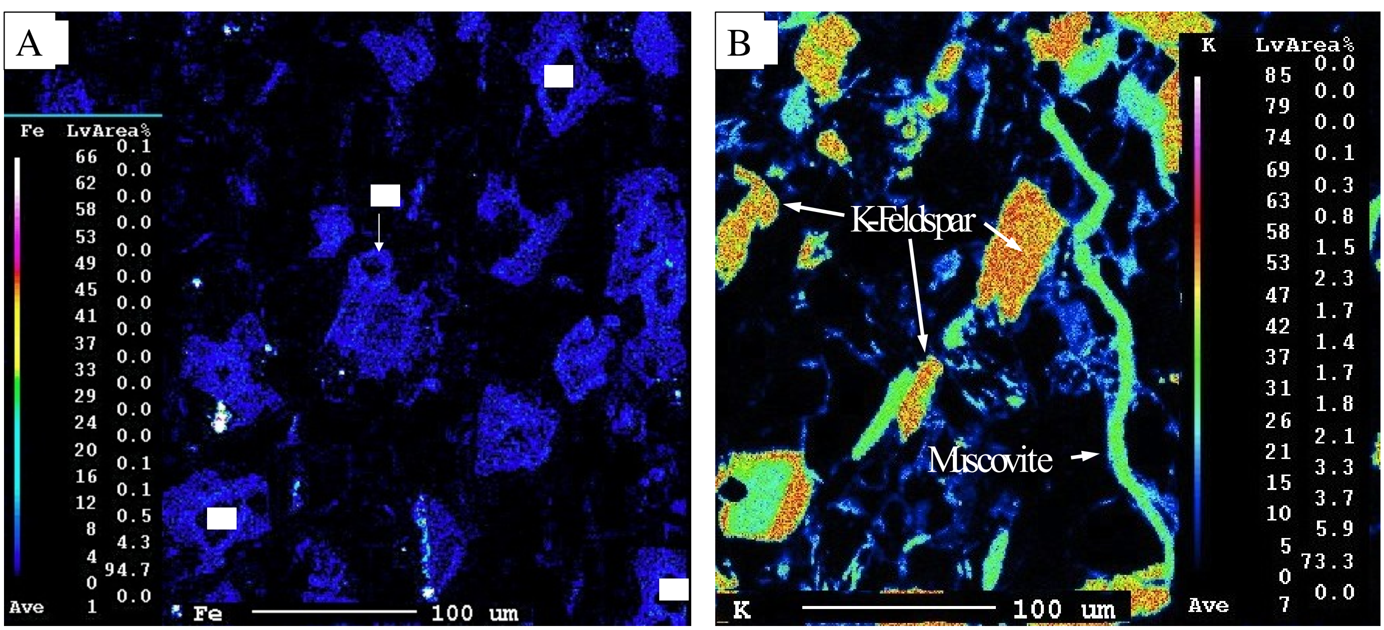

Figure 3 – A.) Chemical element maps for Fe of Fe rich crystalline dolomite overgrowths on Fe depleted detrital dolomite cores (Cr). B.) K-Feldspar minerals and muscovite flakes and diffuse K-bearing clays? in blue. Sturgeon Lake South well 04-28-69-25W05.

Examples

As noted above, we observed a mixture of carbonate and siliciclastic minerals in the Montney Fm. and, of which, the most common one is dolomite. The formation therefore is a siliciclastic dolostone; a response that is also borne out by the P_e log traces following the identification of dolomite other means. In spite of this, at the time of deposition, the rock was shale, as we document with **grain size** analyses from thin sections and microprobe chemical element maps. Modal analyses performed on the dominant siliciclastic fragments (quartz, albite, and K-feldspar mineral grains) range between 4.2 and 4.7 Ø, the size of coarse silt. Notably some crystalline dolomites also contain rounded silt-sized cores that reflect a detrital dolomite particle precursor. Following deposition and during diagenesis these dolomite grains were overgrown syntaxially by ferrroan dolomite and are now irregular, fine sand-sized, rhombic crystals (Figure 3A.). Thus, post-depositional modification of dolomite grains by crystalline ferroan overgrowths has altered the original depositional framework mineralogy to that of a crystalline dolostone.

Conclusions

1. The Montney Fm. in the study area is characterized by a shaly response with total gamma-ray logs (TγR).Importantly, the SγR logs split the TγR log signal into the individual radioactive sources that in this instance originate from K and Th bearing minerals in the formation. Conventionally these records would lead to an interpretation advocating abundant illite clay. An interpretation, which may result in explorationists overlooking this potential hydrocarbon reservoir.

2. Detailed petrologic analysis conducted by us on several subsurface samples from the Sturgeon South Lake area lead us to conclude that suggests that t the Montney Fm. was a carbonate-siliciclastic siltstone at the time of deposition, which was subsequently altered by diagenesis leading to its current mineralogical composition , that of a mixed siliciclastic and crystalline ferroan dolostone or dolarenite.

3. The diagenetic history included the pervasive overgrowth and interlocking of ferroan dolomite crystals around iron-depleted detrital dolomite cores and the enlargement of K and Na bearing feldspars by syntaxial K-feldspar overgrowths.

4.The high K response seen in the SγR logs is due to the presence of abundant K-feldspar and muscovites, rather than illite bearing clays. On the other hand, the scattered minerals, such as monazite and apatite, presumably contribute the Th response.

5. Lastly, our study illustrates conclusively that interpretations based on gamma ray logs have to be ground truthed with rock samples of the formations under scrutiny.

Acknowledgements

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