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Revisiting the Imperial Formation – palaeoenvironmental reconstruction and potential hydrocarbon play

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Summary

The Late Devonian Imperial Formation conformably overlies the carbonates and shales of the Horn River Group, which have been the target of conventional and unconventional oil and gas exploration and development in the Northwest Territories (NWT) for approximately 100 years. The Imperial Formation, however, has been comparatively understudied, and its stratigraphy and regional palaeoenvironmental setting is less well understood. The latest research on the formation was conducted by the Northwest Territories Geoscience Office – now the Northwest Territories Geological Survey (NTGS) for the Peel Project from 2004 to 2007; results of these studies are published in Hadlari et al. (2009a, b) and Pyle (2010).

The Imperial Formation is interpreted to comprise predominantly clastic marine deposits, with up to several decametre thick shale and sandstone packages. Previous studies have divided the Imperial Formation into three informal units: a lower relatively more sand-rich interval, a middle interval with intercalated sandstone and shale, and an upper shale-rich interval (Hadlari, 2009a). The lower sand-rich interval was interpreted to represent a lower shoreface to basin-floor sedimentary succession with westward dipping clinoforms, and a terrestrial sediment source to the east or northeast; and the overlying more shale-rich interval as slope to basin-floor sediments. The terrestrial deposits related to the Imperial Formation deposition are not preserved. In previous projects, the Imperial Formation was only studied in the Peel areas and the northern fringe of the Mackenzie Mountains of the NWT (Hadlari et al., 2009a, b; Pyle, 2010). These studies postulate a hypothetical unconventional gas play in the Imperial Formation, but caution that more study of the petroleum geology throughout the region would be needed to further assess this potential (Hadlari et al., 2009b). This presentation highlights the results of a new preliminary field and well study of the Imperial Formation. This study shows that some of the existing interpretations of the Imperial Formation are in need of revision, and for the formation to be mapped and characterized farther South than previous studies.

Methods

The Energy Group of the NTGS conducted a scoping study to examine six Imperial Formation outcrops: Carcajou River South, Dodo Canyon, Imperial River, Mountain River, Powell Creek, and Gayna Gorge (Figure 1). Carcajou River South and Dodo Canyon, the two southernmost outcrops, are in the Central Mackenzie Valley area of the NWT and have not been studied previously. In the field, all sections were described with a focus on large-scale (m to Dm thick) sedimentary packages, their vertical changes, and the description of small-scale sedimentological palaeoenvironmental indicators. Additionally, samples were taken systematically at each location for geochemical and mineralogical analysis.
Imperial Formation samples were collected from four cores for geochemical analysis, including East Mackay I-78, Loon Creek O-06, Little Bear H-64, Little Bear N-09 (Figure 1).

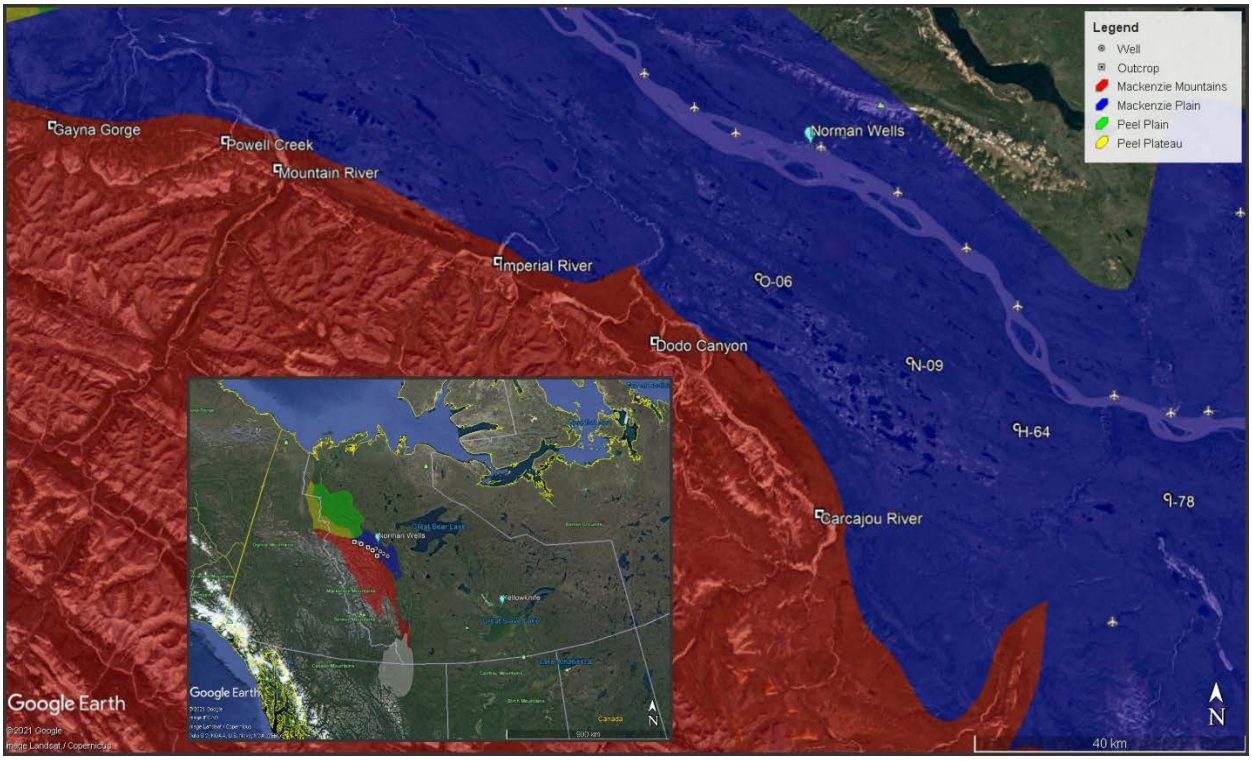

Figure 1: Outcrop and well locations.

Results

Field observations of the Imperial Formation at Carcajou River South show that it comprises intercalated shales and tabular and weakly channelized sandstones. Current and wave ripples, decorated with cm-scale bioturbation, are common and indicate oxygenated shallow marine environments. Carbonate-rich debrites and tempestites suggest the presence of a carbonate shelf or platform that periodically contributed sediment to the clastic depositional system. At Imperial River, the sand-rich middle member of the Imperial Formation comprises an upward shallowing succession, with turbidites common in the lower part of the outcrop. Upward there is an increasing prevalence of current, wave, and interference ripples, bioturbation, and hummocky cross-stratification. Terrestrial vascular plant detritus in the form of mm to dm size coaly fragments is common. This shallowing upward trend was also observed during previous studies, but in contrast to previous interpretations of a shoreface environment, the current interpretation includes foreshore facies. Overall, the interpreted shallowing environment is explained as the result of a prograding shelf and shifting sediment flux. At Powell Creek, tabular sandstones were previously interpreted as a deep-water turbidite fan overlain by more shale-rich slope facies, indicating progradation of the sedimentary system westward. In the current study, the outcrop is similarly divided into two units. The lower unit is, similar to previous interpretations, interpreted as basinal turbidite fan facies. The upper unit is, however, interpreted as shoreface facies evidenced by hummocky cross-stratification, intense bioturbation, and tempestites. This, then, indicates that shallow-water environments stretched farther westward than previously recognized. At Mountain

River and Gayna Gorge only a partial section of the Imperial Formation is present; the observed portions of the Imperial Formation comprise only deep-water turbidite facies.
Lithogeochemical analysis indicates a detrital siliciclastic signature through all sampled sections. The mineralogy comprises ~75% quartz, ~5% feldspar, and ~20% clay in most outcrops, although clay content is variable and up to ~50% in certain intervals. Porosity of sandstones ranges from 7% to 11% across the field sites, and permeability ranges from 0.02 to 0.13 mD. Surface samples yielded an average TOC content from 0.80% at Powell Creek to 2.60% at Dodo Canyon, and in wells averages of 0.83-1.05%. Average T_{max} values in outcrop range from 440 °C to 443 °C and 424 °C to 441°C in wells. A Pseudo-van Krevelen plot of the samples indicates mixed type kerogen present in the Imperial Formation.

Conclusions

The results of the well and field sampling program support and expand on previously published geochemical and petrophysical data of the Imperial Formation. Field observations at Imperial River and Powell Creek indicate that the shallow-water sedimentary system prograded farther toward the West than previously recognized. New observations at Dodo Canyon and Carcajou River South add further insight to the extent of the clastic depositional system. Collectively, these observations highlight the need for additional research to map and sample the Imperial Formation as a potential hydrocarbon source and reservoir.

Acknowledgements

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References

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