geoconvention
Calgary • Canada • June 17-19 2024

Mapping Mackenzie Delta from the surface of Richardson Mountains & Caribou Hills, NWT

Yaqub O. Adepoju, Viktor Terlaky, Jonathan Rocheleau.
Northwest Territories Geological Survey

Introduction

Studying the relationship between the Mackenzie Delta, the nearby Richardson Mountains, and Caribou Hills in the Northwest Territories (NWT) (Figure 1) is crucial for understanding the region's geological history. To gain a better understanding of the geological processes that have influenced the region, the NTGS is currently studying the paleo-depositional environments of the rock formations and the associated tectonic activities of these regions. Additionally, analyzing geomorphic processes such as erosion, sedimentation, and landscape evolution can provide valuable insights. Moreover, considering the presence of valuable natural resources such as oil, gas, and solid minerals, knowledge of the geological history can provide important information for economic development, and environmental management and conservation efforts. The rock outcrops in the northern Richardson Mountains and Caribou Hills offer valuable insights into the geological past of the Mackenzie Basin (Dixon, 1996; Chen et al., 2021).

In this study, our main objectives are to update the geological map of the NWT and research the potential for carbon sequestration by identifying potential reservoirs as part of climate change mitigation efforts. Another important objective of this project is to develop a comprehensive workflow for analyzing factors, estimating, and addressing uncertainty related to using rock outcrops as analogues in subsurface mapping and stratal characterization.

The Energy Group of the Northwest Territories Geological Survey (NTGS) has initiated a 5-year study to collect data from the field, conduct laboratory analyses, and do desktop modeling of the Mackenzie Delta and surrounding regions. Part of the fieldwork is to assess and use outcrop data as analogues for the subsurface layers beneath the Mackenzie Delta. These collected data will be used to create stratigraphic and structural frameworks and facies models of the rock formations in the Mackenzie Basin.

In the summer of 2023, a reconnaissance survey of the northern Richardson Mountains and Caribou Hills was conducted to gather data from outcrops along creeks and river cuts. These field observations and measurements served as calibration points for interpreting data from the subsurface, including seismic and well data, core, logs, and interpretations. The resulting subsurface maps constitute input data for other ongoing projects of the NTGS, including the mapping of the Western Canadian Sedimentary Basin.

Method

Our research method combines field survey observations with desktop analyses of various data. We accessed remote field sites using helicopters or boats, and vehicles for road cuts. During the survey, we recorded visual observations and measurements and collected rock samples from exposures at each station. The selection of field stations was based on predefined criteria, including suitability and accessibility. To identify and locate suitable field stations, we used existing geological maps, geophysical survey data (2D seismic lines), aerial photographs, and satellite images. The accessibility of these rock formations allowed us to analyze the geological context, including the sedimentation process, depositional environments, lithofacies, and structural and tectonic features. In addition to field observations, we consulted relevant literature both in the field and off-site to guide our planned traverses and geological analysis.

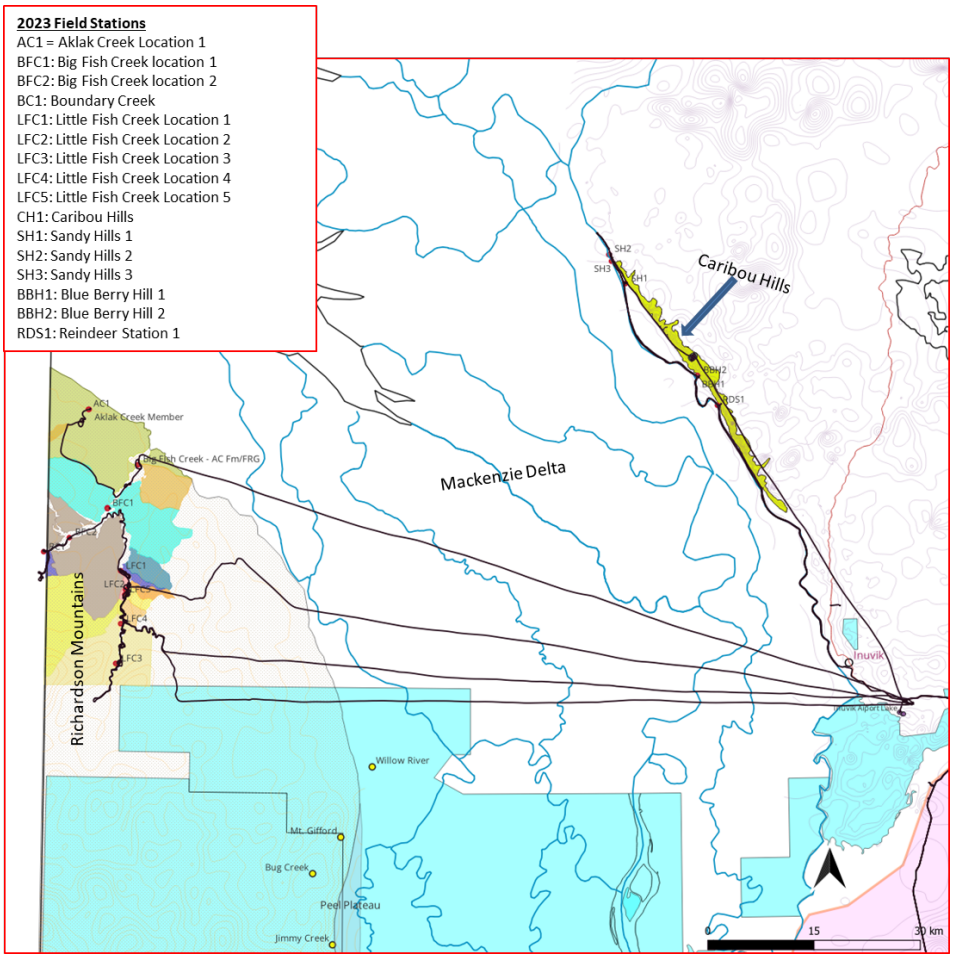

Figure 1: Map showing logistic routes and field stations for the 2023 field season.

We directly logged the rock's physical properties, such as strike and dip, the thickness of strata, and gathered gamma-ray data for further analysis. Laboratory analysis of the rock samples will help us explore the geochemical and petrophysical properties and compare the results with data obtained from cores and geophysical well logs. Given that the rock samples obtained from Caribou Hills are primarily Cenozoic in age, sediment provenance information is crucial. For the Mesozoic rock samples, we intend to perform paleontological analysis, mineralogy analysis using a polarizing microscope, and geochemical analysis including X-ray fluorescence (XRF) and inductively coupled plasma mass spectrometry (ICP-MS) to determine the elemental composition of the rocks. The desktop analysis will combine field data and subsurface data, including publicly available well and seismic data; to support this endeavor, the NTGS acquired 20,500 km of public seismic lines from the Mackenzie Delta and the Beaufort Sea. This analysis will be used to construct a 3D structural and stratigraphic framework for the subsurface of the Mackenzie Delta.

We also plan to carry out uncertainty analysis to quantitatively assess the reliability and variability of data interpretations. This will involve conducting sensitivity analyses, Monte Carlo simulations, or probabilistic modeling to evaluate the impact of uncertain parameters and assumptions on geological models.

Observations

The northern Richardson Mountains predominantly consist of clastic sedimentary rocks that were deposited between the Jurassic and Paleogene. At the southern boundary of the survey area, the main rock types are sandstone and shale, comprising the Jurassic Kingak and Porcupine River Formations, and the Early Cretaceous Husky Formation (Norris, 1977; Dixon 1996). Moving north along the cut bank of Little Fish Creek, younger rock formations are encountered. These formations consist of interbeds of dark shale and ironstone, known as the Rapid Creek Formation, which is overlain by a bituminous iron-oxide-rich dark grey shale identified as the Late Cretaceous Boundary Creek Formation. The Boundary Creek Formation was also mapped at its type locality on the Yukon/NWT boundary (Norris, 1977; Dixon, 1996).

Near the confluence of Little Fish Creek and Big Fish Creek, there are exposed Late Cretaceous and Mid-Paleogene strata. These strata consist of sandstone with shale intervals, and they are believed to belong to the Fish River Group (Norris, 1977; Dixon, 1996). The Fish River Group can be divided into two parts: the Moose Channel Formation, which is a light-gray formation consisting of thick/blocky sandstone and thin layers of conglomerate with shale interbeds; and the Ministicoog Member, which is a light-gray siltstone with mudstone interbeds. The Moose Channel Formation has been further divided into five subunits by Holmes & Oliver (1973) to represent different depositional processes. Overlying the Moose Channel Formation is the Aklak Creek Member of the Reindeer Formation, which is composed of conglomerate and sandstone rich in iron oxide, along with shale and coal layers. This member unconformably overlies the Moose Channel Formation (Norris, 1977; Dixon, 1996; Chen et al., 2021). Although the Aklak Creek Member was observed at the northernmost outcrop of the study at Aklak Creek,

the exact basal contact was not identified during fieldwork. However, the unconsolidated gravels, sands, and mud with thin lignite seams observed in the Caribou Hills are believed to be lateral equivalents of the conglomerates seen on the cliff of Aklak Creek in the Richardson Mountains. Figure 2 presents a preliminary cross-sectional profile along the traverse line from Location 3 in Little Fish Creek to the Caribou Hills, through the Mackenzie Delta

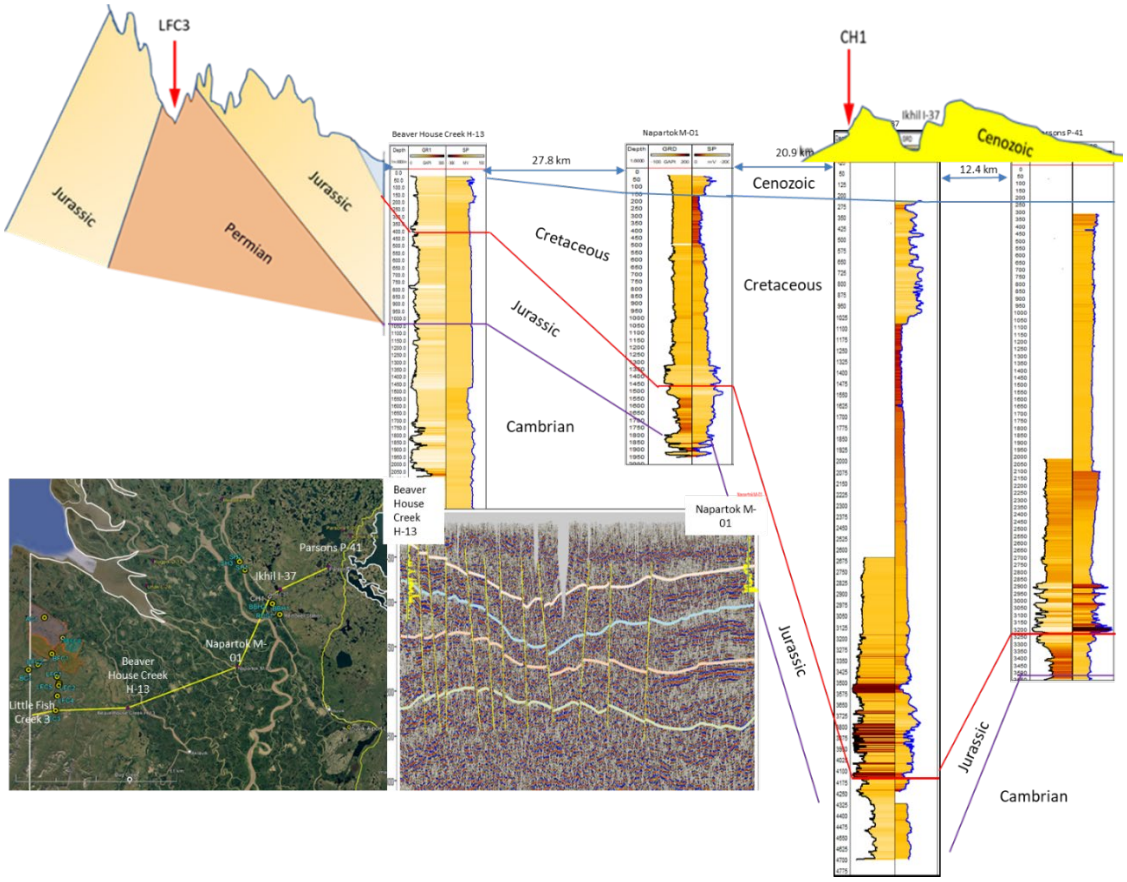

Figure 2: A 2D cross-section of a traverse from Richardson Mountains to Caribou Hills. Inset map and elevation profile created from Google Earth.

The reconnaissance survey has left us with some gaps, particularly regarding the stratigraphic contacts of the rock formations encountered. To address this, we have planned a detailed field survey for the future, which will have a wider scope and cover a larger area. The field survey team is scheduled to return to the study area in the summer of 2024 to conduct a comprehensive mapping exercise. This mapping will specifically focus on locating the contact between the Mesozoic and Cenozoic formations. By doing so, we will ensure that the stratigraphy along the north-to-south traverse of the Richardson Mountains is thoroughly covered.

The project also delivers a preliminary workflow for analyzing factors, estimating, and addressing uncertainty related to the use of geologic analogues in subsurface mapping. This

workflow will encompass various coefficients and calibration factors, as well as comprehensive documentation outlining data sources, methods, assumptions, and uncertainty assessments. To demonstrate the practical application of these workflows, the documentation will include region or formation-focused case studies.

Conclusions

The NTGS Energy Group has recently conducted a reconnaissance field survey of the Richardson Mountains and Caribou Hills. This survey marks the beginning of a 5-year project, with detailed mapping planned for 2024. The information gathered about the structural, stratigraphic, and sedimentological characteristics of the rock formations in the study area will greatly contribute to the development of a new basin model and an updated geological map. Additionally, this project will support the identification and characterization of formations suitable for carbon sequestration in the Mackenzie Delta region.

Acknowledgments

The project was made possible with support from the Mineral and Petroleum Resources Division (MPRD-GNWT), Office of the Regulator of Oil and Gas Operations (OROGO-GNWT), Geological Survey of Canada, Environmental Impact Screening Committee (EISC), Aurora Research Institute (ARI), Gwich'in Tribal Council, Inuvialuit Land Administration, Aklavik Hunters and Trappers Committee, and the Polar Continental Shelf Program (PCSP) for logistical support. We would also like to acknowledge the support received from the NTGS Permafrost team during field planning.

References

Chen, Z., Dietrich, J., Lane, L. S., Li, M, and Dixon, J., 2021. Beaufort–Mackenzie Tectono-Sedimentary Element. From: Drachev, S. S., Brekke, H., Henriksen, E. and Moore, T. (eds) Sedimentary Successions of the Arctic Region and their Hydrocarbon Prospectivity. Geological Society, London, Memoirs, 57, https://doi.org/10.1144/M57-2016-3.

Dixon, J., 1996. Geological Atlas of the Beaufort Mackenzie Area, Geological Survey of Canada, Miscellaneous Report 59, 1996

Lane, L., 1996. Geometry and tectonics of Early Tertiary triangle zones, northeastern Eagle Plain, Yukon Territory. Bulletin of Canadian Petroleum Geology vol. 44, no. 2, 1996 p. 337-348

Norris, D. K. 1977. Geological map of Blow River and Davidson Mountains, Yukon Territory and the Mackenzie District, MAP 1516A. Geological Survey of Canada, Open File 499. https://doi.org/10.4095/129297

Holmes, D. W., Oliver; T. A., 1973., SOURCE AND DEPOSITIONAL ENVIRONMENTS OF THE MOOSE CHANNEL FORMATION, NORTHWEST TERRITORIES. *Bulletin of Canadian Petroleum Geology* 1973; 21 (4): 435–478. doi: https://doi.org/10.35767/gscpgbull.21.4.435