PERMAFROST THICKNESS VARIATION ON PEAT PLATEAU IN THE CENTRAL MACKENZIE VALLEY, NWT

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INTRODUCTION

Permafrost temperature, thickness and distribution in the central Mackenzie Valley is principally known from the eastern side of the Mackenzie River between Wrigley and Fort Good Hope [1-4]. The relative lack of permafrost data beyond this development corridor limits our regional understanding of permafrost conditions across a diversity of physical environments that characterize the central Mackenzie Valley. This bias in distribution of field investigations makes it unclear whether the inferred state of permafrost along the development corridor applies to conditions across the wider region. This project investigates the thicknesses of permafrost under peat plateau in the central Mackenzie Valley, through the transition zone from regionally discontinuous to continuous permafrost. Here, we assess the material properties, ground ice content and permafrost thicknesses at four sites located at varying elevations, vegetation cover, and geological settings using electrical resistivity tomography and ground temperature data.

STUDY AREA AND METHODOLOGY

1 STUDY AREA

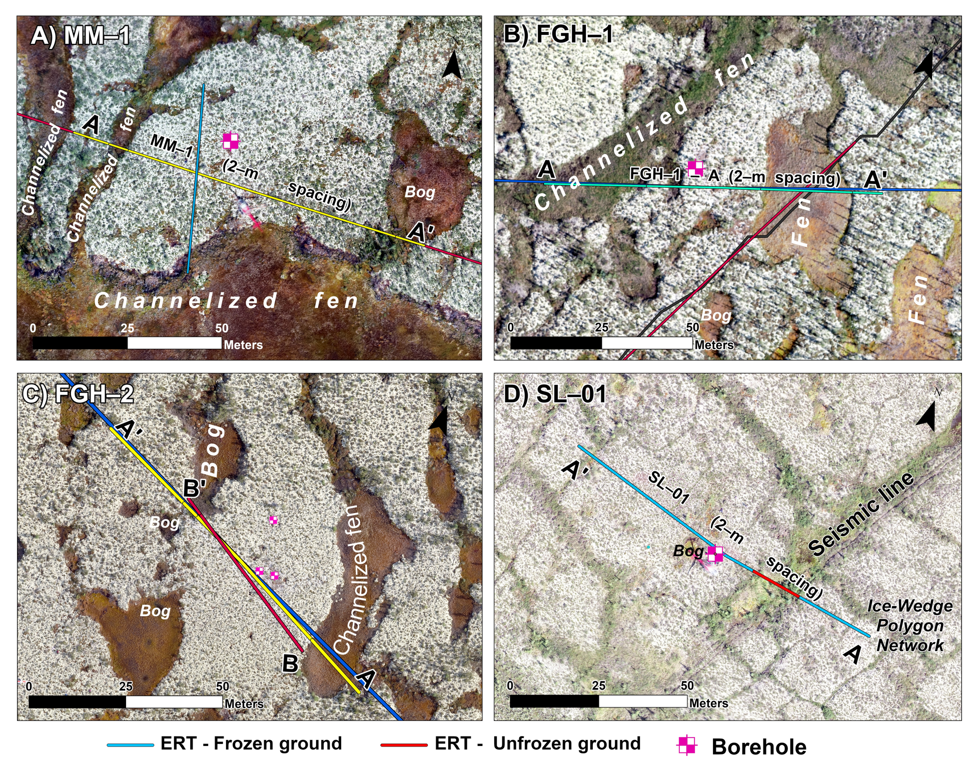
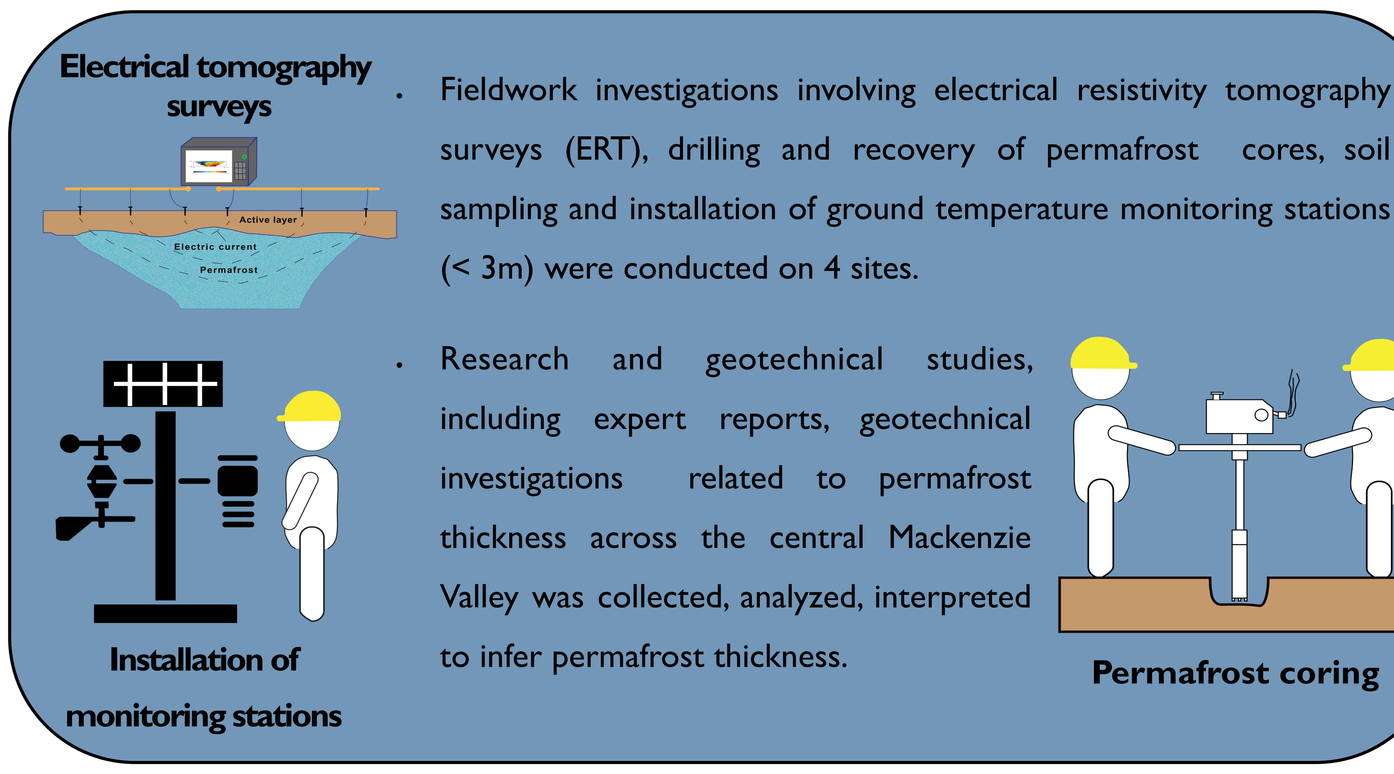
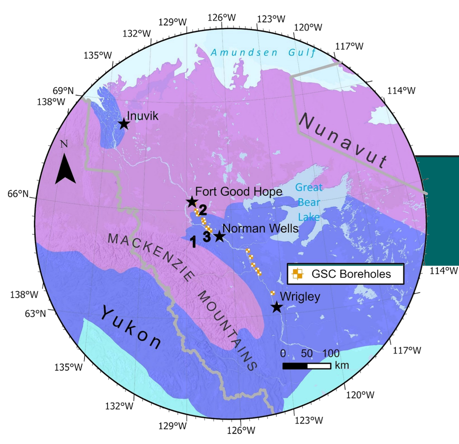


Figure 1. High resolution drone imagery of the central Mackenzie Valley study sites showing raised permafrost peat plateau and collapse bogs, channels and troughs and the position of the ERT transects.

2 FIELD INVESTIGATION AND LITERATURE REVIEW



- Fieldwork investigations involving electrical resistivity tomography surveys (ERT), drilling and recovery of permafrost cores, soil sampling and installation of ground temperature monitoring stations (< 3m) were conducted on 4 sites.
- Research and geotechnical studies, including expert reports, geotechnical investigations related to permafrost thickness across the central Mackenzie Valley was collected, analyzed, interpreted to infer permafrost thickness.



ELECTRICAL RESISTIVITY TOMOGRAPHY

Thirteen ERT surveys were collected at four permafrost peat plateau sites (**Figure 1**). Here, we present ERT profiles showing estimated permafrost thickness at each of the 4 study sites within the central Mackenzie Valley.

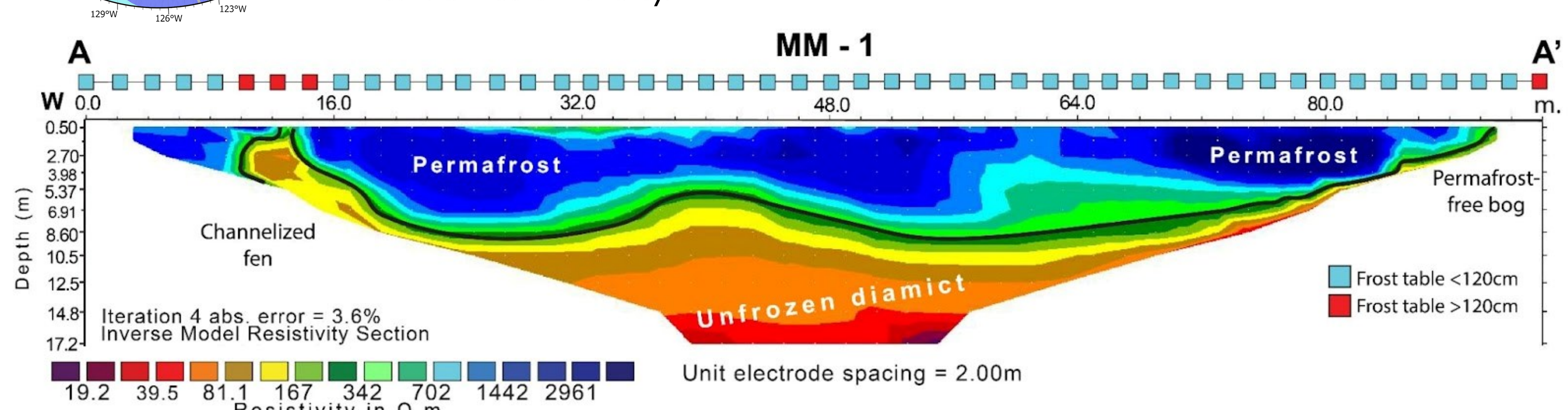


Figure 2. ERT profile (2-m spacing) and frost table probing results across a permafrost peat plateau and a channelized fen.

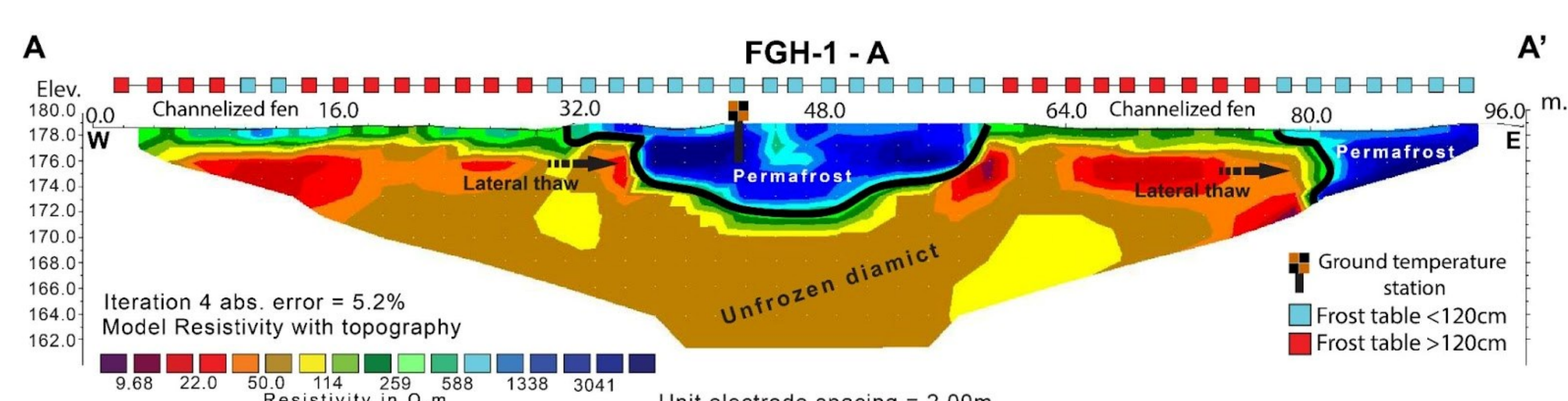


Figure 3. ERT profiles at FGH-1 of the dendritic peat plateau near Fort Good Hope. ERT profile (2-meter spacing) and frost table probing across permafrost peat plateaus and channelized fens. A topographic elevation model was used for the vertical axis. Black lines represented the inferred base of permafrost.

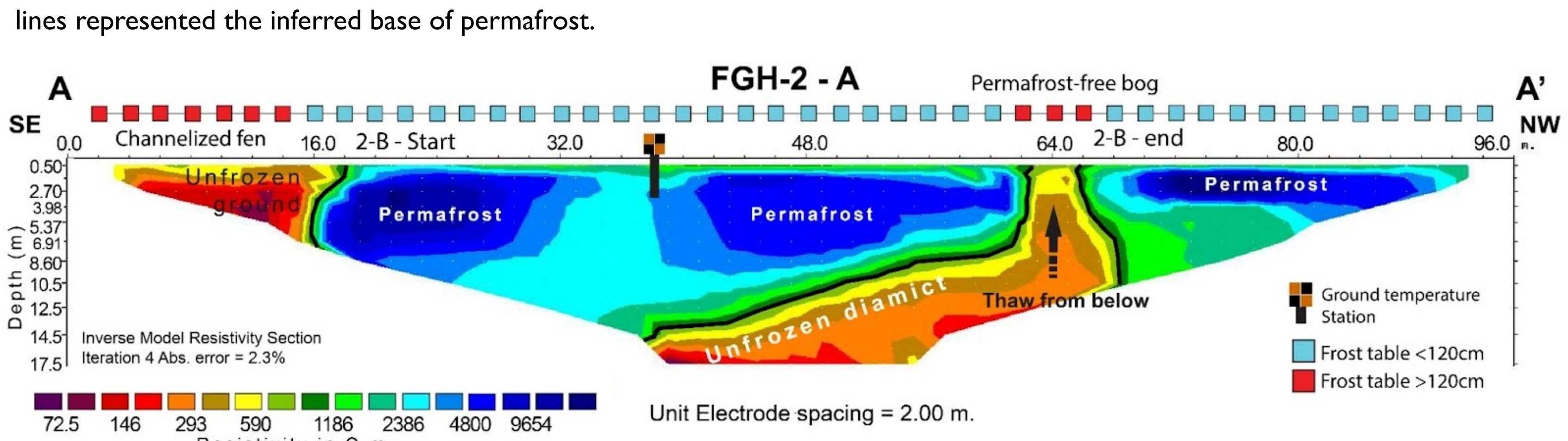


Figure 4. ERT profiles at FGH-2 of the dendritic peat plateau near Fort Good Hope. ERT profile (2-meter spacing) across permafrost peat plateaus and a channelized fen, and a bog.

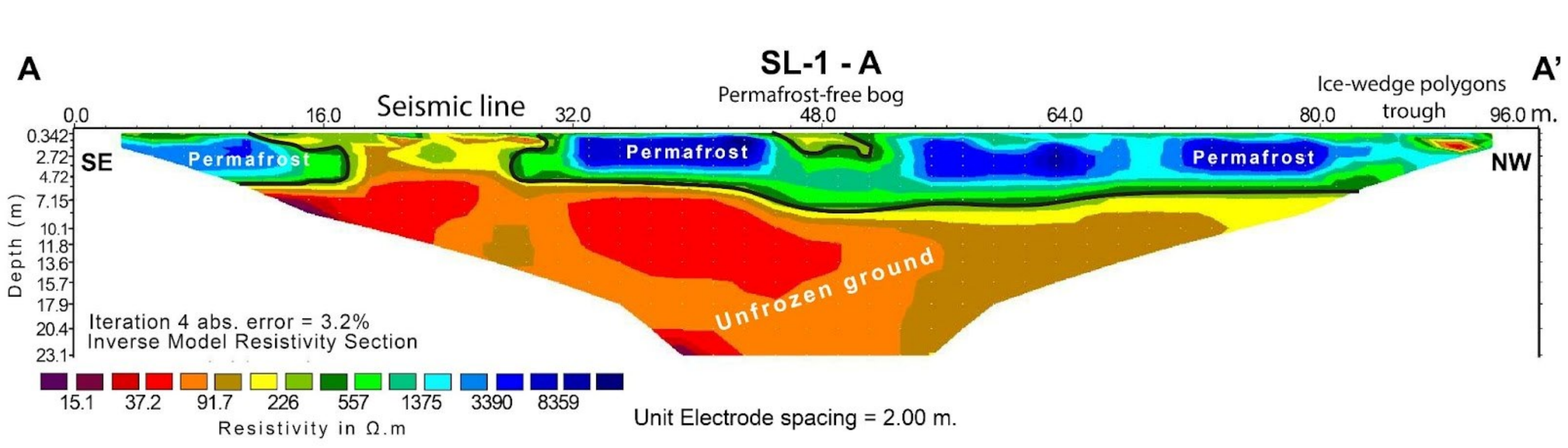


Figure 5. A 2-m ERT survey profile at a polygonal peat plateau near Norman Wells.

GROUND TEMPERATURE DATA AND RESULTS

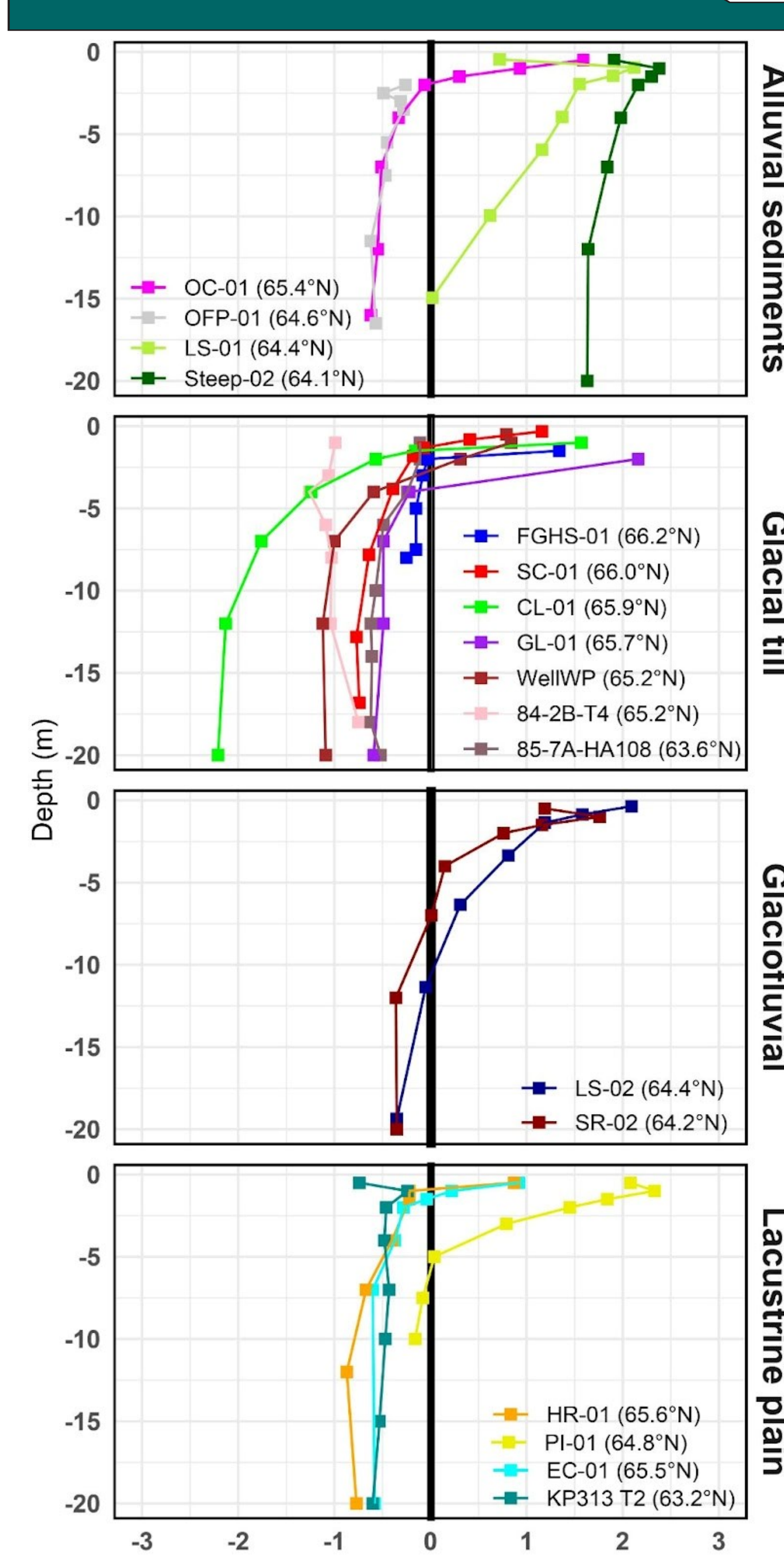


Figure 6. Maximum annual ground temperature (2017-2018) separated by sediment types for selected sites along the eastern side of the central Mackenzie Valley, NWT (Modified from [3] Duchesne et al. 2020).

- In **Figure 2**, high resistivity values (>300 Ω.m) characterize the upper 7 m of the profile. Frost probing and ERT values suggest a permafrost resistivity boundary of about >300 Ω.m for frozen peat [4-5].
- The ERT data in **Figure 3** shows high resistivity (>500 - 600 Ω.m) values in the first 6 meters of the profile. Boundary contact between unfrozen/frozen ground was inferred at around 500-600 Ω.m based on the presence of coarse sands and gravels at depth (high modeled resistivity values) [5].
- From profile FGH-2-A (**Figure 4**), ERT data showed high-resistivity regions (≥700 Ω.m) under the peat plateau, suggesting that permafrost extends to 15 ± 3 m depth. The lower ERT values (≥600 Ω.m) agree with frost probe data along the ERT transect, in which no frozen material was encountered at the edges and in the center of the wetlands during frost probe measurements.
- **Figure 5** shows high resistivity throughout the profiles, probably associated with the presence of ice wedges (**Figure 1D**) and permafrost to a depth of ~7.5 m. The resistivity boundary betw een frozen and unfrozen sediments was inferred to be between 300 and 400 Ω.m. The lowest resistivity (~15 to ~300 Ω.m) in the near-surface corresponds to the disturbed ground where the (~12 metre wide) seismic line was cut in the 1970s.

DISCREPENCIES, DISCUSSION AND NEXT STEPS

- This study demonstrates notable heterogeneity and discrepencies in permafrost thickness across the central Mackenzie valley.
- The synthesis of past data/observations indicates permafrost thicknesses commonly exceed 20 m at sites with well-drained mineral soils with thin organic matter (> 1 meter) at the surface [1-3] (**Figure 6**).
- These observations contrast significantly with the thin, discontinuous and fragmented permafrost conditions and thickness varying between ~5 to ~15 m observed within all of the dendritically drained, and polygonal peatlands that we studied in the central Mackenzie Valley.

Future Work

- Future work will explores the sensitivity of organic deposits to thawing and the importance of fragmentation, lateral and advective heat flux in controlling permafrost thickness and patterns of degradation in permafrost peatlands in the central Mackenzie Valley.

References

1. Smith, S.L., Burgess, M.M., Riseborough, D., & Mark Nixon, F. 2005. Recent trends from Canadian permafrost thermal monitoring network sites. Permafrost and periglacial processes, 16(1), 19-30.
2. Smith, S. L., Romanovsky, V. E., Lewkowicz, A. G., Burn, C. R., Allard, M., Clow, G. D., ... & Throop, J. 2010. Thermal state of permafrost in North America: a contribution to the international polar year. *Permafrost and Periglacial Processes*, 21(2), 117-135. https://doi.org/10.1002/ppp.690
3. Duchesne, C., Chartrand, J., and Smith, S.L. 2020. Report on 2018 field activities and collection of ground-thermal and active-layer data in the Mackenzie corridor, Northwest Territories; *Geological Survey of Canada, Open File 8707*, 84 p. https://doi.org/10.4095/321921
4. Lewkowicz, A.G., Etzelmüller, B., and Smith, S.L. 2011. Characteristics of discontinuous permafrost based on ground temperature measurements and electrical resistivity tomography, southern Yukon, Canada. *Permafrost and Periglacial Processes*, 22(4), 320-342.
5. Way, R.G., and Lewkowicz, A.G. 2015. Investigations of discontinuous permafrost in coastal Labrador with DC electrical resistivity tomography. In Proceedings of GéoQuebec: *68th Canadian Geotechnical Conference and 7th Canadian Permafrost Conference*. Quebec City, Canada (p. 8).

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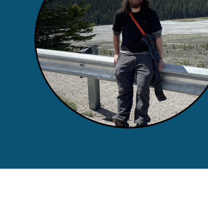

Collaborators

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