Thermal dissection and radiocarbon analysis of organic matter released from permafrost thaw slumps using online ramped oxidation-accelerator mass spectrometry (ORO-AMS).

Conference Poster

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Thermal dissection and radiocarbon analysis of organic matter released from permafrost thaw slumps using online ramped oxidation-accelerator mass spectrometry (ORO-AMS).

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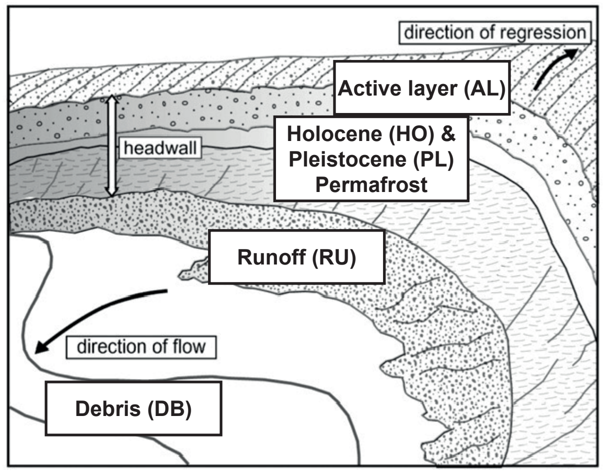
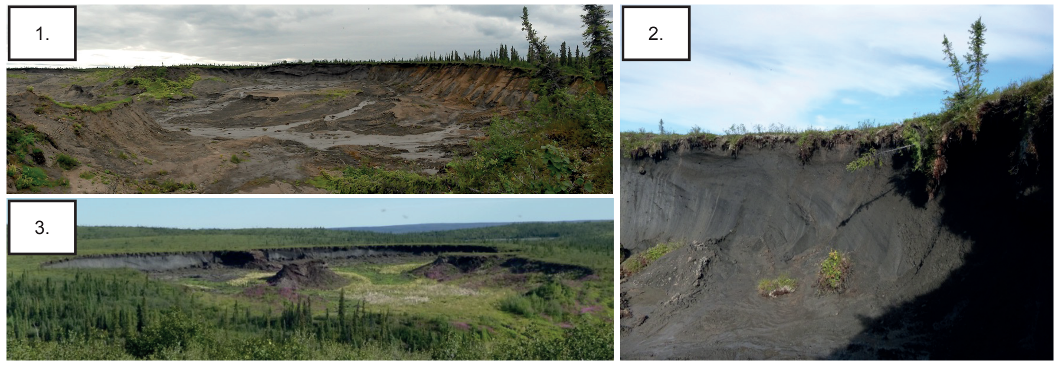
1 Motivation and study area

Throughout the rapidly warming Arctic, permafrost thaw mobilizes vast amounts of old, potentially labile organic matter (OM). Retrogressive thaw slumps (RTS) cause significant landscape changes and facilitate greenhouse gas emissions as CO_2 and CH_4 through thaw-driven erosion, creating large, teardrop-shaped scars. The Peel Plateau in Northwest Territories, Canada, has experienced increased RTS activity since the early 2000s. To better assess the susceptibility of this mobilized OM to decomposition from permafrost, we collected material from various sources: different permafrost layers, the seasonally thawed active layer, recently thawed debris, and runoff exiting the slump. Here we investigate two well-studied RTS features:

Fm2 (1.): *headwall height 25 m, affected area: 48 ha, growth rate 15 m/yr, age >70 yrs [1].*

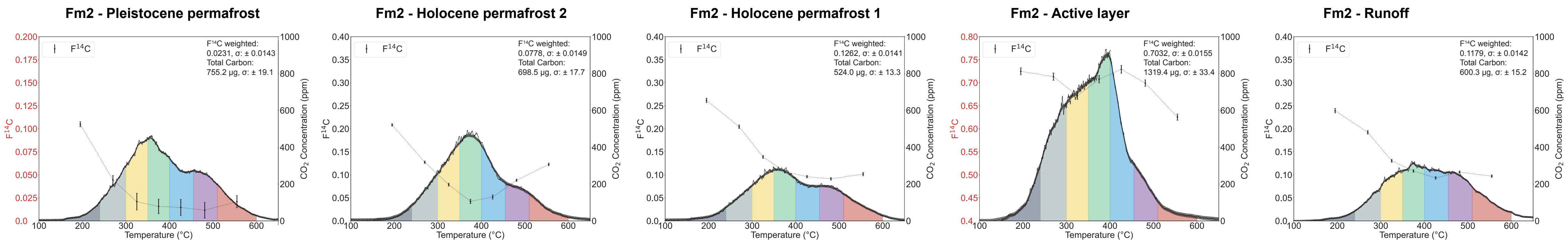
Fm3 (2., 3.): *headwall height 6.5 m, affected area: 10 ha, growth rate 12.5 m/yr, age <25 yrs [1].*



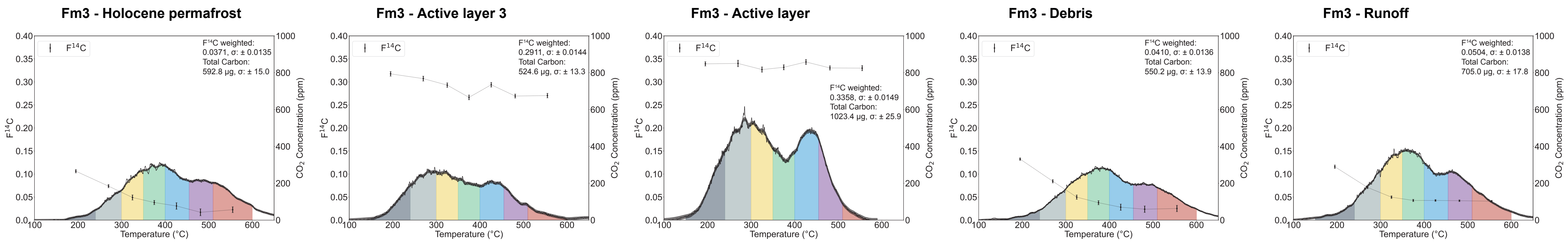


Left, modified conceptual scheme of RTS, from [2]. Picture 1.: location RTS Fm2 by Zolkos. Picture 2. and 3.: from location Fm3 by Bröder. 2.) headwall close-up 3.) the area affected.

2 Preliminary results: slump organic matter characterisation



In the Fm2 RTS features, 3 permafrost, runoff, and active layer samples were analyzed. The $F^{14}C$ axis shows different scales (in red) for the Pleistocene permafrost exhibiting $F^{14}C$ values close to 0 (radiocarbon dead), while the active layer displays particularly modern (i.e., close to 1) $F^{14}C$ values. In all the thermogram plots (CO_2 over temperature), two shoulders are visible, with permafrost and runoff showing a more prominent shoulder at ~ 350-400°C. The active layer distinctly shows a peak for CO_2 at 400°C and decreasing rapidly. We believe this is due to the active layer containing more labile OM, likely compounds such as cellulose and lignin, based on the combustion temperature. The bulk and weighted $F^{14}C$ values are within the margin of error for all samples. Typically, more labile compounds are expected to be younger ($F^{14}C$ close to 1) compared to more recalcitrant ones ($F^{14}C$ closer to 0). However, in the case of the permafrost, we observe a reverse trend in the later fractions. For the active layer, there is a general trend of decreasing $F^{14}C$ with higher temperatures. This trend is mitigated by an increase in $F^{14}C$ within the thermal window of 400 - 455°C.



In the Fm3 RTS features, permafrost, debris, runoff, and 2 active layers samples were analyzed. The thermograms for the active layers show more CO_2 at lower temperatures (i.e., 240 to 350°C), generating a peak at around 300°C. In contrast, the runoff, debris, and permafrost layers show combustion at higher temperatures, resulting in a peak between 350 - 400°C. This suggests the presence of more labile OM in the active layers, which is not as prevalent in the debris, runoff, and permafrost. The $F^{14}C$ shows a general trend of older OM at higher temperatures for the debris, runoff, and permafrost, as expected. However, the active layers do not follow this trend. Specifically, AL2 does not show the expected decrease in $F^{14}C$, which might indicate that AL2 contains both labile and recalcitrant material originating from the same period.

Radiocarbon (^{14}C) analysis can be used to trace the sources and fate of OM. Online ramped oxidation (ORO) coupled with accelerator mass spectrometry (AMS) provided insights into the thermal stability and decomposition susceptibility of OM combined with its radiocarbon age. For this study the following themal window cutoffs were selected **150**, **240**, **300**, **350**, **400**, **455**, **510**, **600 °C**.

Earlier studies showed permafrost layer samples, runoff, and debris with uniform grain size and carbon content (1.2% to 1.5%) and bulk fraction modern ($F^{14}C$) values reflecting Holocene and Pleistocene epochs corresponding to the timing of permafrost formation. Active layer samples had higher carbon content (up to 16%) and varied $F^{14}C$ values, indicating conventional ^{14}C ages between approximately 10,000 and 2,600 years [1].

3 Summary & outlook

The thermograms reveal an overall decreasing trend in $F^{14}C$ per fraction, with permafrost samples exhibiting the lowest values and RU samples showing consistent values. AL samples display the most variation, characterized by larger CO_2 peaks at lower temperatures, while RU and DB samples resemble HO and PL characteristics. However, some $F^{14}C$ measurements in specific fractions do not follow this expected decreasing trend. To better understand the $F^{14}C$ evolution, we need to identify the organic compounds combusted in these thermal windows. By using pyrolysis gas chromatography mass spectrometry (Pyro-GCMS), we aim to chemically fingerprint the different compounds in each fraction, which will provide insight into the sources and nature of the organic matter.

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