Buried-ice degradation controls the evolution of a high-Arctic proglacial landscape: the Comfortlessbreen forefield, Svalbard

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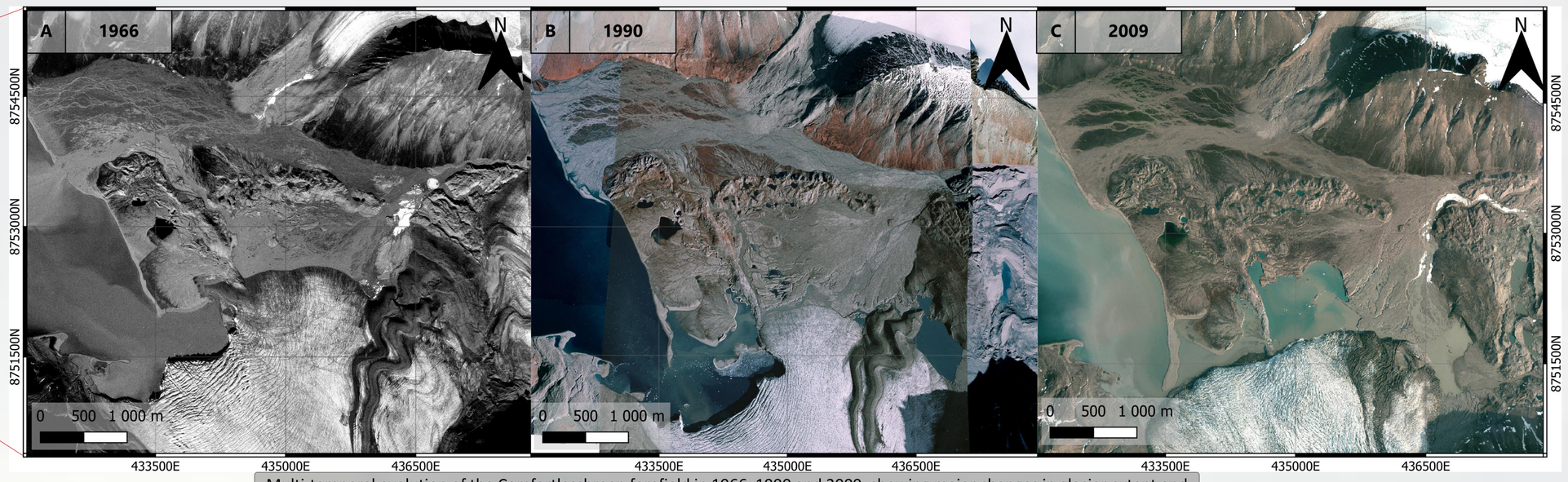
1. Introduction

Recently deglaciated Arctic forefields commonly contain ice-rich sediments and buried glacier ice, whose degradation can produce kettle holes, collapse structures and other distinctive landforms (Hambrey, 1984). Understanding these processes also provides valuable terrestrial analogues for interpreting ice-related landforms on Mars.
The Comfortlessbreen forefield, western Svalbard, serves as a natural laboratory to investigate these processes. A glacier surge during the 2000s modified the glacier geometry and the proglacial environment setting, reaching its late surge phase by 2009 (Sund & Eiken, 2010; King et al., 2016).
Multi-temporal observations reveal Ring-Like Features (RLFs), comparable to recently described glacial ring forms (Hibbard et al., 2025), and a related morphology here termed Trench-Like Features (TLFs). Their origin and evolution provide an opportunity to investigate the role of buried ice in proglacial landscape degradation.

Location of the study area in western Svalbard, Norwegian High Arctic.



Multi-temporal evolution of the Comfortlessbreen forefield in 1966, 1990 and 2009, showing major changes in glacier extent and the proglacial landscape.

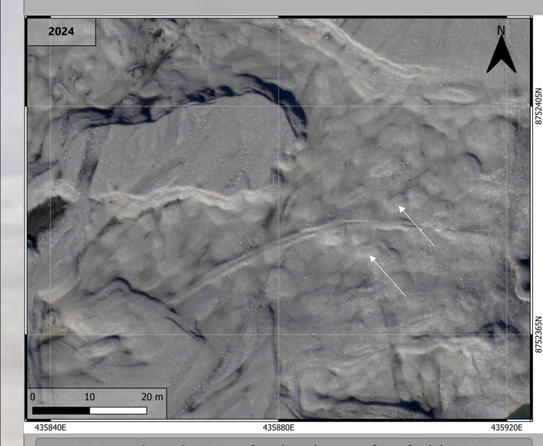
How does buried-ice degradation control the evolution of the Comfortlessbreen proglacial landscape?

2. Data & Methods

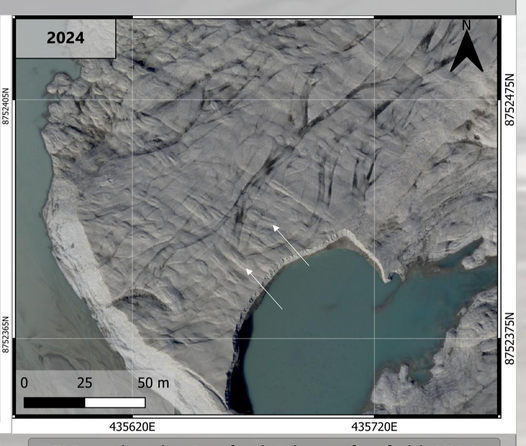
A multi-temporal remote-sensing approach was used to reconstruct the evolution of the Comfortlessbreen forefield over nearly six decades. Historical and recent orthophotos were compared to map geomorphological changes and track the development of degradation landforms.
High-resolution DEM, NIR and thermal datasets were used to characterise surface morphology and identify signatures potentially associated with subsurface-ice degradation. RLFs and TLFs were mapped and compared through time to assess their spatial distribution, morphology and evolution.

	RGB	NIR	DEM	Thermal	Panchromatic
1966					•
1990	•				
2009	•	•		•	
2024	•		•		

3. Results



RLFs within the Comfortlessbreen forefield, 2024 orthophoto.



TLFs within the Comfortlessbreen forefield, 2024 orthophoto.

Ring-Like Features (RLFs)
Circular to elliptical depressions occur individually or in clusters within the proglacial deposits.

Trench-Like Features (TLFs)
Elongated, sub-parallel depressions occur in nested arrangements, locally forming distinctive "onion-peel" patterns.

Rapid and spatially heterogeneous degradation (2009–2024)
Previously continuous fan surfaces developed numerous depressions and collapse structures between 2009 and 2024, while adjacent surfaces underwent little visible change.

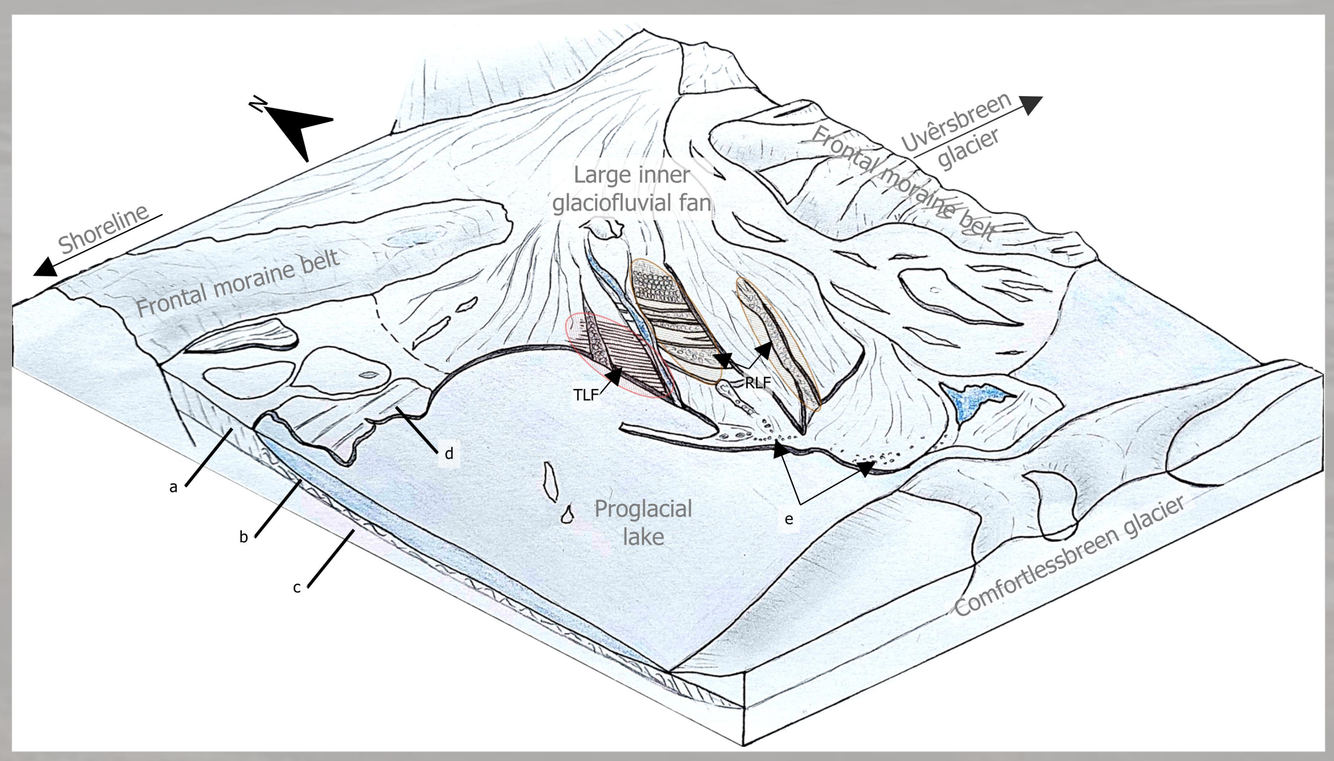
Evolution of the same outwash-fan surface between 2009 and 2024.

4. Discussion & Conclusions

The morphology and progressive development of RLFs and TLFs are consistent with buried-ice degradation. **RLFs and TLFs may represent different expressions of the same degradation process:** discrete buried-ice bodies may favour RLF development, whereas the nested geometry of TLFs may reflect a more complex, layered ice–sediment architecture.

Strongly degraded surfaces coexist with comparatively stable terrain, suggesting an **uneven distribution of buried ice** inherited from differences in depositional history and ice incorporation during outwash-fan construction.

Successive episodes of sediment deposition may have buried ice within parts of the proglacial system. Subsequent melting progressively destabilised the overlying sediments, producing **RLFs, TLFs and extensive surface collapse.**



Conceptual model of the Comfortlessbreen–Uvêrsbreen proglacial system, illustrating the proposed relationship between sediment deposition, buried ice and subsequent development of RLFs, TLFs and surface collapse.

RLFs and TLFs may represent distinct surface expressions of buried-ice degradation, preserving a geomorphological record of ice incorporation during proglacial deposition.

Sources

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