

# Glacier structure influence on Himalayan glacial lake expansion

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## 1. Introduction

As glaciers in the Himalaya have lost mass, their proglacial lakes have expanded (Nie et al., 2021). Despite increasing interest in the role of glacier structures in controlling patterns and rates of glacier recession, and subsequently of lake expansion, have not yet been investigated in detail (Richardson and Reynolds 2000a; 2000b; Westoby et al., 2014). We aim to quantify the role of glacier structures in Himalayan glacial lake expansion, to achieve this we identify and map glacier structures over a 20-year period and investigate their role in ice front recession and glacier calving across four distinct glacial lake systems in the Himalaya.

## 2. Materials and Methods

- Four glacial lakes and their associated debris-covered glaciers have been examined in the Everest Region of Nepal and China: Imja Tsho, Tsho Rolpa, Lumdin Tsho, and Dang Pu Tsho (Figure 1).
- Lake area was mapped yearly between 2000 and 2020 using images acquired from Landsat 5/7/8 and Sentinel 2 (available at <https://earthexplorer.usgs.gov>).
- Discrete glacier flow units were identified and transverse features, (fracture and fracture traces) were digitised using the finest-resolution panchromatic bands (10 – 15 m).
- The relationship between ice front position and transverse structures between 2000 and 2020 was investigated.
- Additional inferences were made from field site images.

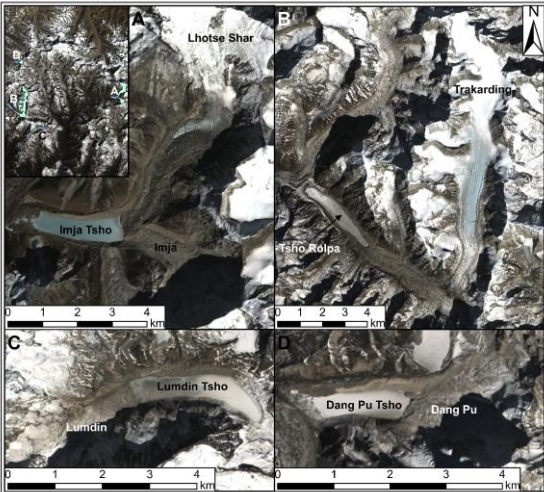


**Figure 1:** Study Sites. **A:** Imja Tsho, **B:** Tsho Rolpa, **C:** Lumdin Tsho, **D:** Dang Pu Tsho. (Image Acquisition date (01/06/2020))

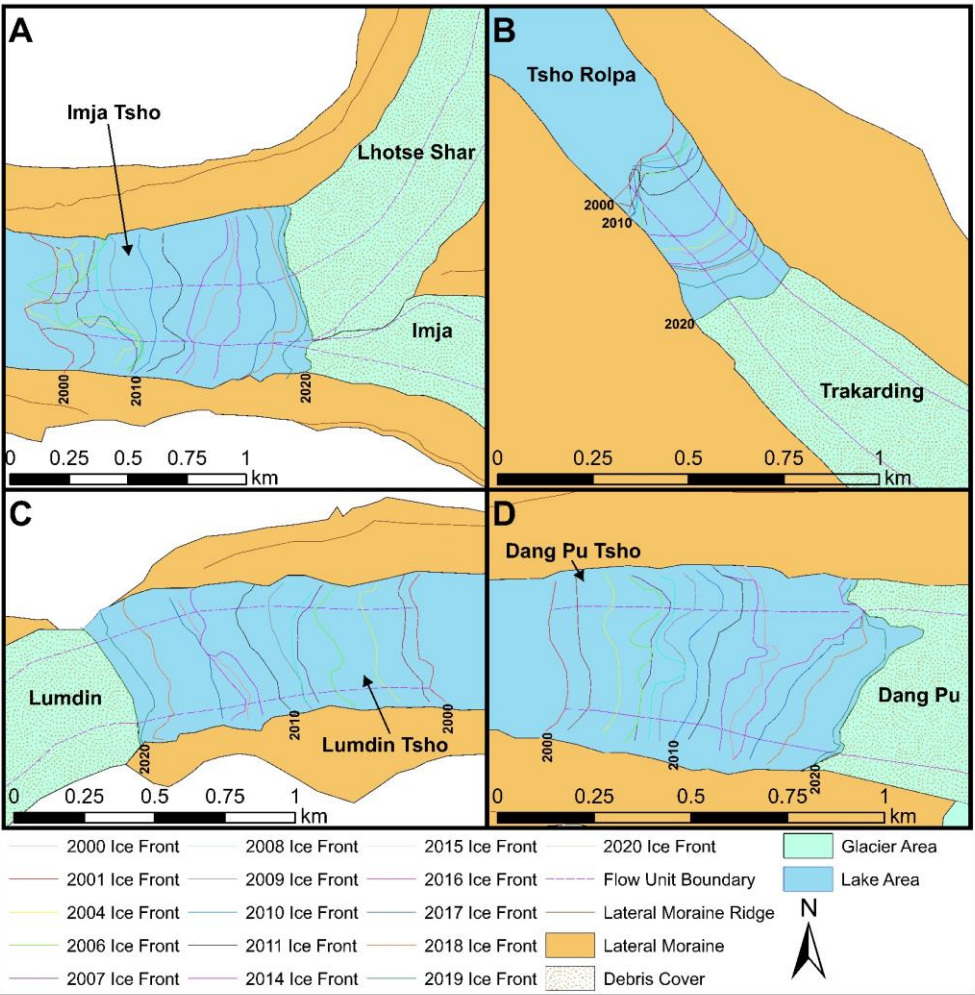


**Figure 2:** 2020 Geomorphological interpretation of study sites with overlaid ice front positions between 2000-2020. **A:** Imja Tsho, **B:** Tsho Rolpa, **C:** Lumdin Tsho, **D:** Dang Pu Tsho.

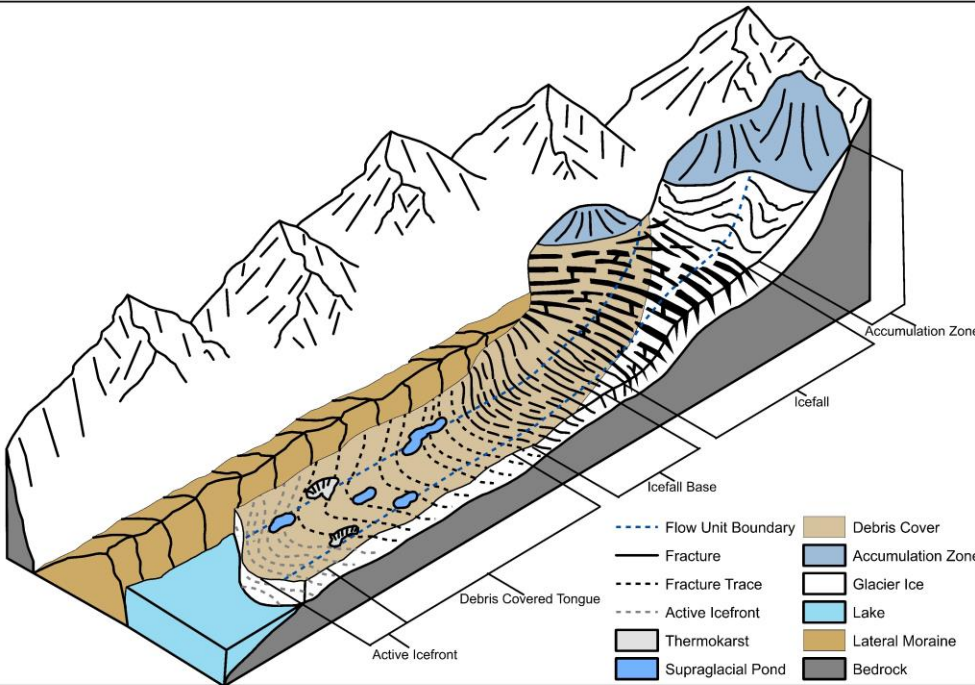


**Figure 4:** Conceptual model of structural controls on ice front morphology and position.

## References

Nie et al., 2021. Remote Sensing of Environment  
Richardson and Reynolds, 2000a. IHAS Publication  
Richardson and Reynolds, 2000b. Quaternary Intl  
Westoby et al., 2014. Earth Science Reviews

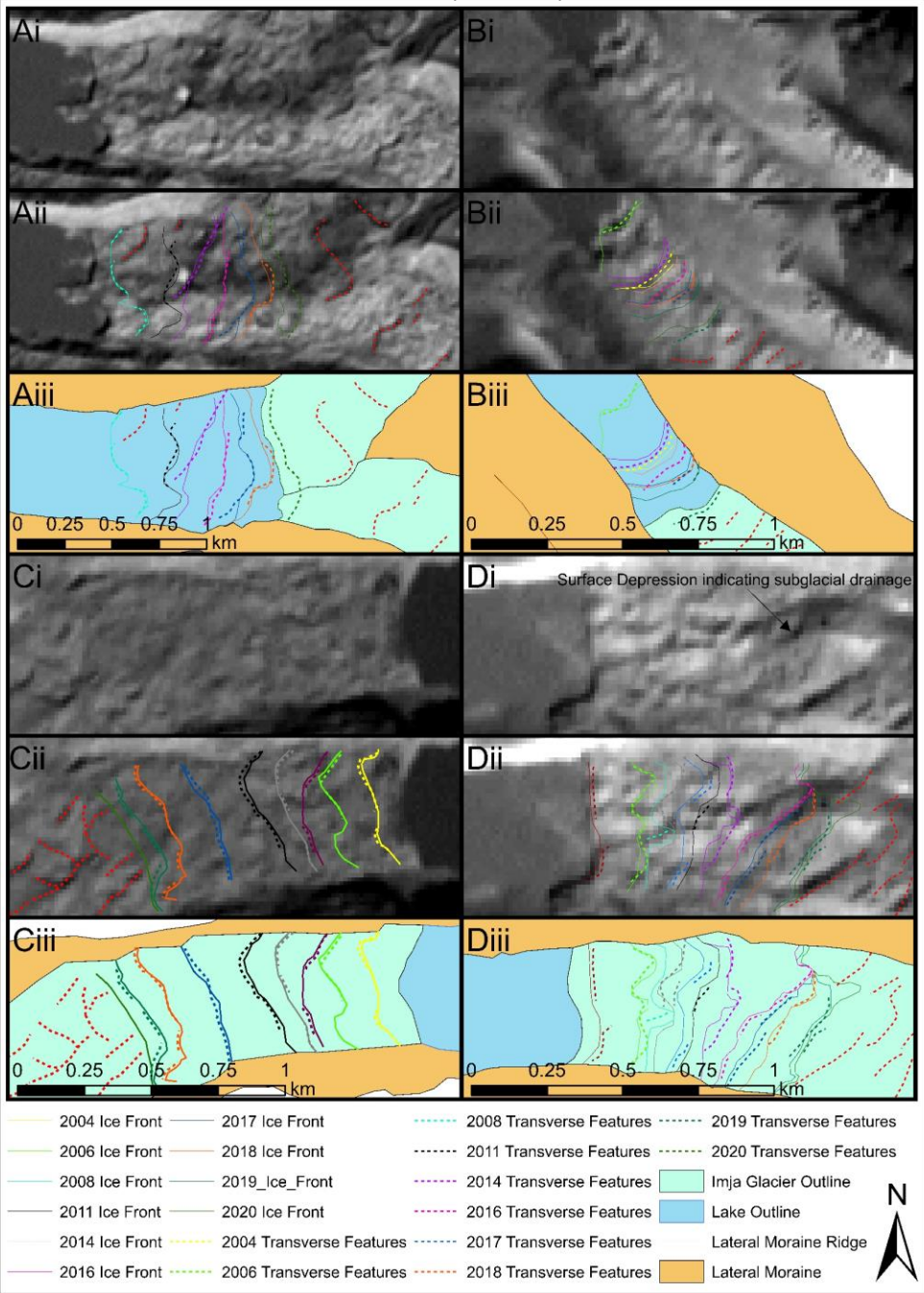


**Figure 3:** Structural interpretation of transverse features and ice front positions. **A:** Imja Tsho, **B:** Tsho Rolpa, **C:** Lumdin, **D:** Dang Pu. **i:** Panchromatic Landsat 7 image (30/10/2000), **ii:** Interpretation overlaid on Panchromatic Image, **iii:** Interpretation.

## 3. Results and Discussion

- We reveal a distinct pattern of transverse features, including fractures and fracture traces originating in the accumulation zone of each glacier that can be related to ice frontal position through time (Figure 2).
- The presence of flow unit boundaries affects the shape and position of the ice front (Figure 3) with dominant flow units creating convex morphologies and flow unit boundaries leading to concave morphologies. Longitudinal surface depressions indicate subglacial conduits (Figure 3 Di), creating concave profiles in the ice front as seen at Dang Pu (Figure 3Diii). Our investigation shows that pre-existing glacier structures influence the ice front morphology and pattern of ice front deterioration across all four sites (Figures 2 and 3).
- The links between glacier structures and ice from morphology are summarised in Figure 4 where the morphology of features found to originate in the accumulation zone will affect the morphometry of the ice from when reactivated during calving events.
- These observations could be used to indicate future ice front positions, behaviour, calving processes and rates of glacier recession and of lake expansion.