



Debris emergence at Fox Glacier, New Zealand and formation of an ablation-dominant medial moraine

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Medial moraines can form important routeways of sediment transport in valley glaciers, and may consist of sediment from a range of sources. Despite the presence of medial moraines on several glaciers in the New Zealand Southern Alps, medial moraines there have hitherto generally escaped attention. The evolving morphology and debris content of the 12.5 km-long Fox Glacier on the western flank of the Southern Alps is the focus of this study. This tests the hypothesis that medial moraine at Fox Glacier is the product of down-glacier lateral compression of accumulation zone rockfall material within a narrow valley tongue, followed by supraglacial emergence due to down-glacier ablation gradients. Using clast orientation, clast shape, and clast lithological data, combined with ablation rates and topographic surveys, this hypothesis is applicable to such a valley glacier with an accumulation area ratio (AAR) of 0.8. Metamorphic grade increases down-valley toward the Alpine Fault at the range front. Hence, as the debris consists of slabby, very angular to angular argillaceous mudstones that generally cleave, and very angular to subangular blocky sandstones, it is likely sourced from rocks located well above the equilibrium line altitude (ELA) near the Main Divide. The debris takes a medium-level to high-level passive transport pathway through the glacier, emerging at a point-source left of centerline in the lower icefall. As the debris layers progressively melt-out, down-glacier widening of the moraine occurs. This growth in moraine width is accompanied by an increase in local relief of the moraine above adjacent debris-free ice. This width and relief increase is itself accompanied by an increase in maximum cross-glacier slope of the moraine down-glacier, reaching around 30° toward the terminus. Cross-sections of the medial moraine exposed in chevron crevasses display a layer of debris around 5 cm thick, with exceptions at the base of steep slopes. Margins of the medial moraine are marked by a discontinuous cover of debris, grading to scattered clasts forming rock tables. Dirt cones are also prevalent along the margins, forming beneath <2 cm thick coarse/very coarse sand-sized (0.5-2 mm) 'fines'. Fabric of clasts reveals a consistent flow-parallel orientation, consistent with foliation and measured strain-rates and vectors. The proglacial area preserves limited evidence of the medial moraine, in the form of low-relief 'dumped' material at the terminus. However, this has low preservation potential due to continual switching of the proglacial river exit portal across the snout.