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Genesis, stability and preservation potential of large lateral moraines of Alpine valley glaciers – towards a unifying theory

S. Lukas (1), A. Graf (2), S. Coray (2), and C. Schlüchter (2)

(1) Queen Mary, University of London, School of Geography, London, United Kingdom (s.lukas@qmul.ac.uk), (2) Institut für Geologie, Universität Bern, Switzerland

Lateral moraines are prominent features of glaciated landscapes in high-mountain environments and key landforms in glacier and palaeoclimatic reconstructions, yet, compared to smaller moraines, they have been little studied and several aspects are not well understood. This presentation will present detailed sedimentological results from the lateral moraines of Findelengletscher in SW Switzerland to gain new insights into the formation of these landforms. The lateral moraines studied here stand up to 140 m above the valley floor, are over 3 km long and strongly asymmetrical in cross-profile, with distal slopes between 29-36° and proximal slopes that are commonly 41-64°, but locally reach angles of up to 80°. Recorded lithofacies comprise loose clast and matrix-supported, stratified diamicts and intercalated sorted sediments in the distal slopes and near the crestline; overconsolidated matrix-supported, massive and weakly stratified diamicts and streaked-out sorted sediment lenses in the core and proximal slopes; and partly intercalated dark-brown layers overlain by loose and consolidated diamicts exposed in near-vertical walls in the proximal flank. These are interpreted as supraglacial debris flow units with intercalated fluvial 'wash' horizons; glaciotectonised and subglacial traction till with boudinaged and streaked-out sediment lenses; and palaeosoils overlain by sediment produced by overtopping of the former moraine surface during a subsequent advance of the glacier. Clast shape analysis and process observations reveal that the dominant mode of transport is subglacial and glaciofluvial, and that the main mode of sediment delivery to the moraines is by debris flows after the material has been transferred from the bed via englacial debris bands and meltout at the surface. This differs from previous studies that found that a supraglacial source was dominant. Sedimentary structures, clast fabric and process observations during the 1979/1980 readvance of Findelengletscher strongly suggest that proximal layers of reworked pre-existing sediments and/or basal traction zone till have been plastered onto the moraine core in several locations, causing a high degree of overconsolidation and strongly-clustered fabric eigenvalues ($S1 \leq 0.94$) with clustering parallel to the moraine crestline. This suggests that a combination of basal-lateral drag and lateral plastering produces the observed proximal stability and ensures a high preservation potential. The data are synthesised into a conceptual model that describes Alpine lateral moraines as structurally complex landforms that do not just record a single event as often surmised; implications for palaeo-glacier reconstruction and the application of numerical dating methods are also discussed.