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Formation of minor moraines in high-mountain environments independent of a primary climatic driver

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Closely-spaced minor moraines allow observations of moraine formation and ice-marginal fluctuations on short timescales, helping to better understand glacier retreat and predict its geomorphological effects (e.g. Sharp, 1984; Boulton, 1986; Bradwell, 2004; Lukas, 2012). Some minor moraines can be classified as annual moraines given sufficient chronological control, which implies a seasonal climatic driver of minor ice-front fluctuations. This leads to annual moraines being utilised as very specific and short-term records of glacier fluctuations and climate change. However, such research is sparse in high-mountain settings (Hewitt, 1967; Ono, 1985; Beedle et al., 2009; Lukas, 2012).

This study presents the detailed sedimentological results of minor moraines at two high-mountain settings in the Alps. Minor moraines at Schwarzensteinkees, Austria, formed as push moraines in two groups, separated by a flat area and sloping zone with scattered boulders and flutings. The existence of a former proglacial lake, evident from ground-penetrating radar surveys and geomorphological relationships, appears to have exerted the primary control on minor moraine formation. Minor moraines at Silvrettagletscher, Switzerland, exist primarily on reverse bedrock slopes. The presence of these bedrock slopes, and in some areas medial moraines emerging beyond the ice front, appear to exert the primary controls on minor moraine formation.

These findings show that climate may only play a small role in minor moraine formation at these study sites, echoing similar findings from another glacier in the Alps (Lukas, 2012). These two glaciers and valleys are differentiated primarily by geometry, sedimentation, and mechanisms of minor moraine formation. Despite these crucial differences, valley geometry and pre-existing geomorphology play a large, if not dominant, role in minor moraine formation and are at odds with a primarily-climatic control of minor moraine formation in lowland settings. This compelling discrepancy requires further investigation.

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