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Formation and interpretation of eskers beneath retreating ice sheets

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Eskers are long sinuous ridges, thought to be deposited subglacially or proglacially during ice-sheet retreat. An improved mechanistic understanding of their formation would provide insights into how the Pleistocene ice sheets retreated, how meltwater influenced retreat, and would hence inform our understanding of potential future retreat rates.

We develop a quantitative theory for esker formation based on the initial work of Rothlisberger modified for sediment transport and inclusion of surface meltwater forcing. The primary subglacial ingredients include water flow through subglacial tunnels with the addition of mass balances and empirical descriptions for sediment transport. Eskers form when water flow slows below a critical stress for sediment motion, leading to deposition in a localized region near the ice sheet margin.

The model suggests that very long eskers form sequentially as the ice front retreats. The position of the esker follows the path of the channel mouth through time, which does not necessarily coincide with the instantaneous route of the feeding channel, but in most cases will be similar. The spacing of the eskers reflects the spacing of major channels. We predict that high surface melt rates lead to narrower catchments but that the greater extent of the ablation area means that channels are likely larger in size. At the same time, for a given channel size (and hence sediment flux), the size of a deposited esker depends on the margin retreat rate. Hence, the size of the eskers is related delicately to the balance between surface melt rates and margin retreat rates. We discuss how our theory can be combined with observed esker distributions to infer the relationship between these two rates and help understand the melt history of ice sheets.