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Influences of rock avalanches on glacier behaviour and moraine formation in the Western European Alps

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Rock avalanching is a very hazardous process in mountain areas, that generates a high risk in inhabited valleys. Present glacier shrinkage and permafrost degradation in steep rockwalls could increase the frequency and magnitude of rock avalanching in the context of the current climate change. In high glaciated mountain, rock avalanches interact with glaciers in different ways. Oversteepening of rock slopes by glacial erosion, and effects of glacier thinning and retreat on debuttressing of rockwalls and on permafrost prepare rock avalanche triggering. Channelling of rock avalanche by moraines and glacial valleys, incorporation of ice, and irregularities on the glacier surface modify the rock-avalanche mobility. High elevated scars resulting from rock avalanches favour the formation of small glaciers. Here, we describe how rock avalanche deposits modify glacier dynamics, and how complex could moraine complexes result from rock avalanches onto glaciers, basing our arguments on case studies mainly located in three of the larger massifs of the Western Alps: Mont Blanc, Vanoise and Ecrins massifs.

Large debris accumulation deposited by a rock avalanche onto the glacier surface is a driving factor of the glacier dynamics because it can strongly reduce its ablation, especially when the glacier becomes debris-covered. Modification of the glacier mass balance by a dense debris cover allows: (i) the rate of retreat or advance of its front to be different than this of a clean-type glacier, with accelerated advance during positive mass balance periods, and slow down retreat during negative ones; this is illustrated for instance by the control of 1920 and 1997 rock avalanches on the dynamics of Brenva Glacier; (ii) advances to last longer or to reach further downvalley, as shown by the case of Miage Glacier both during the Neoglacial and the 20th Century; and (iii) small glaciers to survive at a lower elevation than the regional ELA (e.g. Grande Casse or Drus Glaciers). In a secondary way, the supplementary mass of debris can play a role in the modification of small, thin glacier behaviour. Finally, impact of the rock avalanche, and debris that penetrate into the glacier can alter the subglacial drainage system, contributing to short-term glacier accelerations, as possibly illustrated by the 2000-2002 surge-type advance at Belvedere Glacier (Monte Rosa massif).

Melting of incorporated ice in a rock avalanche deposit generally reduces the maximum thickness of the hummocky final deposit to 1-2 metres at the glacier surface. When mainly supplied by this large amount of avalanche debris, moraine complexes may be characterized by: (i) huge lateral moraines for large- (e.g. Miage), medium (e.g. Grande Casse) or even small-sized (e.g. Drus) glaciers, the topographical shape of which can be modified (e.g. Brenva) ; or (ii) lateral and end moraine ridges composed of massive blocks with little or no matrix, and having a discontinuous and disorderly pattern (e.g. Triolet) – in contrast to the sub-concentric moraines of neighbouring proglacial margins of clean-type glaciers. Finally, we deal with the distinction between rock avalanche deposits and moraine sets in valleys of glaciated mountains – two assemblages of landforms which often look alike.

To study these relations between rock avalanches and glacier and moraine dynamics, we combine historical data with detailed geomorphological mapping, stratigraphic observation, and absolute and relative dating.