Lateglacial-Holocene rock glacier dynamics in the western Alps and Pyrenees: long-term geomorphic archives of mountain permafrost and paleoclimatic conditions

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Abstract

Rock glaciers are widespread cryospheric landforms in mid-latitude high-elevation mountain ranges, and are characterized by rock-debris accumulation together with interstitial ice. Their activity is a strong indicator of sustained permafrost conditions, and they are considered one of the most resilient cryospheric bodies in alpine environments. In addition, internal-ice deformation of rock glaciers allows transport of heterogenous rock boulders from cirque headwalls to their terminus, participating in high-mountain slope evolution and sediment transfer. Although their modern activity is highly documented and monitored in the context of current climate change (for e.g. natural hazards, water resources), their long-term activity and evolution in postglacial-periglacial contexts has remained largely under-constrained. Here we focus on the western Alps and Pyrenees, two mid-latitude mountain belts that have undergone contrasted paleoclimatic conditions since the last glacial period. Such paleoclimatic evolution has resulted in different glacier retreat dynamics during the Lateglacial period, allowing asynchronous onset of periglacial conditions including rock glacier activity. We thus target different rock glaciers in the western Alps and eastern-central Pyrenees, with the motivation to assess how rock glaciers can provide quantitative information on spatially-variable paleoclimatic conditions during the Lateglacial to Holocene times. We sampled the surface of rock glaciers, targeting both longitudinal and transverse profiles, to apply *in situ*

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quartz 10Be(-26Al) surface exposure dating on rock boulders. Our results provide key information on their persistence throughout the Lateglacial-Holocene, with potentially multiple phases of activity, and on the headwall erosion dynamics in high-elevation cirques, to be confronted with modern observations and monitoring.

Keywords: Rock glaciers, Mountain permafrost, in situ quartz 26Al/10Be dating, Alps and Pyrenees, Lateglacial, Holocene, Surface exposure dating