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Pebbly versus bouldery rock glaciers: Morphology, structure and processes

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Abstract

Differences in rockwall geology cause two types of rock glaciers: *a bouldery rock glacier*, having the active layer composed of matrix-free boulders derived from crystalline rocks and massive limestone; and *a pebbly rock glacier*, consisting of matrix-supported debris derived from less resistant shale and platy limestone. Such material composition controls transport processes responsible for the shape, size and internal structure of the two types of rock glaciers. This paper compares the major processes controlling the morphology and structure of the two types in the Swiss Alps, based on mapping, description of geological and morphological characteristics, direct observation of stratigraphy and geophysical soundings of internal structure.

In the Swiss Alps, pebbly rock glaciers are distinguished from bouldery rock glaciers by the clast size of 15–20 cm in the mean *b*-axis diameter. The former are fed by small-scale rockfalls, debris flows and solifluction, whereas the latter mainly originate from large rockfalls. Pebbly rock glaciers are generally smaller (<200 m in length) than bouldery rock glaciers, because the small exposure of the less resistant source rockwall (<50 m in height) strongly constrains debris supply. As a result, pebbly rock glaciers usually terminate within a valley-side slope, whereas many bouldery rock glaciers extend into the valley bottom. The location of pebbly rock glaciers results in the low frontal slope (≤20 m) and the lack of transverse ridge-furrow topography, because of the lack of compressive flow. The pit-borehole stratigraphy and low DC resistivities (<10 kΩm) indicate ice-cemented or slightly supersaturated permafrost in the pebbly rock glaciers, which presumably originates from groundwater freezing. In contrast, highly ice-supersaturated structure indicated by high DC resistivities (>100 kΩm) in bouldery rock glaciers appears to originate from snow banks buried with deposits of large rockfalls from the large source rockwall.

Keywords: Rock glacier; Mountain permafrost; Debris supply; Geophysical soundings; Rock control; Swiss Alps

1. Introduction

The dynamics of rock glaciers reflects geology of the source rockwall, which controls the manner of debris supply. A few studies have highlighted the geological constraint on the development of rock glaciers (Wahrhaftig and Cox, 1959; Evin, 1987; Chueca,

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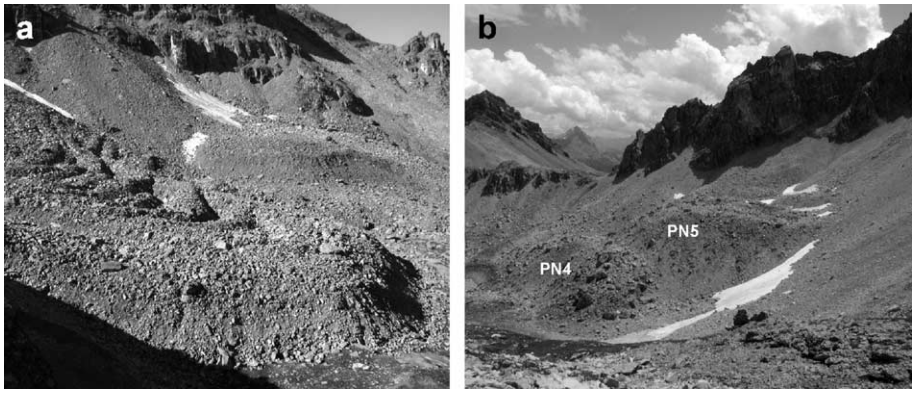

Fig. 1. Typical bouldery rock glaciers in the study area. (a) Murtèl I (MT) rock glacier having well-developed ridges and furrows and rimmed with a steep frontal slope 20 m in height. The surface boulders consist of gneiss and schist. (b) PN4 and PN5 rock glaciers originating from a massive limestone rockwall. The total height of the front reaches about 50 m.

1992). These studies state that rock glaciers mainly develop in lithology producing blocky debris, whereas they are infrequent on slopes composed of platy debris with finer materials. The size of clasts composing rock glaciers varies significantly with lithology. Evin (1987) has found that most rock glaciers in the southwestern Alps consist of coarse blocky debris derived from resistant rockwalls (granite, gneiss, sandstone and massive limestone), whereas rock glaciers derived from less resistant schistose rockwalls contain a large amount of fine debris and small pore volume. Other studies have examined the volumetric relationships between rockwalls and rock glaciers (e.g. Barsch, 1977; Frich and Brandt, 1985; Humlum, 2000). Details are rarely understood, however, on the processes that the source rockwall contributes to the dynamics of rock glaciers.

Here, we focus on the material composition of rock glaciers, which reflects the lithology of the source rockwall and controls slope processes. In this respect, we

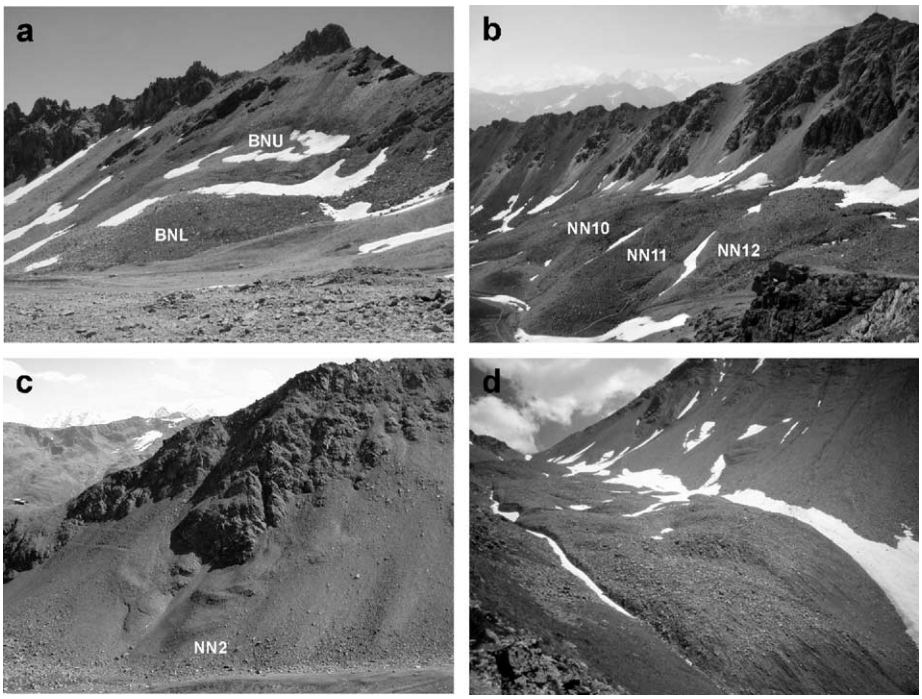

Fig. 2. Pebbly rock glaciers in the study area. (a) BN rock glacier consists of the upper lobe (BNU) and lower lobe (BNL). The surface clasts are mainly shale pebbles and cobbles. BNL lacks a steep frontal slope. (b) NN10-12 rock glaciers, consisting mainly of shale pebbles and cobbles. (c) NN2 rock glaciers lying on the middle of a talus slope. (d) Exceptionally long (740 m) pebbly rock glacier A7, flowing along a valley bottom.