Geogr. Fis. Dinam. Quat.
36 (2013), 27-38, 13 figg.

DOI 10.4461/GFDQ.2013.36.2

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PRESENT STATUS AND DEVELOPMENT OF ROCK GLACIER COMPLEXES IN SOUTH-FACED VALLEYS (45°N, FRENCH ALPS)

ABSTRACT: BODIN X., *Present status and development of rock glacier complexes in south-faced valleys (45°N, French Alps)*. (IT ISSN 0391-9838, 2013).

The landscapes of the Vallon de la Route and Vallon de Pradieu (France) display typical geomorphological features of the Southern French Alps, with very few or no glaciers but a wide periglacial belt that extends from 2500 to 3100 m a.s.l. These valleys are unusual in that they contain several generations of rock glaciers that, from their rooting zone to their front, have developed in a topoclimatic setting characterised by high mean insolation (southerly aspect) and relatively low altitude. In this work, we determined the present status of these landforms, and more precisely the characteristics of the icy layers within the rock glaciers, *via* electrical soundings and thermal measurements, which we then combined with field observations. The permafrost zones in both areas are highly fragmented, whereas ground-ice can be present in landforms previously assumed as relict on the basis of their geomorphological characteristics alone. We used an empirical relationship between rock glacier flow velocity and terrain slope to estimate the time needed for both rock glacier assemblages to reach their present size. Our analyses therefore provide at the same time a broad relative chronological framework of the landscape setting up together with an overview of the spatial patterns of ice-rich permafrost features. It also suggests a number of hypotheses for the development of these landforms; however, further work involving more accurate dating methods is required to constrain these hypotheses.

KEY WORDS: Rock glacier, Permafrost, Landform development, Southern French Alps.

INTRODUCTION

Since the retreat of the Quaternary glaciers, the rock glaciers that have developed in relatively dry and poorly glaciated ranges, such as the Southern French Alps, are one of the most prominent features of mountain landscapes. Many valley bottoms are filled by multi-generational complexes of periglacial landforms that may extend for several kilometres (Evin, 1987), illustrating both the importance of rock glaciers as material conveyors and the variations over time in the conditions needed for their development, generally indicated by a succession of active, inactive and fossil forms (Haeberli & *alii*, 2006).

In the present context of changing climate, the stability of ice-cemented debris slopes has become an important issue (Arenson & *alii*, 2002; Gruber & Haeberli, 2009; Haeberli & Gruber, 2009), especially at the marginal boundaries of permafrost where transient equilibrium conditions may change rapidly and substantially. Nevertheless, it is difficult to determine the present state of mountain permafrost-related features, the most common of which are rock glaciers, and to discriminate between intact (presence of ground-ice) and relict (absence of ground-ice) rock glaciers, on the basis of geomorphological information alone (Barsch, 1996). This is especially true in crystalline lithology, such as in our study area, where the lack of fine material within the rock glacier body leads to a small decrease of the volume when the ice melts and to weaker morphological criteria. Additional datasets are therefore needed to decipher the state of rock glaciers: a good alternative, in a feedback approach, is to use ground-based data to improve the interpretations made from geomorphological observations.

From this point of view, the Vallon de la Route and Vallon de Pradieu rock glacier assemblages (Combeynot Massif, Hautes-Alpes, France; fig. 1) are ideal study areas, as they contain several generations of active, inactive and fossil landforms marked by high insolation (southerly aspect), and have similar geological settings. In addition, a

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This work is a part of a Ph.D thesis funded by the French Ministère de l'Enseignement Supérieur et de la Recherche and conducted at Université Paris-Diderot (Paris 7) between 2003 and 2007, under the supervision of Monique Fort: I warmly thank her for having raised my interest to Alpine geomorphology and for her invaluable support since the beginning. The co-supervisor of this Ph.D, P. Schoeneich, is also greatly acknowledged for wise advices and help for fieldwork and data interpretation. S. Gruber, from University of Zürich, is thanked for providing the PSIR data from Tebal model, as well as W. Haeberli and M. Hoelzle for welcoming me during an internship at the Department of Geography of University of Zürich (March-June 2005). The «Maître français» of VES in rock glaciers, D. Fabre, and all the people that helped for winter and summer field work are also acknowledged (E. Blervaque, M. Claros Paz, V. Magnabal, A. Rabatel, A. Ribolini, M. Spagnolo, M. Trarieux), as well as the keepers of the Refuge du Plan de l'Alpe, André & Sabine Kaincz, for their friendly support during field campaigns.