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Use of Digital Elevation Models to understand and map glacial landforms — The case of the Canigou Massif (Eastern Pyrenees, France)

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ABSTRACT

This paper presents an improved geomorphological methodology that uses remotely-sensed data, a Geographical Information System and a brief field campaign to allow rapid, yet, precise mapping as well as interpretation and analysis of glacial earth surface morphology in high mountain areas. The study area consists of the Quaternary-glaciated part of the Coumelade valley (Canigou massif, eastern Pyrenees, France), which ranges between 1450 and 2731 m a.s.l. A topographical-map-derived Digital Elevation Model was used for analyzing glacial landforms by extracting the slope gradient, valley profiles and the slope aspect. The results were gradually refined from the interpretations of aerial photograph and the field investigation. Glacial landforms are present above 1500 m a.s.l. and include glacial and nivation cirques, cirque and latero–frontal moraines ($7.7 \times 10^6 m^3$) and micro-scale landforms such as chattermarks, crescent grooves and polished surfaces. The geomorphological investigation reveals that the Quaternary glaciation of the Coumelade valley remained limited, resulting in a low denudation rate of 0.011 mm yr^{-1} over the last glacial cycle.

1. Introduction

In the Pyrenees, research on the Quaternary glaciations has mainly focused on the extent and chronology of the glaciations (Calvet, 2004). Mapping of glacial landforms produced comprehensive maps at a scale of 1:50 000 (Viers, 1961; Taillefer, 1963; Viers, 1966, 1968; Martinez de Pisón, 1989; Serrano and Martinez de Pisón, 1994; Garcia-Ruiz et al., 2000) that provide overviews of the existing glacial morphologies. Detailed geomorphological maps, which are necessary to accurately represent and understand glacial dynamics in high-altitude mountain areas (de Graaff et al., 1987), are lacking but should be considered when evaluating the precise impact of the Quaternary glaciations.

The increasing technical possibilities that are offered by Remote Sensing (RS) and Geographical Information Systems (GIS) facilitate the geomorphological investigation of inhospitable and inaccessible mountain areas (van Asselen and Seijmonsbergen, 2006). Digital Elevation Models (DEMs) are valuable tools for approximation of the real world's continuous surface (Dragut and Blaschke, 2006; Smith et al., 2006; van Asselen and Seijmonsbergen, 2006). They allow a visual analysis of the earth's surface morphology, quantification of sediment volumes and the calculation of topographic derivatives such as the slope gradient, slope aspect and profile curvature that consume field investigations and optimize time (Smith et al., 2006). However, it should be stressed that in-depth fieldwork remains the basis of detailed geomorphological analyses by means of providing ground truth. Furthermore, spatial and temporal limitations in RS data imply that fieldwork will continue to be the integral part of geomorphology (Walsh et al., 1998). Therefore, RS and GIS techniques should be combined with fieldwork within a GIS environment so that scientific questions can be answered by the most suitable approach of geomorphologic investigation, within an analytical framework for data synthesis (Walsh et al., 1998).

This paper presents an improved geomorphological methodology that uses RS and GIS techniques with subsequent field verification and refinement of the interpretations. It allows rapid yet precise mapping as well as the interpretation and analysis of glacial earth surface morphology in high mountain areas. The results are presented on a geomorphological map at a 1:10 000 scale.

2. Study area

The study area is situated on the southern flank of the Canigou massif, in the eastern Pyrenees (Fig. 1). It consists of the Quaternary-glaciated part of the Coumelade valley, which ranges between 1450 and 2731 m a.s.l. and covers 13.4 km². This study area was selected for the good, if not complete, representation of existing glacial landforms in the Canigou massif. Due to the climatic peculiarities (see below),

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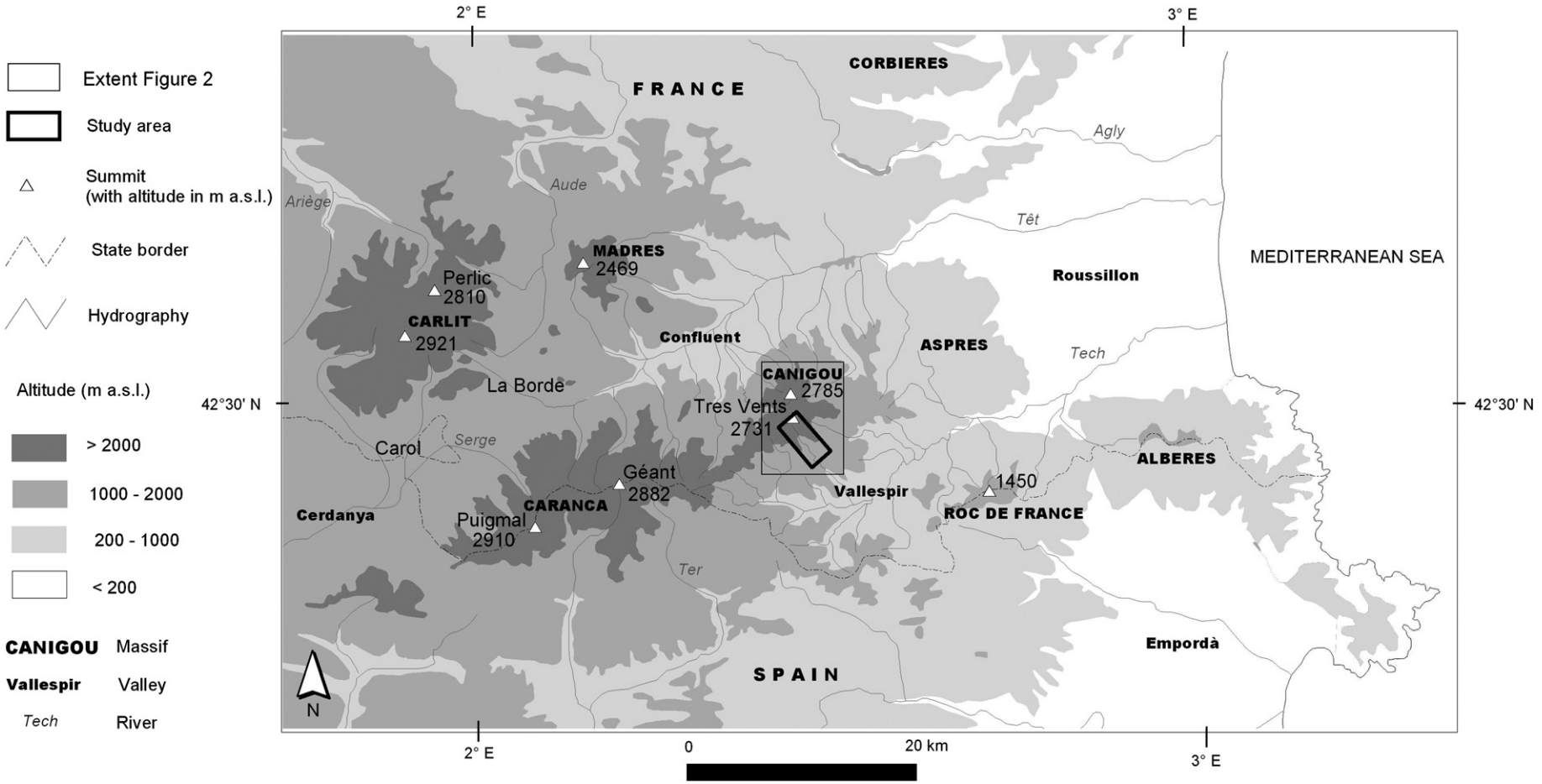

Fig. 1. Map of the Eastern Pyrenees (redrawn after Conseil Général Pyrénées Orientales, 2005).