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Sediment budget quantification of a sub-Alpine river catchment since the end of the last glaciation

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ABSTRACT

Changes in sediment budget and quantification of sediment fluxes of a small (5.3 km^2) Mediterranean sub-Alpine river catchment (Charanc catchment, Southern French Alps, 44°30′44N/5°51′55E) are estimated for the last 20,000 years using a GIS-based approach and 3D palaeotopographic reconstructions. Following field surveys, a high-resolution morphometric map was established. Ten ^{14}C ages of sub-fossil trees and charcoal beds were compiled. All datasets were integrated into a Geographic Information System. We computed three palaeosurfaces by masking the Digital Elevation Model of the current topography, and calculated the sediment budget of the catchment. Estimations of specific hillslope erosion, sedimentation and export rates highlight the evolution of the catchment and its sensitivity to variations in the ratio of sediment load to stream discharge. Between 20,000 and 14,500 cal. BP, sediment that was eroded (37 million m^3) within the Charanc catchment was entirely exported. A change to a sedimentation regime commenced at around 14,500 cal. BP. Between 9000 cal. BP and 7000 cal. BP, footslopes were buried by fan-shaped deposits at a rate of 6700 m^3/yr. Since 7000 cal. BP, the overall morphogenetic regime has been one of vertical incision. 73% of the material eroded over the last 14,500 years (14 million m^3) was stored in fan-shaped deposits. At the present time, 46% of this volume (6 million m^3) is still stored in the catchment. 8 million m^3 of sediments have thus been exported out of the Charanc catchment since 14,500 cal. BP. Annual specific erosion rates on marly slopes are estimated at: (1) 98 to 111 t/ha/yr for the period 20,000–14,500 cal. BP, which is comparable to present rates measured on denudated marls in the Southern French Alps, under a probably climate-driven erosion regime, and (2) 17 to 20 t/ha/yr since 14,500 cal. BP, a reduction in erosion rate that may have been favoured by a more extensively wooded landscape.

1. Introduction

Soil erosion and sediment deposition have strongly determined Mediterranean mountain landscape development during the Holocene, especially in erosion-sensitive areas characterised by a marly sub-stratum. Widespread rill erosion processes have progressively shaped these landscapes, generating large-scale development of badlands and corresponding high sediment yields in valleys (Bryan and Yair, 1982). Studies aimed at quantifying such sediment yields have generally been conducted using geomorphic and sedimentary data (e.g., Torri et al., 2000), including in the Mediterranean basin (Gallart et al., 2002). Nadal-Romero et al. (2011) recently showed the high variability of sediment yield in Mediterranean catchments and the complex relationship between such yield and catchment size. They determined yield values ranging from 9.3 t/ha/yr to 475 t/ha/yr. These various studies concern short timescales (days, years or decade), and also show that erosion rates are strongly influenced by climatic and land-use changes. In the present-day context of: (1) global warming, expected to lead to an increase in the frequency and/or intensity of extreme precipitation events liable to generate torrential floods, especially in the Mediterranean region (Giorgi and Lionello, 2008; IPCC et al., 2007), and (2) increase in vegetation cover due to rural exodus, there is a need for contextualising fluvial sediment dynamics within the longer-term Late Pleistocene to Holocene framework.

Only a few studies have attempted to quantify sediment budgets, soil losses and sediment storage over long (centennial or millennial) timescales, mainly because of the difficulty of dating accurately sediment infills, the preservation of which, moreover, may be poor and/or

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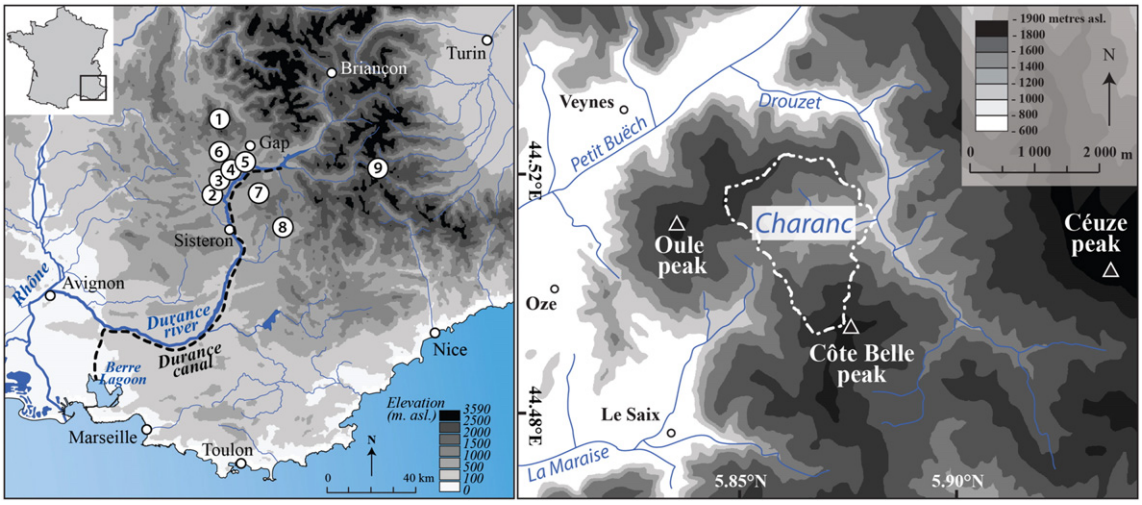

Fig. 1. Location of the study site (1) the Charanc, and sites described in the text in the framework of the regional morphogenetic evolution: (2) Rue, (3) Clachier, (4) Barbiers, (5) Mardaric, (6) Aup, (7) Saignon, (8) Fontarasse, (9) Larche.

discontinuous (e.g., Meade, 1982; Förster and Wunderlich, 2009; Macaire et al., 2002; Notebaert et al., 2009; Verstraeten et al., 2009a,b; Ward et al., 2009; Wolf and Faust, 2013). In the Southern French Alps, the Durance basin (Fig. 1) is a particularly suitable area for such a long-term sediment budget study. It represents a sensitive environment for recording budget changes because of an orographic context dominated by steep slopes, the large extent of easily erodible marls (Callovian–Oxfordian "Black Earths" and Lias marls), and the widespread occurrence of thick, well-dated Holocene alluvial sedimentary sequences. The steep altitudinal gradients and strong weathering and erosion processes in this sub-Alpine Mediterranean bioclimatic setting result in highly turbid river discharges, especially during torrential or flash floods which represent the greatest natural risk in these mountain environments. Since 1860, the National Forest Bureau has attempted to control erosion by building breakwaters along the gullies and by encouraging reforestation. Despite these actions, sediment transfers within the catchment are

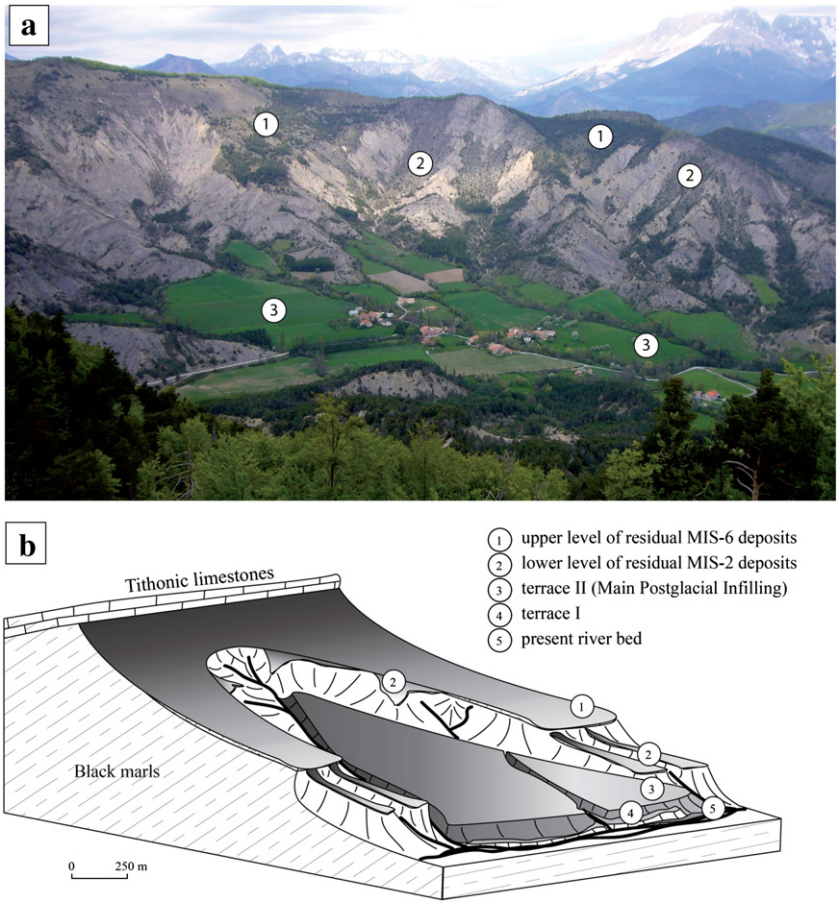

Fig. 2. Geomorphic levels in the Charanc catchment: (a) landscape photograph, (b) conceptual diagram (Gautier, 1992, modified).