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Postorogenic planar palaeosurfaces of the central Pyrenees: Weathering and neotectonic records

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ABSTRACT

Flat high-elevation surfaces in the Pyrenees are defined by thick weathered horizons that were developed from granitic lithology. We analysed such horizons in detail within two areas: the Bordères–Louron granite and the Aston massif. They are characterized by a lower fissured zone overlain by unconsolidated saprolite. Mapping these horizons allows a 3D reconstruction of the ancient palaeosurface with an elevation uncertainty of 50 m. We discuss the age of weathering by means of stratigraphy and low-temperature thermochronology. The surfaces are clearly postorogenic, postdating Eocene–Oligocene denudation. Their incision and the fact they are stepped suggest (1) an increase of the local relief and (2) recent normal faulting.

1. Introduction

Relicts of ancient surfaces have been observed in the Pyrenees (Fig. 1), mostly in their eastern part (Babault et al., 2005; Calvet, 1996; Calvet and Gunnell, 2008; Goron, 1937; Ortuño et al., 2013). Similar surfaces have been observed in other mountain ranges like the Rocky Mountains, the Atlas, the Betic Cordillera, or the Altay and Gobi-Altay mountains (e.g., De Sitter, 1952; Farines et al., 2015; Jolivet et al., 2007b; Scott, 1975). They are considered key features for investigating the recent history of such mountain ranges, with special attention paid to their relief and elevation history (Calvet et al., 2015). Here, we evidence that some of these surfaces are associated with strong weathering profiles, before reconstructing their shape and determining whether they record deformations related to recent tectonic activity.

The nearby Massif Central is known to have undergone strong weathering phases whose ages are: (i) pre-Late Carboniferous; (ii) pre-Permian; (iii) pre-Triassic; (iv) pre-Liassic; (v) pre-Late Cretaceous; and (vi) Eocene (e.g., Gandolfi et al., 2010; Migoń and Lidmar-Bergström, 2001a; Pierre, 1989; Wyns et al., 2003). During these weathering phases, a weathering profile developed, which, from bottom to top, encompasses bedrock, fissured zone, and alterites (or saprolite), subdivided into a laminated zone and loose saprolite. In plutonic rocks, the fissured zone is characterized by horizontal jointing due to the swelling of some minerals when hydrating, the most efficient one being biotite, whose volume increases by 40% when it is transformed into chlorite or vermiculite (Wyns et al., 2004). The fissure density increases upwards, up to

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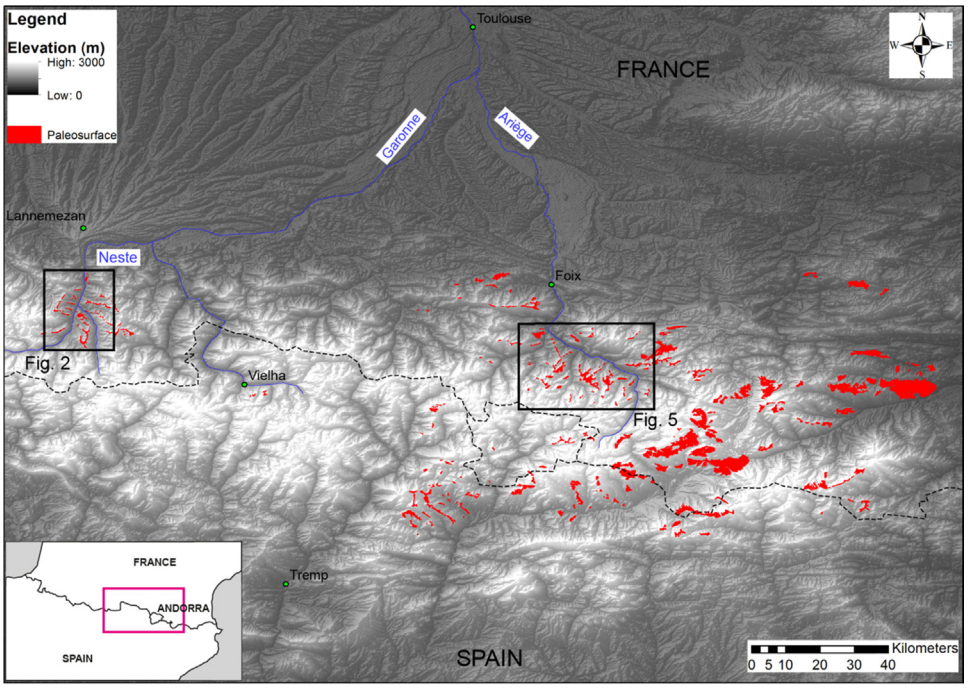

Fig. 1. The relief of the Pyrenees and palaeosurfaces mapped within the mountain belt. The compilation of palaeosurfaces is derived from the computation of slopes lower than 10°, and from Calvet (1996) and Delmas (2009). Fig. 2: Bordères–Louron area; Fig. 5: Aston area. Dashed line is the border between France and Spain, with Andorra in the middle.

1 fissure per 10 cm. The alterites consist of highly weathered minerals. In the bottom part (the laminated zone), it is laminated and the original rock structure is still observed, whereas in the upper part the rock is transformed into loose material. The very top of the profile is a planar surface that formed before further weathering, ensuring the necessary low-draining conditions that allow chemical weathering rather than physical erosion. The formation of a weathering profile implies a long duration, 5–10 Ma at least under such low-draining conditions (Wyns, 2002; Wyns et al., 2003). In Europe, excluding subsidence areas, saprolite thickness can reach several tens of metres, but usually less than 50 m (Migoń and Lidmar-Bergström, 2001b; Wyns et al., 2003).

In the Pyrenees, the link between ancient weathering periods and planar surface development has never been investigated. Because plutons and gneisses are good protoliths for the development of weathering profiles, we focused our work on two of such well-developed planar surfaces at Bordères–Louron in the Neste Valley and at Aston in the Ariège Valley, within the central and eastern Pyrenees, respectively (Fig. 1).

2. Planar surfaces of the central and eastern Pyrenees

In the Nestes Valley, the 310-Ma-old Bordères–Louron pluton is exposed southeast of Arreau, the main village (Gleizes et al., 2006). It is centred on Bordères–Louron (0.38°E; 42.88°N), a village lying within the Louron Valley at 850 m asl. The granite intruded Early Carboniferous shale and limestone, and is unconformably overlain by Triassic sandstone and shale (Fig. 2). Where preserved, planar surfaces appear mostly on top of the interfluves, well above the main moraine systems and associated glacial deposits. Many villages are settled on the most prominent surface, as Lançon for at ~1100 m asl (Figs. 2 and 3). To the east and southeast, this main surface can be connected to smaller remnants, mostly located along the Louron Valley, for example around Ilhan and Ris villages, at similar elevations of 1100 and 1120 m asl, respectively (Fig. 4). In addition to these sub-horizontal surfaces, the landscape exhibits low-relief morphology up to 1360 m above Lançon village. Weathered rocks outcrop below every surfaces of the area.

The Aston area lies mostly south of the N120E-trending Ariège Valley for ~20 km between Tarascon and Ax-les-Thermes (1.7°E; 42.7N), with a valley floor at ~500 m asl. It is characterized by 5–10 km wide planar surfaces, as already indicated by local names, such as "plateau" or "pla", the best known being the *Plateau de Beille* on which is built a Nordic skiing station (~1800 m asl). The main surface, which we called Aston surface, is developed at elevations between 1300 and 2100 m and gently dips north with an average slope of 3 to 5 degrees. The Aston planar surface developed over various lithologies, the most common being the Riète Gneiss formation (Fig. 5A). A section parallel to the Ariège Valley, five kilometres to the south (Fig. 5B), shows the different plateaus, separated by three valleys, defining a dissected low-relief surface. To the north of the Aston massif, near the Ariège Valley, the surface is associated with stepped surfaces at lower elevations: two levels are observed at 1700–1800 m and