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# Evolution of the Late Pleistocene Aspe River (Western Pyrenees, France). Signature of climatic events and active tectonics

Bertrand Nivière [a,*], Pierre Lacan [a,b], Vincent Regard [c], Magali Delmas [d], Marc Calvet [d], Damien Huyghe [a], Bernard Roddaz [e]

[a] UMR UPPA CNRS Total 5150, Laboratoire des fluides complexes et de leurs réservoirs, IPRA, BP 1155, 64013 Pau cedex, France
[b] Centro de Geociencias, Universidad Nacional Autónoma de México, boulevard Juriquilla, 3001, 76230 Juriquilla, Querétaro, Mexico
[c] GET–UPS (OMP), CNRS, IRD, Université de Toulouse, 14, avenue Édouard-Belin, 31400 Toulouse, France
[d] EA 4605 Medi-Terra, Université de Perpignan, 52, avenue Paul-Alduy, 66860 Perpignan, France
[e] Université de Pau et des Pays de l'Adour, BP 1155, 64013 Pau cedex, France

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ABSTRACT

We make use of the cosmogenic nuclide $^{10}$Be exposure to date an alluvial terrace of the Aspe River in the foothills of the northwestern Pyrenees. Initially ascribed to the Rissian glaciation, our dating shows that the terrace was abandoned at $18 \pm 2$ kyr. In reference to the Late Pleistocene climatic chronology, two kinds of terraces can be distinguished: high-standing fill terraces probably deposited during glacial events and lower cut-in-fill and strath terraces cut during the postglacial river incision. A part of the terrace aggradations could have occurred during the Würmian glacial episodes. Hence, the dated terrace fits in with the prevailing view of incision during climate transitions. Our study also shows that elevation is not a good criterion of terrace correlation, which should be better carried out on the basis of absolute dating. In addition, this dating also suggests a potential Late Pleistocene fault reactivation of the Mail Arrouy thrust in this tectonically active area of the Western Pyrenees.


## 1. Introduction

Foothill (or piedmont) deposits record climatic and tectonic fluctuations that control the growth of mountain chains (Beaumont et al., 2000; Hovius, 2000; based on Babault et al., 2005). Indeed, incision and aggradation in fluvial networks are ruled by three main factors: (i) base level changes (Blum and Torqvist, 2000), (ii) climate oscillation (Molnar, 1994), and (iii) tectonic activity (e.g., Burbanks et al., 1994). The nature and thickness of these deposits provide information on the intensity of erosion, the efficiency of sediment transport and the amount of deformation. In the North Pyrenean foothills, the last main fluvial depositional phase occurred between the Late Miocene and the Early Pleistocene, leading to the formation of fans more than 100 m thick (from west to east, the Ossau, Ger–Pau, Adour, Lannemezan, Ger and Salat fans; Fig. 1). These fan deposits are silicoclastic and differ from earlier formations by their lack of a carbonate fraction. They rest on the Aquitanian molasse whose top can be attributed to the Late Serravallian due to the occurrence of the MN 8 biozone at Montréjeau–Saint-Gaudens in the

* Corresponding author.
*E-mail addresses:* bertrand.niviere@univ-pau.fr (B. Nivière), placan@geociencias.unam.mx (P. Lacan), regard@lmtg.obs-mip.fr, vincent.regard@get.obs-mip.fr (V. Regard), magali.delmas@univ-perp.fr (M. Delmas), calvet@univ-perp.fr (M. Calvet), damien.huyghe@univ-pau.fr (D. Huyghe), bernard.roddaz@univ-pau.fr (B. Roddaz).

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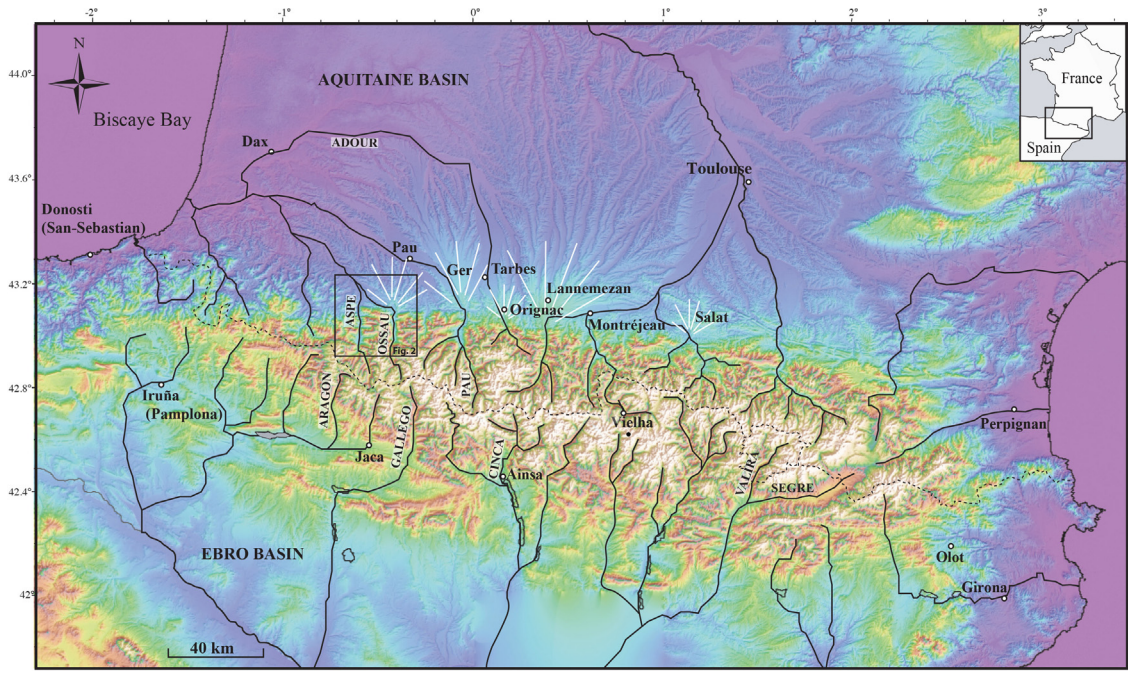


**Fig. 1.** Topography of the Pyrenees (SRTM DEM). Major rivers draining the Pyrenees are also shown.

Lannemezan fan (Antoine et al., 1997; Crouzel, 1957). Near Lannemezan, the top of the series is ascribed to the Plio-Quaternary transition owing to charcoals collected at the margin of the fan (Dubreuilh et al., 1995).

During the Pleistocene, the foothills underwent a strong incision stage that led to the formation of five main alluvial sheets (Barrère et al., 2009). The correlation of these sheets between valleys is based solely on their elevation. In continuity with the moraine fronts in the valleys, some of these alluvial sheets are clearly controlled by glacial pulses. Although numerous absolute ages are now available on the glacial deposits (review in Calvet et al., 2011), the chronology of the North Pyrenean alluvial sheets is still based on relative criteria, such as the degree of weathering of pebbles and topsoil eluviation (Alimen, 1964; Hubschman, 1975; Icole, 1974). Until recently in the Pyrenees, the only absolute dating available on fluvioglacial terraces concerned the southern flank of the belt (Lewis et al., 2009; Peña et al., 2004; Sancho et al., 2003, 2004; Stange et al., 2013; Turu I Michels and Peña Monné, 2006).

In this study, we make use of the $^{10}$Be cosmonuclide method to carry out the dating of one of these remnant terraces. Together with works by Stange et al. (2014) and by Delmas et al. (2015), this represents the first attempt of absolute dating of a remnant terrace on the northern flank of the Pyrenees. Investigations are conducted on the main terrace shaped by the Aspe River near Oloron-Sainte-Marie. Apart from their input to the geological mapping, the resolution of this new dating allows a detailed discussion of terrace formation in the framework of the Würmian glaciation. More particularly, we discuss the genetic link between the alluvial system and climatic forcing. In addition, this age yields a crucial time constraint on the Late Pleistocene tectonic activity in the area.

## 2. Geological and morphological setting

### 2.1. Morphostructural setting

We focus on two rivers, the Ossau and Aspe Rivers, of the mountain front near the northern limit of the North Pyrenean Zone, in the Chaînons Béarnais. It is marked here by the Mail Arrouy thrusted anticline that reaches an elevation of 1400 m (Fig. 2). North of the Mail Arrouy, the piedmont is formed by hills of moderate relief, with heights decreasing from $>$ 500 m to 300 m towards the north. This piedmont zone is notched in its middle part by a 2–3-km wide depression trending WNW–ESE, known as the Herrère plain, which is a former course of the Ossau River. The catchments of the Aspe and Ossau Rivers that rise in the Axial Zone of the Pyrenees, show outcrops of sedimentary, metamorphic and magmatic rocks of Palaeozoic age. Blocked at Arudy by the terminal moraines of the Ossau Glacier (e.g., Barrère, 1963), the Ossau River now flows more to the south of the Herrère plain (Fig. 2; e.g., Depéret, 1923). It follows first an east–west direction and then bends towards the NNW before joining the Aspe River near Oloron-Sainte-Marie (Fig. 2). To the west, the Aspe River runs roughly north–south at the outlet of the Aspe Valley. Both rivers are deeply entrenched into the bedrock.

The main structural feature consists of thrusts striking approximately east–west (e.g., Castéras et al., 1970; Fig. 1). To the north, the south-dipping Rébénacq thrust is picked out by the contact between Triassic evaporites and a Late Cretaceous flysch at Rébénacq to the northeast. Its structural trace disappears to the west.

Farther south, the southward facing Mail Arrouy thrust (MAT) cuts across the area over a distance of more than