

VIII Congreso Ibérico Permafrost

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EXCURSION BOOK

Authors: Marcelo Fernandes
Jordi Gavalda

Editor: Julia Garcia-Oteyza Ciria

Discovering the Aran Valley through Expert Eyes



Excursion book of the CIP 2025
Coordinators: Marcelo Fernandes, Jordi Gavaldà, Julia Garcia-Oteyza, Marc Oliva.
Design and Layout: Julia Garcia-Oteyza Ciria

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Itinerary of the field trip

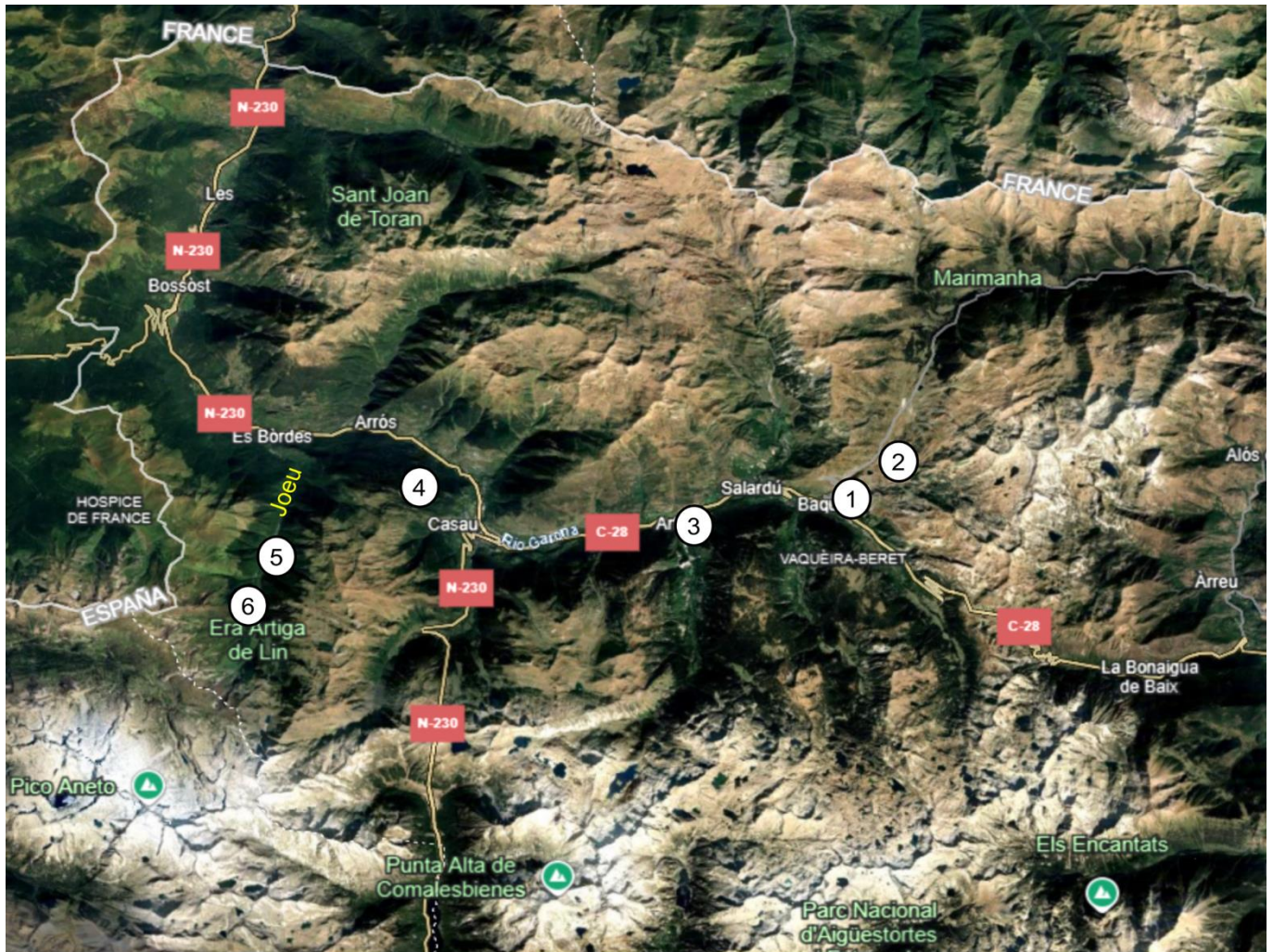


Fig. 1. Itinerary of the field trip to Plan de Beret - Artiga de Lin

Context at Pyrenean scale

The Pyrenean range forms the isthmus between the Iberian Peninsula and Europe (2°W-3°E; 42°-43°N). Stretching across 450 km-long and 75-150 km-width, the Pyrenees are oriented ESE to WNW. The highest elevations exceed 3000 m a.s.l. are primarily concentrated along the Central Axis (e.g. Aneto Peak - 3404 m). The current regional 0 °C isotherm is estimated between 2950 and 3150 m, with lower values on the northern slope. In the Central Pyrenees, 19 small glaciers persist on the northern slopes, all of which have been retreating since the Little Ice Age. The recent shrinking trend accelerated, averaging 0.7 m/year between 2010 and 2020.

The Pyrenean range forces the transition zone between Atlantic and Mediterranean climates, creating a rapid shift between cold, wet northern valleys—dominated by westerlies with abundant winter precipitation—and warm, dry southern valleys, where the Azores anticyclone governs summer atmospheric stability. These climatic asymmetries influence Pyrenean hydrology with substantial water discharge in the northern Garonne catchment (average 630-700 m³/s) compared to the southern Ebro one (average 430 m³/s).

The entire Pyrenean range emerged from Alpine orogenic uplift of the Hercynian basement. During the Paleozoic, tectonic stability in the Cambrian-Ordovician was interrupted by an uplift phase in the Mid Ordovician. The region then underwent widespread sedimentation from the Silurian to Devonian, including the deposition of black carboniferous shales in a marine environment. By the end of the Carboniferous, the collision of Laurussia and Gondwana led to the uplift of the Hercynian Mountain range. During this uplift, batholiths have intruded (e.g. Bossòst), which affected sedimentary sequences with deformation and metamorphism. During the Permian, Hercynian Mountains were dismantled due to the Pangea break up. Later, during the Alpine orogeny, the Iberian plate collided and subducted beneath the European plate, uplifting and deforming sedimentary basins from the Late Cretaceous onward.

The major morphostructural units of the Pyrenees have existed since the Paleogene, with post-orogenic changes in the foreland during the Neogene, such as the accumulation of large megafans like the Lannemezan Formation. During the Quaternary, these deposits were dissected by changes in fluvial regimes until approximately 300 ka. The presence of erratic boulders in these deposits fueled discussions on the magnitude and timing of Quaternary glaciations in the northern Pyrenean foreland (Fig. 2).

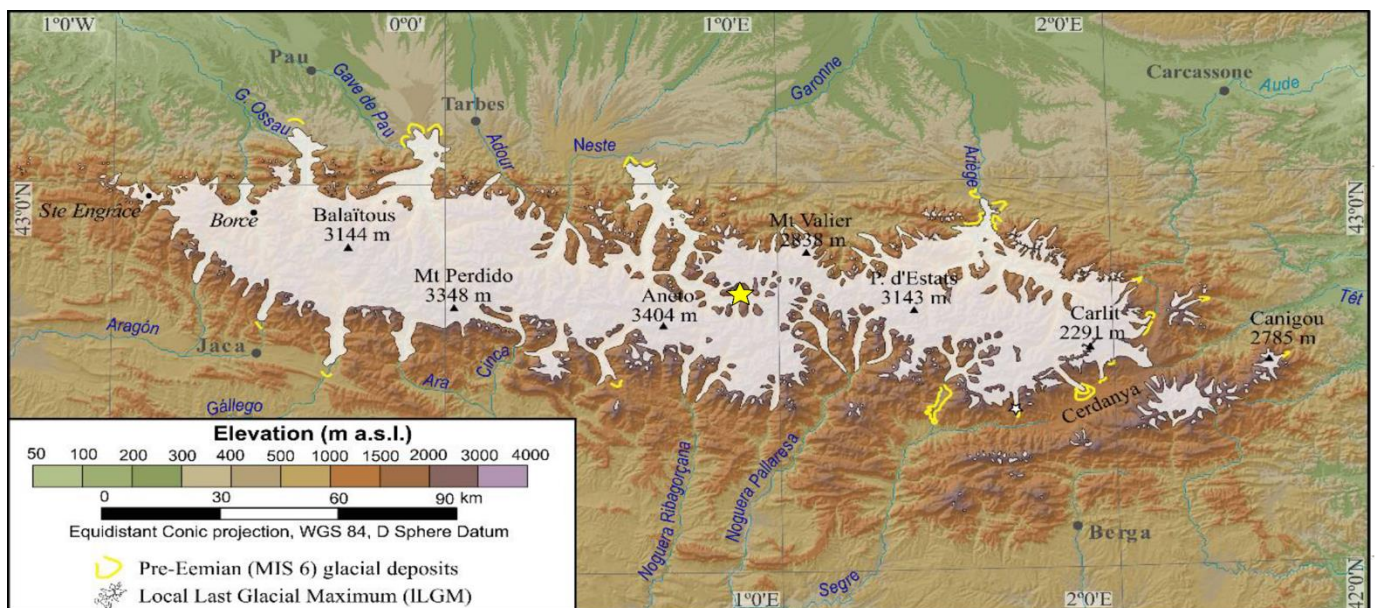


Fig. 2. Distribution of the Pyrenean glaciers during the LGM and location of the Aran Valley (Delmas et al., 2022a).

The field trip stop by stop

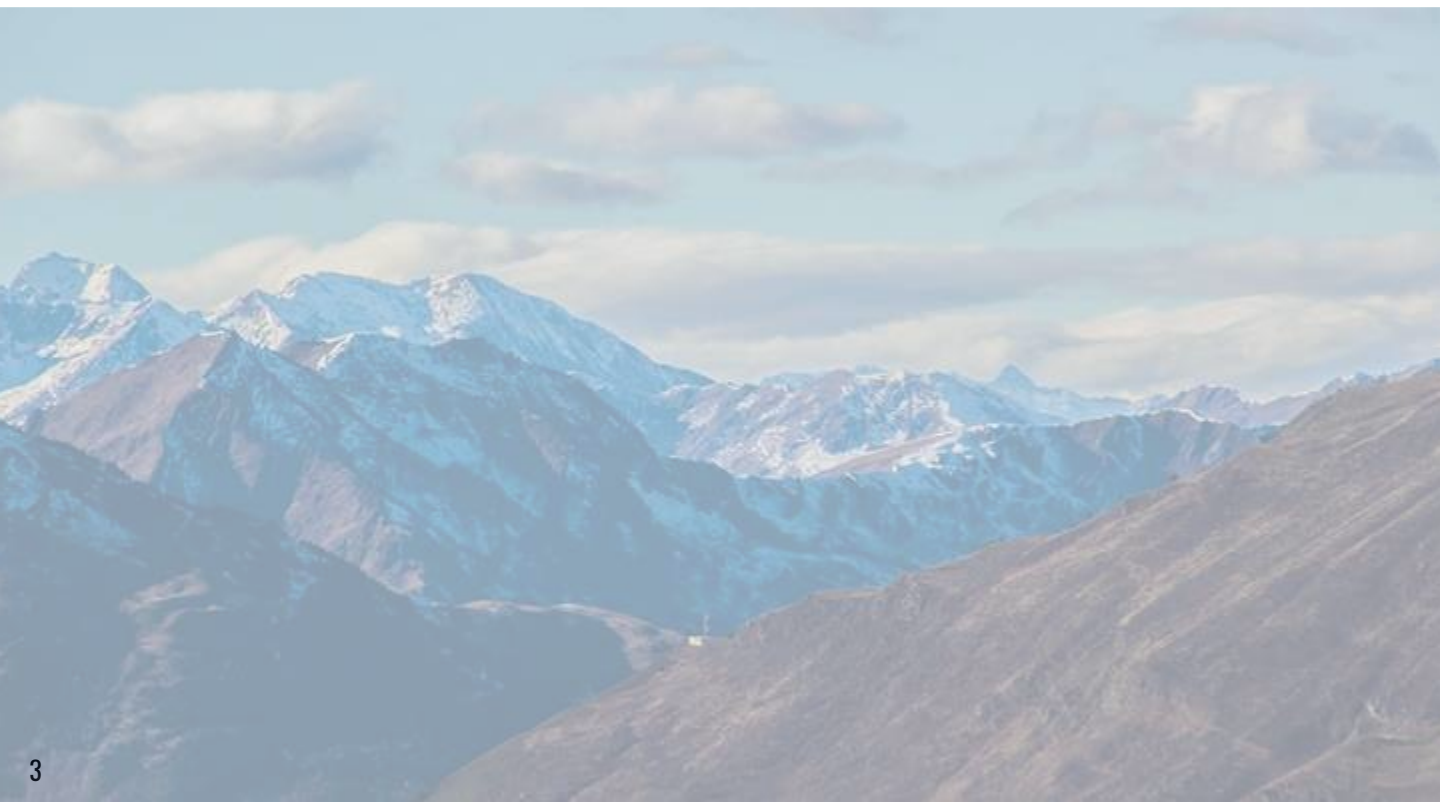
Stop 1. Mirador ctra de Beret (09-10h):

The Aran Valley encompasses 630 km² and is mostly located on the northern slope of the Pyrenees. It extends from the high peaks of the Pyrenean Axial Zone (Molières Peak, 3010 m) to the French border, at ca. 600 m. It consists of three morphostructural units with distinct geological, climatic, and ecological characteristics:

The highest peaks and glacial cirques (>2100 m) are primarily located in the Pyrenean Axial Zone, and lie on Carboniferous granitoids, such as the Maladeta Batholith and the Dome of Lys-Cailaouas. Glacial cirques are widespread and tend to be oriented NE and periglacial processes—frost shattering, patterned ground formation, and permafrost-related features—occur under cold conditions (MAAT ~3°C, 1100 mm annual precipitation). These harsh environments sustain subnival and alpine vegetation, mainly alpine grasslands and sparse coniferous trees.

The mountain slopes and high valleys (2100–1100 m) are composed of Cambrian to Devonian sedimentary and metamorphic rocks. These W-E glacial valleys are structurally controlled by folds and faults. Steep valley sides experience frequent snow avalanches, debris flows, and rockfalls, influencing vegetation and infrastructure stability. The climate is milder (MAAT ~10°C, 900 mm annual precipitation), supporting a dense subalpine belt (1600–2100 m) of coniferous forests dominated by *Pinus uncinata* and *Abies alba*.

The valley bottoms and forelands (1100–600 m) are at lower elevations consisting of Quaternary deposits overlaying Paleozoic formations. Glacial, lacustrine, and fluvial sediments have accumulated since deglaciation, forming flat valley floors where erosion and flood events drive fluvial incision (0.68-1.56 mm yr⁻¹). Land cover is heavily influenced by agriculture, while riparian woodlands persist along the Garonne River, where peak discharges are driven by snowmelt and heavy rainfall.



The field trip stop by stop

Stop 2. Plan de Beret (10-11h):

Bacivèr is a vast cirque with an amphitheater-like structure, spanning 5 km in length and 3.8 km in width. It serves as the source of the Malo River, which flows toward the Beret Plateau before merging with the Garonne River 6 km downstream. This complex cirque consists of three primary geomorphological sections: (i) the peaks and cliffs that form its headwalls, (ii) a collection of glacial, periglacial, and paraglacial landforms at the foot slopes, and (iii) an expansive flat floor characterized by polished surfaces, minor depressions, and scattered erratic boulders.

The cirque experienced extensive glaciation during the last glacial period, that was followed with a massive deglaciation by 15-14 ka, as evidenced by CRE dating from polished surfaces features. Thereafter, climatic conditions at the transition between the Bølling-Allerød (B-A) and Younger Dryas (YD) supported glacial advances, leading to the probable formation of small moraines on cirque slopes by ~12.9 ka. Subsequent glacier melting intensified paraglacial dynamics, fostering the development of rock glaciers and debris-covered glaciers, which remained active into the Early Holocene until at least ~7 ka (Fig. 3).

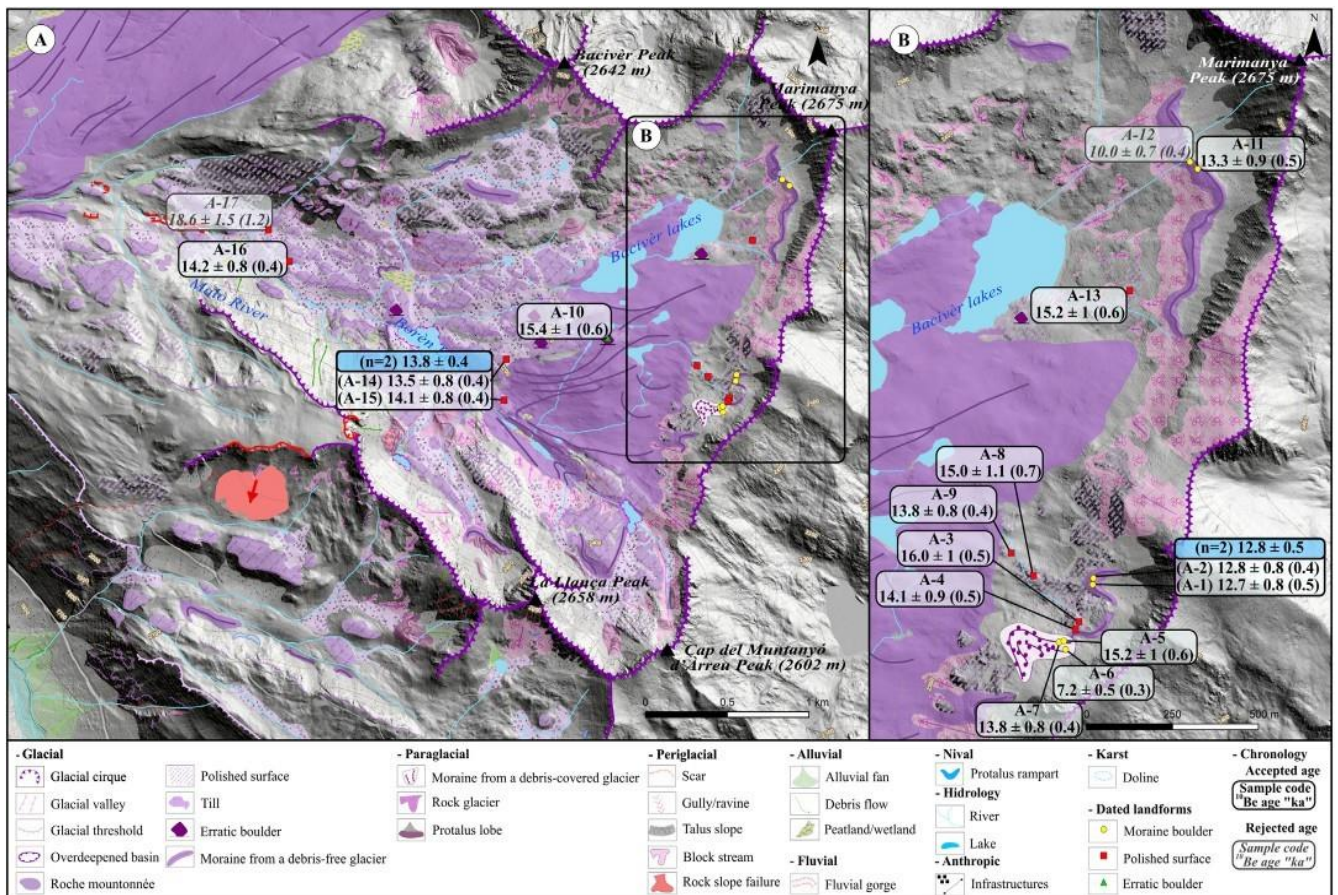


Fig. 3. Distribution of the landforms and CRE dating from the Bacivèr Cirque (Delmas et al., 2022a).

The field trip stop by stop

Stop 3. Arties Ermita Sant Pelegrí (11-12h):

The purpose of this stop is to observe the impact of natural hazards on the town of Arties, both its exposure to snow avalanches and flooding. Arties (1,140 m asl) is located at the confluence of the Valarties and Garona rivers. On its northern border is the Artigues ravine, at 2,180 m asl at its highest point. In this south-facing ravine, at least eight avalanches have been recorded in the last 100 years, reaching the apex of the cone, affecting buildings, the road, and one of them reaching the Garona River. Avalanches of both dry snow (with spray) and wet snow have been observed. Between 2000 and 2005, defence structures were built consisting of snow retention nets at the start zone and two retention dams at the beginning of the runout zone.

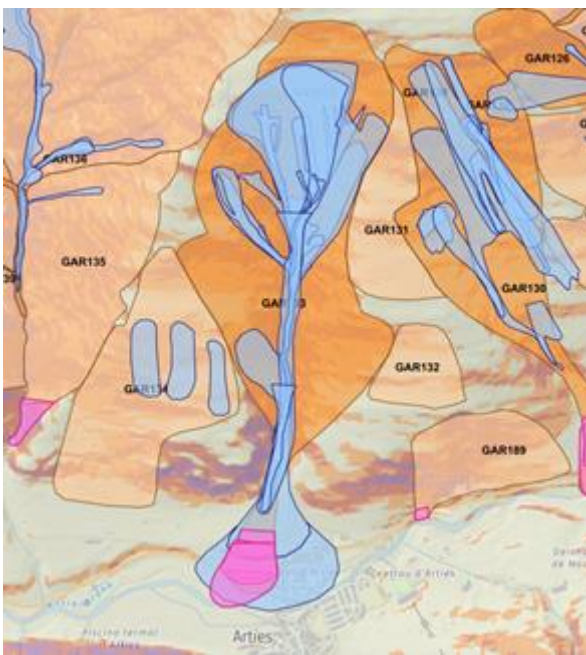


Fig 4. Left: Avalanche zone location map of the area (ICGC 1:25,000). Orange indicates avalanche areas determined by geomorphological and vegetation criteria. Violet indicates avalanches observed in the past, known from surveys of the local population. Blue indicates recent avalanche observations, after 1986. Right: Filled dikes by avalanche deposits after the snowfalls of January 2005.

Regarding flooding, the headwaters of the Garona river have historically suffered from flooding due to meteorological, lithological, and geomorphological conditions. The main historical floods of the Garona were recorded in 1875, 1907, 1963, 1982, and 2013. Of these, the ones that had the greatest impact on the population of Arties were the one on August 3, 1963, and the most recent one on June 18, 2013. Heavy rains in late July 1963 caused the aquifers to become saturated. The rainfall on the night of August 2-3 caused a significant sediment washout, destroying protective dikes, the medieval bridge, and the Sant Pelegrí neighbourhood. The passage of a warm front from the southwest on November 16 of the same year caused further flooding in the town but without causing any damage.

The field trip stop by stop

Stop 3. Arties Ermita Sant Pelegrí (11-12h):



Fig.5. Flood impacts in Arties. Left: August 3, 1963 (Magazine: *Aran Ath Dia*, 2007; *Arxiu Calzado de Les*). Right: Impact on June 18, 2013.

The floods of June 18, 2013, are the most recent and have caused the most damage in the Aran Valley as a whole. The cause was the combination of heavy rainfall (>100 mm in Vielha in 24 hours) with a strong melting of the snowpack, exceptional for the month of June, and high pre-summer temperatures. This event caused significant excavation in the course of Garona and its tributaries, resulting in landslides in adjacent rivers. In the case of Valarties River, it reached 32% of its length (2 km). Seventy-two gravitational movements (landslides, mixed dynamics, and torrential flows) were inventoried in the Aran Valley as a whole, generally of small size but some significant, such as the Aubeta ravine at the head of the Valarties, which mobilized nearly 90,000 m³ of sediment.

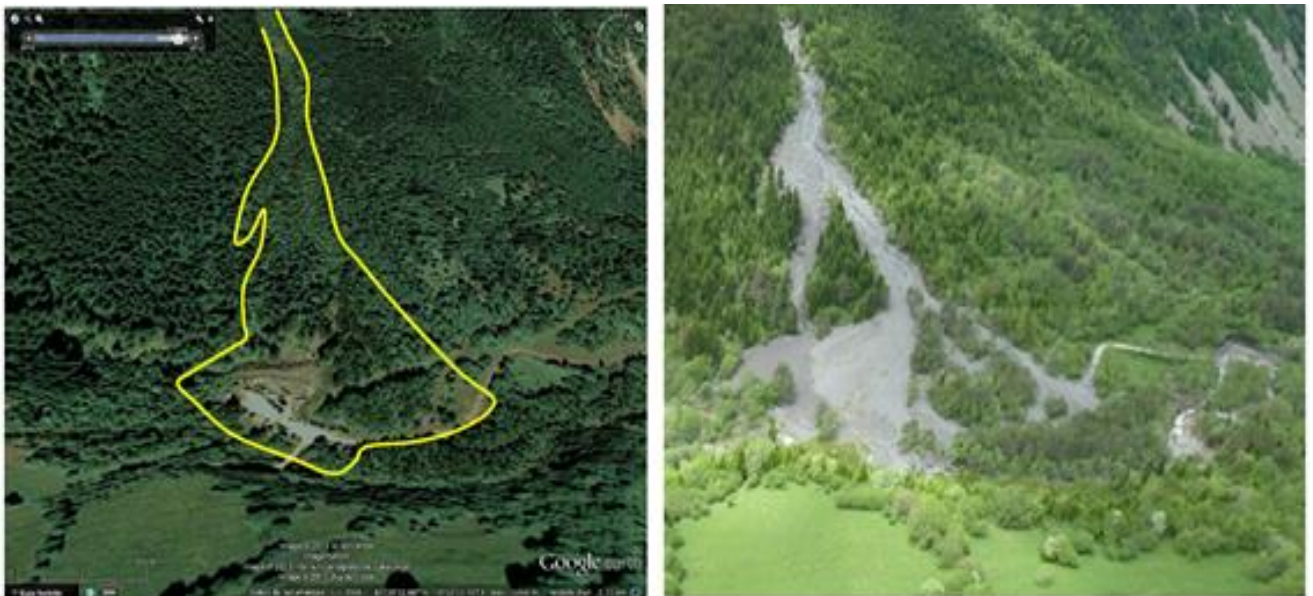


Fig. 6. The Aubeta ravine's debris cone destroyed the Ressec bridge section, destroying the bridge, access road, tourist booth, and parking lot.

The field trip stop by stop

Stop 4. Bassa d'Oles (12:30-14h): Lunch time

Stop 5. Uelhs deth Joeu (14-15h):

The water from the Uelhs deth Joeu drains into Joeu River, a tributary of the Garonne, contributing to the unique situation where Pyrenean glacial and snow meltwater ultimately flows northward into the Atlantic via France, rather than southward into the Mediterranean. The annual average recorded in Arlos of water drained in the Aran Valley, including the Joeu River, represents approximately 600 m³/s in the Garonne catchment (Lescure et al., 2015).

The spring Uelhs deth Joeu is a resurgence fed by the underground water that travels through the Devonian limestone unit, which lies on the impermeable granodiorite from the Maladeta Batholith. This contact allows the meltwater from the glaciers and snow of the Maladeta massif, which infiltrates into the sinkhole of Forau d'Aigualluts, to travel through approximately 4 km of underground karst system below the peak of Tuca Blanca de Pomero (2696 m) and finally re-emerges at the Uelhs deth Joeu. This geological and hydrological context partially allows the meltwater from the Ésera catchment to contribute to the drainage of the Garonne River.

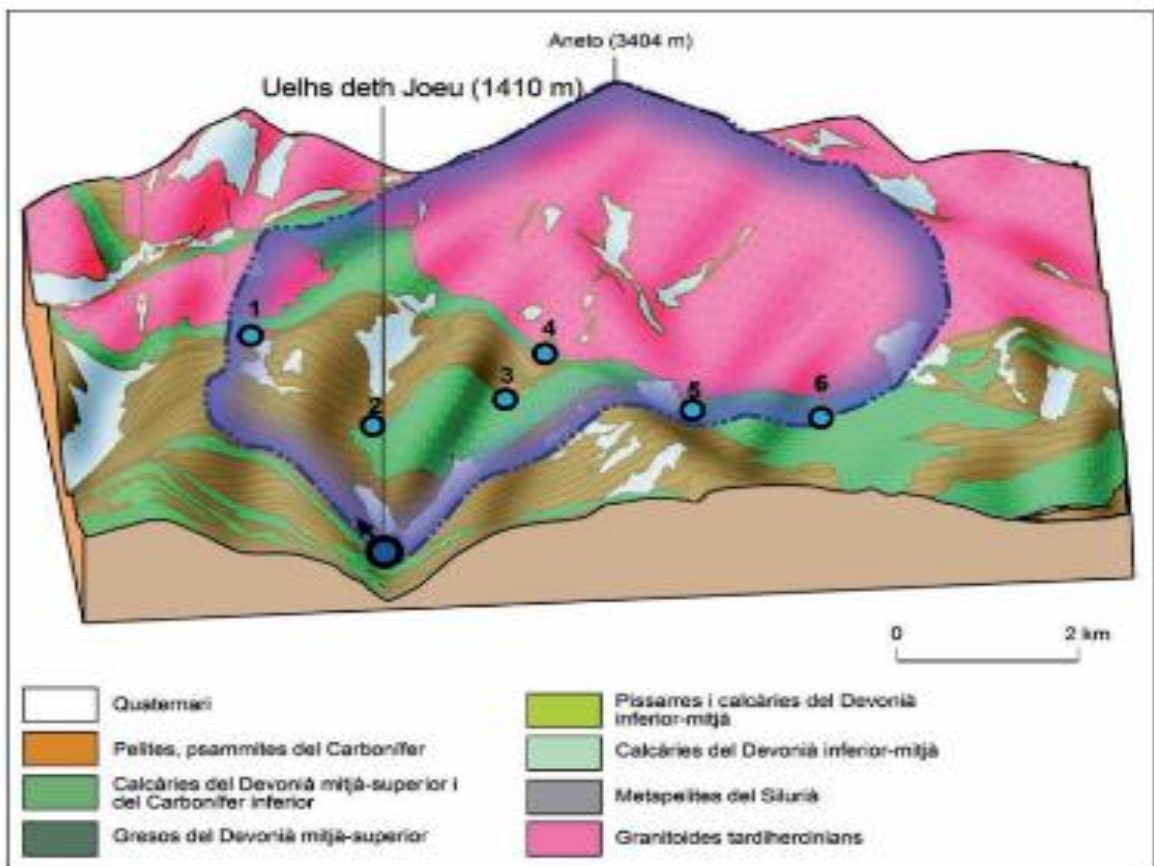


Fig 7. 3D model of the Uelhs Deth Joeu system (Freixes, 2014).

The field trip stop by stop

Stop 5. Uelhs deth Joèu (14-15h):

Hydrologically, the Uelhs deth Joèu represent the most spectacular resurgence of the Aran Valley, where the discharge average is of 2 m³/s and the peaks occur during late spring snow melt (April–June), reaching up to 10 m³/s. The temperature oscillates between 4 and 10 °C (6.5 °C average) and low mineralization conditions that vary according to the season. During the melt season (spring–summer) and storms, the mineralization levels are lower, with ca. 30 mg/l, whereas during the period of less water available, the mineralization levels are ca. 80 mg/l (Freixes, 2014).

Stop 6. Artiga de Lin (15-16h):

Following the ILGM, glacial widespread erosion features became exposed and are currently well-preserved in the Upper Garonne basin. The retreat of glaciers exposed overdeepened basins filled with postglacial sediments, interrupted by large roche moutonnées from Marignac (~500 m) to the entrance of the Ruda Valley (~2000 m). Glacial thinning also revealed polished surfaces and striated rock slopes (~1000 m). However, this glacier retreat was interrupted by a glacier advance that formed moraines within the valleys, whose deposits are especially preserved within the parallel tributaries to the main Garonne Valley, such as the Joèu Valley (Fig. 4; table 1). In the highest areas, the renewal recession of the deglaciation exposed glacier cirques that became gradually occupied by periglacial processes, sometimes difficult to interpret (Fig. 5).

Table 1. Chronological reconstruction of the glacial evolution in the Upper Garonne valley.

Glacial phase	Glacier system	Glacial type	Elevation of the moraines (m)	Summer temp. (°C)*	Chronology
Phase 1	M-1a	Piedmont	420-720	9.3	MIS-6: 130 ka
	M-1b	Piedmont	460-820	?	<LLGM(?)
Phase 2	M-2a	Alpine	1000-1850	?	OD(?)
	M-2b	Alpine	2000-2100	4.2-3.9	B-A: 13.5-13.0 ka
Phase 3	M-3a	Cirque	2400-2500	3.4-3	YD: 12.8-12.6 ka
	M-3b	Cirque	>2590	?	Neoglaciation(?)

The field trip stop by stop

Stop 6. Artiga de Lin (15-16h):

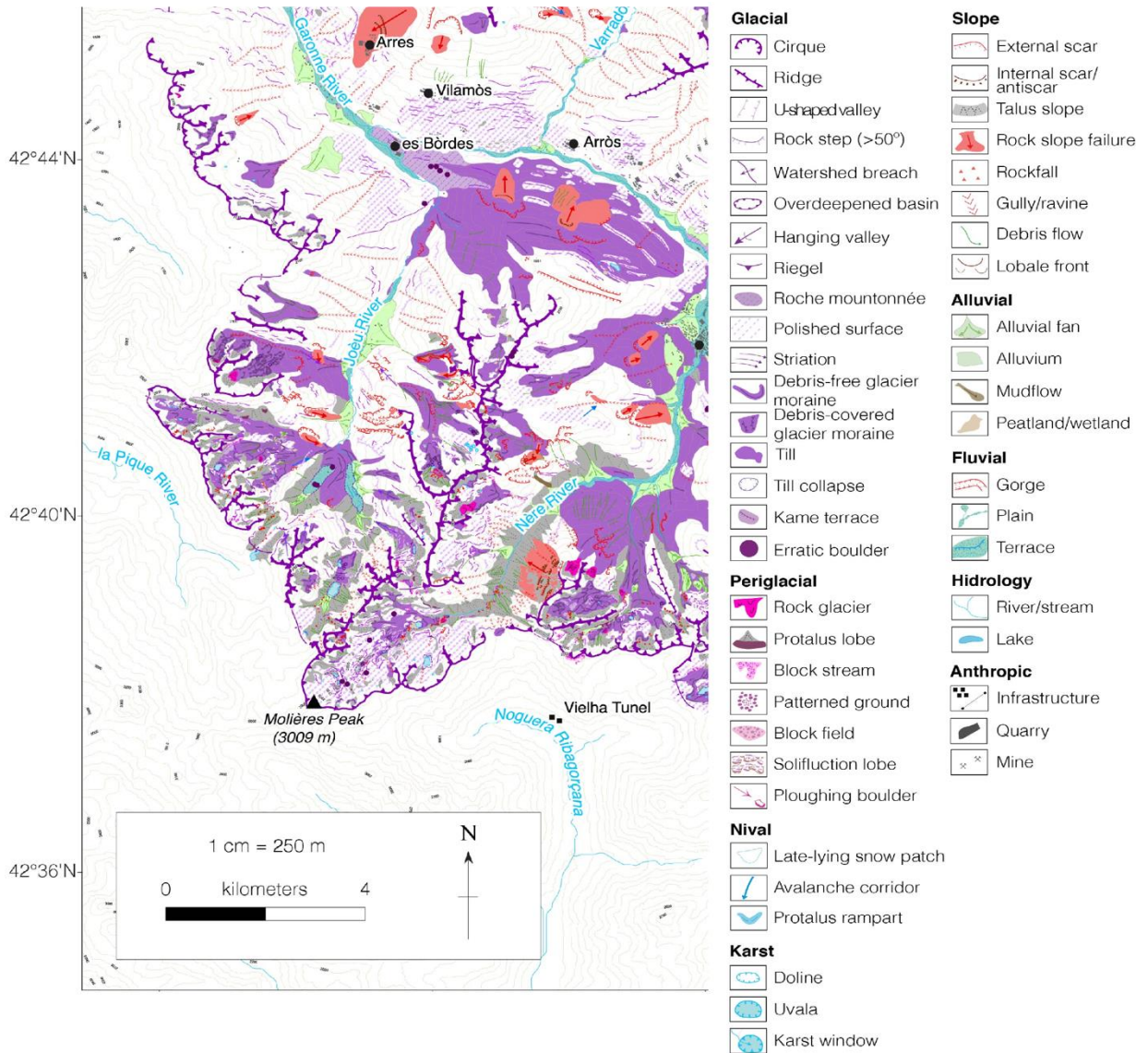
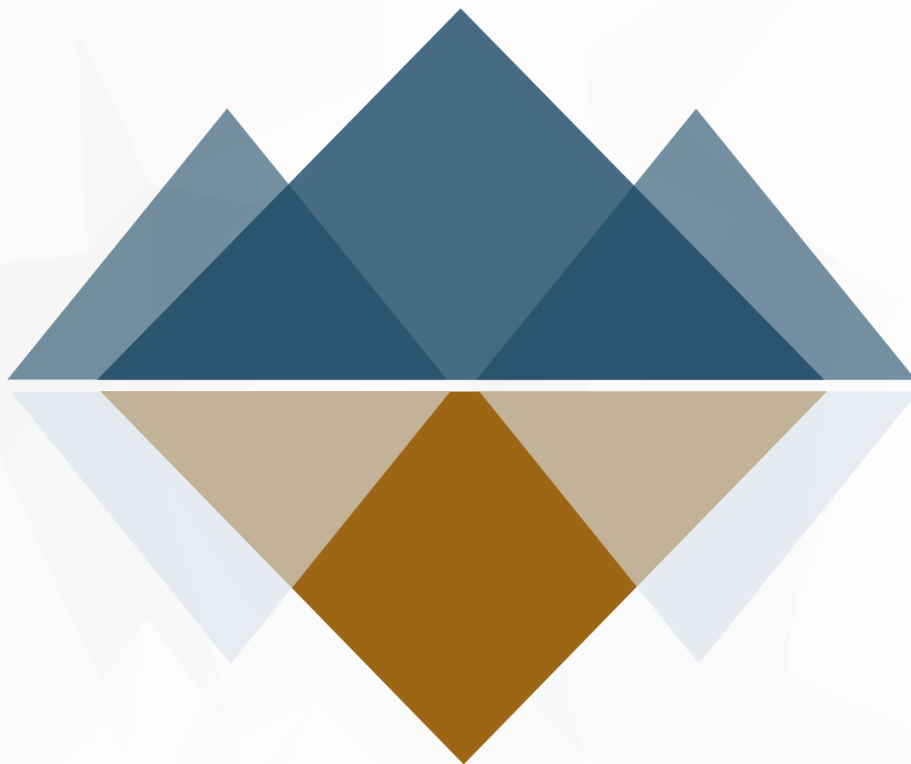


Fig. 8. Geomorphological map from the Joèu Valley (Fernandes et al., 2021).



Fig. 9. Periglacial landforms in the Joèu Valley.



Conference support



GRELARCTIC - Holocene glacial response and environmental dynamics in Greenland and Ellesmere. Ministerio de Economía y Competitividad, Spain, PID2023-146730NB-C31. PI: Dr Marc Oliva, Xosé Lois Otero. 2024-2026

ISLANDSINHEICE – Deglacial history and environmental consequences in west-central Greenland. Ministerio de Ciencia, Innovación y Universidades, Consolidación Investigadora 2023, CNS2023-144040. PI: Dr Marc Oliva. 2024-2026.

