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The Gavarnie Cirque : a celebrated “nature’s colossus

Monique Fort

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Keywords (separated by “-”)	Calcareous cirque - Thrust nappes - Pyrenean glaciation - Waterfalls	

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[AU1]

12 The Gavarnie Cirque: A Celebrated "Nature's Colossus"

Monique Fort

Abstract

Surrounded by peaks at height more than 3,000 m, the Gavarnie cirque forms, with two other cirques and the adjacent Spanish canyons, an exceptional landscape recognised in 1997 as a UNESCO World Heritage site for both its natural and cultural values. It is an outstanding geomorphosite straddling the Central Pyrenees, famous for its 1,500-m-high limestone amphitheatre, its waterfalls, and the *Brèche de Roland*. It results from a long evolution, including the formation of the Pyrenean range, the development of Quaternary glaciers, and a long history of human occupation and exchanges across the French/Spanish border. It has always been an inspiring place for many artists and is much appreciated by tourists and climbers.

Keywords

Calcareous cirque • Thrust nappes • Pyrenean glaciation • Waterfalls

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12.1 Introduction

The Gavarnie cirque is a unique site along the Pyrenean range. Celebrated by many artists at the end of the nineteenth century, it is one of the most visited places in the Pyrenees. Surrounded by peaks at height more than 3,000 m on the French/Spanish border, the Gavarnie cirque forms, with the two cirques of Estaubé and Troumouse and the adjacent Aragonese canyons and the cirque of Barrosa, an exceptional landscape recognised in 1997 as a UNESCO World Heritage site for both its natural and cultural values (Fig. 12.1). It is sited in the central part of the collisional Pyrenean system, where a maximum shortening has occurred, as revealed by the thrust units exposed within the slopes surrounding the cirque. Both karstic processes and glacial erosion contributed to shape this outstanding, deep natural amphitheatre that "*resembles nothing that is found anywhere else*" (V. Hugo). Adjacent to the Mont Perdu (3,352 m), it is a place of legend and praise, where coexist a traditional pastoral landscape and a tourism-oriented economy sustained by both Catholic pilgrims from Lourdes and sportsmen attracted by this "*Nature's Colossus*" (V. Hugo).

12.2 Geographical and Geological Setting

When coming from the north of France, after the vast Landes plains or the Lannemezan plateau, the traveller abuts against compact, continuous relief towered by the Astronomic Observatory of the Pic du Midi de Bigorre. When getting closer, the Pyrenean range rises like higher and higher waves. It becomes difficult to clearly separate the mountain front from its foothills (administratively, it is the 500 m contour line which sets the limits); it is also difficult to discern those valleys that permit to penetrate deeper into the mountain and reach the top of this great barrier. The Gavarnie cirque stands in the very upper part of the Gave de Pau catchment, locally called the Lavedan country (Fig. 12.2). From upstream of Lourdes, this is a fairly deep valley, which also leads to other prestigious sites of the Central Pyrenees, i.e. Cauterêts valley,

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Fig. 12.1 The Gavarnie cirque seen from the northern trail up to the Refuge des Espuguettes (Credit: M. Fort). Note the stone circles, traces of earlier settlements of shepherds coming from both sides of the French–Spanish border

with the Pont d'Espagne and the Gaube lake at the foot of the steep Vignemale north face.

12.2.1 At the Crossing of Climatic Influences

The Gavarnie cirque and adjacent landforms correspond to the central part of the Pyrenees, where a number of >3,000 m high peaks are present: Mont Perdu, Astazou (3,012 m), Marboré (3,250 m), Taillon (3,144 m), and Vignemale (3,298 m), to name a few (Fig. 12.3). This dominating relief plays an important role in the climatic regime and determines a sharp contrast between the influences from the Atlantic to the North and the West and those from the Mediterranean to the Southeast. In the Lavedan valley, westerlies command humid fluxes and abundant precipitation, yet the topographic contrasts may locally create rain-shadow effects and temperature inversions. Mediterranean influences, locally known as the "*balaguere*", a foehn-like wind in Lavedan, bring sudden heat that generally precedes heavy rains or snowfalls. These contrasts are expressed in the rich, endemic flora and fauna specific of each altitudinal belt and are accentuated at high elevation by extreme climate, steep landforms, and bedrock nature (predominance of limestone).

12.2.2 Where Spain Tightens Against France

The east–west trending Pyrenean mountains represent the westernmost end of the Alpine–Himalayan collisional system (Fig. 12.4). They are the result of a long evolution during which the boundary of the Iberian and European plates evolved until the final compressional stage of the Pyrenean orogenic growth (Late Cretaceous to Tertiary times), responsible for the present-day asymmetry of the mountains. Indeed, the steep, narrower (≈45 km) northern flank on the French side contrasts sharply with the gently sloping southern Spanish side, where ridges elevation progressively declines down to the Ebro basin (≈100 km).

The general structure of the Pyrenees displays a fanlike, flowerlike arrangement: large thrust nappes lean towards the north on the northern side, while they lean towards the south on the southern side. They are flanked on both sides by two foreland basins, the Aquitanian and the Ebro basins

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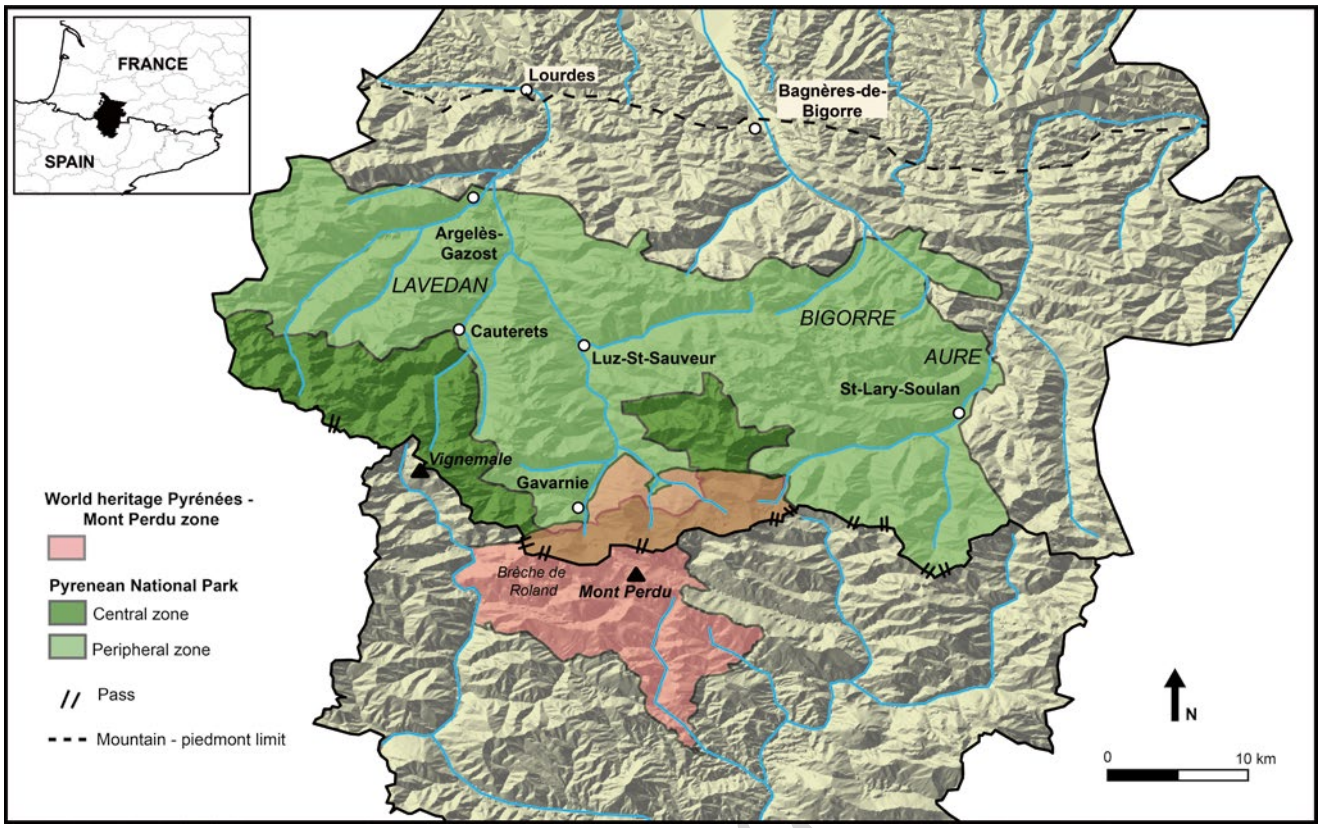

Fig. 12.2 Map of the UNESCO World Heritage zone: on the Spanish side, it includes the totality of Parque Nacional de Ordesa y Monte Perdido, whereas the French side extends over the core zone and the peripheral zone of the Pyrenees National Park. *Thick solid line* marks the international boundary

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(Fig. 12.5a). In fact, as revealed by extensive seismic reflection profiling, the European wedge is overlain by the upper Iberian wedge, whereas at the lower crustal levels, the tectonic wedge of the European crust has indented the Iberian plate (Choukroune and ECORS team 1989; Teixell 1998). This tectonic wedging at different crust levels is one major thickening mechanism, at the origin of orogeny and uplift of the Pyrenees.

The Gavarnie cirque area is sited in a central position, the axial zone, where a maximum shortening occurred and where this geologic architecture is the most distinct and nearly horizontally emplaced. It is mostly composed of the Gavarnie–Mont Perdu nappe complex, a series of thrust units piled up on the autochthonous Palaeozoic crystalline rocks (migmatitic gneisses): this is particularly well expressed along the eastern side of the cirque (Fig. 12.5b). In detail, the Gavarnie–Mont Perdu nappe is composed of highly tectonised Palaeozoic material, with its tightly folded, Cretaceous and Eocene sedimentary cover that overthrusts to the south and culminates with Cylindre du Marboré and Mont Perdu. The extent of the Gavarnie nappe is very large, at least more than 50 km from north to south, and represents fairly well the tectonic forces that produced the Pyrenean range. Most of the uplift appears to have started in the Eocene period, but it continued during the Oligocene when most of the deformation occurred.

12.3 Landform Evolution

12.3.1 Long-Term Evolution

The Gavarnie and two adjacent cirques of Estaubé and Troumouse are the result of a long and complex history, which started well before the cold periods of the Quaternary era. It is generally considered that the drainage divide dates back to the Eocene: located in the axial zone – the area of maximum relief of the orogen – the divide appeared when the axial zone was uplifted by the Gavarnie thrust *s.l.* This led to active denudation, and eroded debris was transferred to the subsiding foreland, contributing to the very thick Mio-Pliocene molasses of the Ebro and Aquitaine forelands, with the Bigourdan piedmont close to the mountain (Teixell 1998; Vergés et al. 2002; Figs. 12.4 and 12.5).

In the Central Pyrenees, the original position of the divide in the mid-Eocene was located in the southern North

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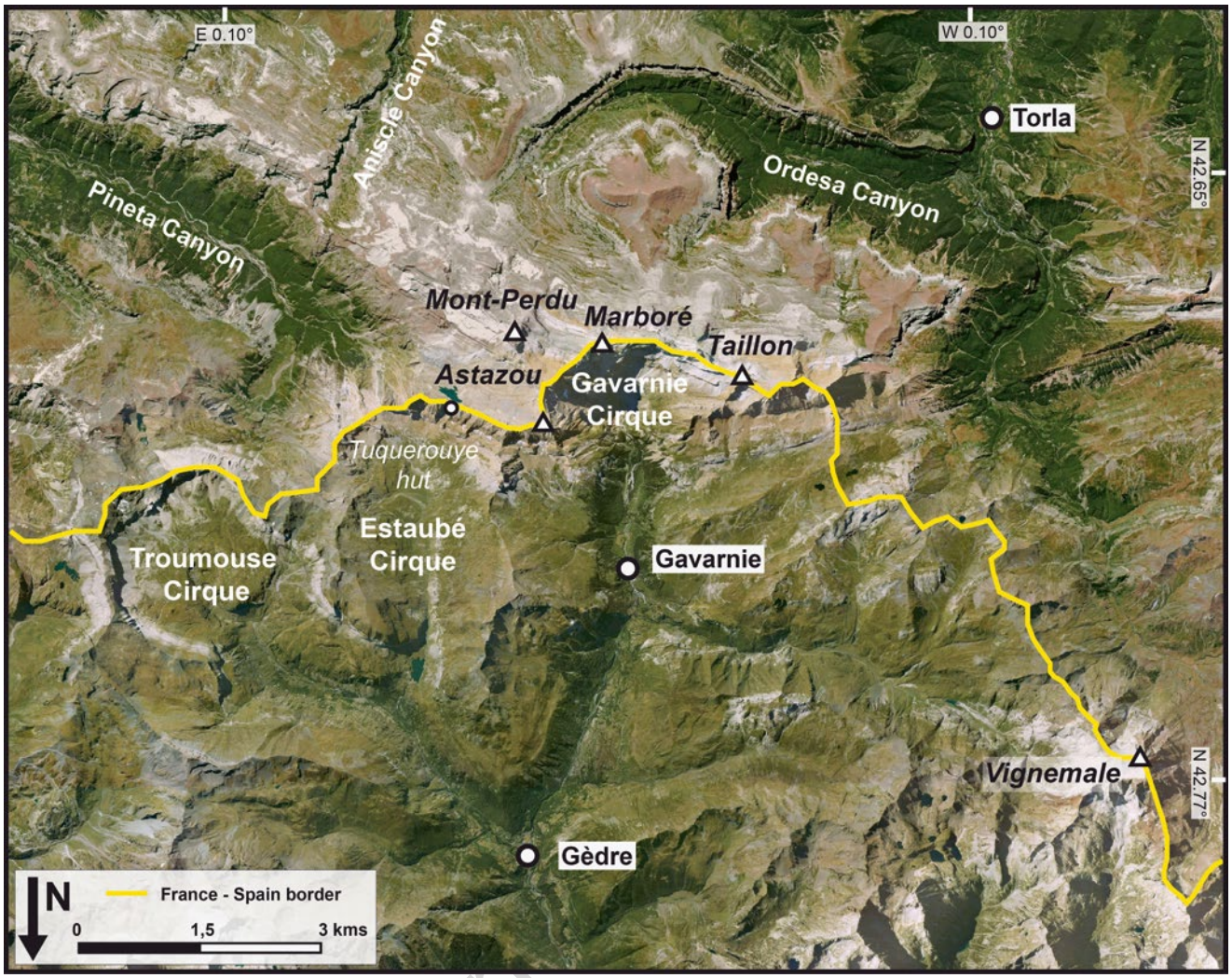

Fig. 12.3 The Gavarnie–Mont Perdu site includes spectacular cirque walls on the French side; two emblematic, still glaciated peaks (Mont Perdu and Vignemale); and three of the largest and deepest canyons on the Spanish side (Google map in the background, North oriented towards *bottom*)

Pyrenean Zone (retro-side of the belt). This is where exhumation was centred at that time, before erosion migrated southwards by tectonic control, divide migration being achieved by captures of the southern drainage network by the northern rivers, in particular with the source of the Garonne River in Val d'Aran (Babault et al. 2011). In the adjacent Aure valley (Fig. 12.2), the Neste River was also quite active: the Lannemezan megafan is the topmost relief feature where more than 2,000 m thick sediments are piled up in the subsiding foreland of the mountain, reflecting a significant incision of the rivers, probably favoured by both the steepness of the French side of the Pyrenees and the dominant moisture supply from the northwest, then by glaciation. In both the Val d'Aran and Aure valleys, granitic, joint substrate was deeply incised. In contrast, in the Gave de Pau valley, the presence of the thick and massive calcareous Gavarnie–Mont Perdu nappe did not allow further significant retrogressive erosion in its upstream part due to karstic, underground drainage network; indeed, the upper Gave de Pau valley evolved more like a calcareous "blind" valley, whose amphitheatre shape was then accentuated by Quaternary glaciations.

12.3.2 The Glacial History

During the Quaternary period, the Pyrenees have been extensively glaciated down to the piedmont (Calvet et al. 2011a; Delmas et al. 2011). During the maximum of the last glaciation (which occurred in the early part of the last glacial cycle), a large glacial tongue, more than 70 km long, fed by many tributaries from adjacent valleys, occupied the Gave de Pau valley and built up a complex, multilobate morainic system in the vicinity of Lourdes (Calvet et al. 2011b; Fig. 12.6). Around this area, 45-ka-BP-old morainic deposits are preserved and form a series of hills (≈600 m) perched above the present Gave de Pau valley floor (≈150 m).

With the retreat of glaciers that began before 34 ka BP under dry climatic conditions (Jalut et al. 1992), some

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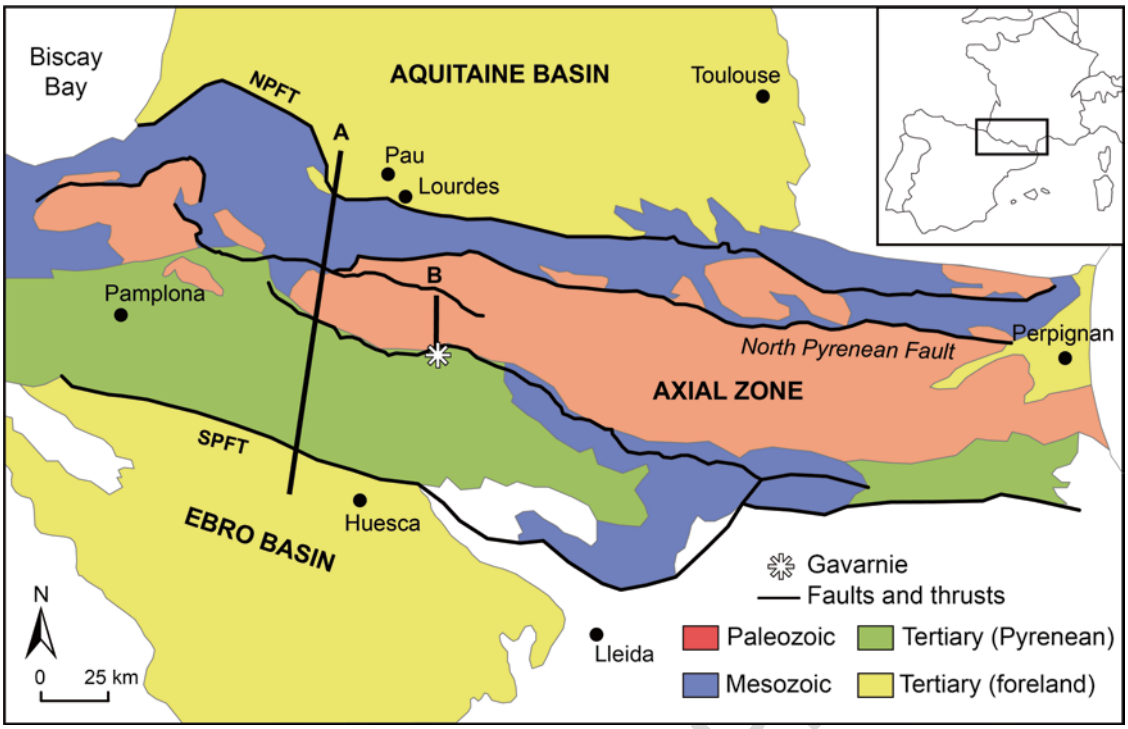
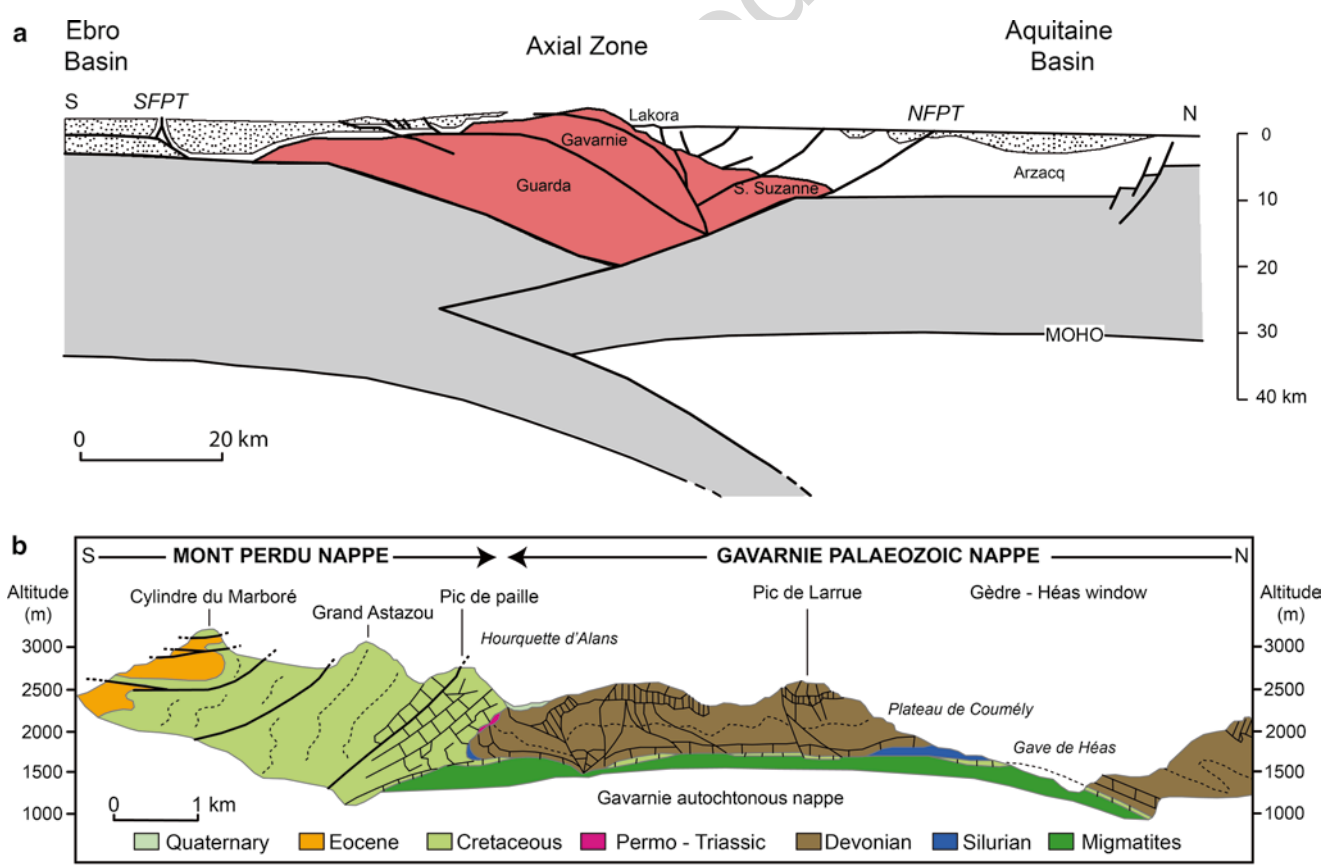


Fig. 12.4 Major geological entities of the Pyrenean range. A–A′ and B–B′ refer to the two cross sections of Fig. 12.5a, b



[AU3] **Fig. 12.5** Geological cross sections. (**a**) Across Western Pyrenean range (Adapted from Teixell 1998), with major structural units, i.e. from north to south: the Aquitaine retro-foreland basin, the North Pyrenean Thrust system of the Pre-Pyrenees, the Axial zone with basement rock units, the South Pyrenean Thrust System, and the Ebro foreland basin. (**b**) Detailed emplacement of the Gavarnie–Mont Perdu nappes (Redrawn and adapted from Gavarnie's Geological Map, 1:50,000, BRGM Edition 2002). Location of cross sections in Fig. 12.4

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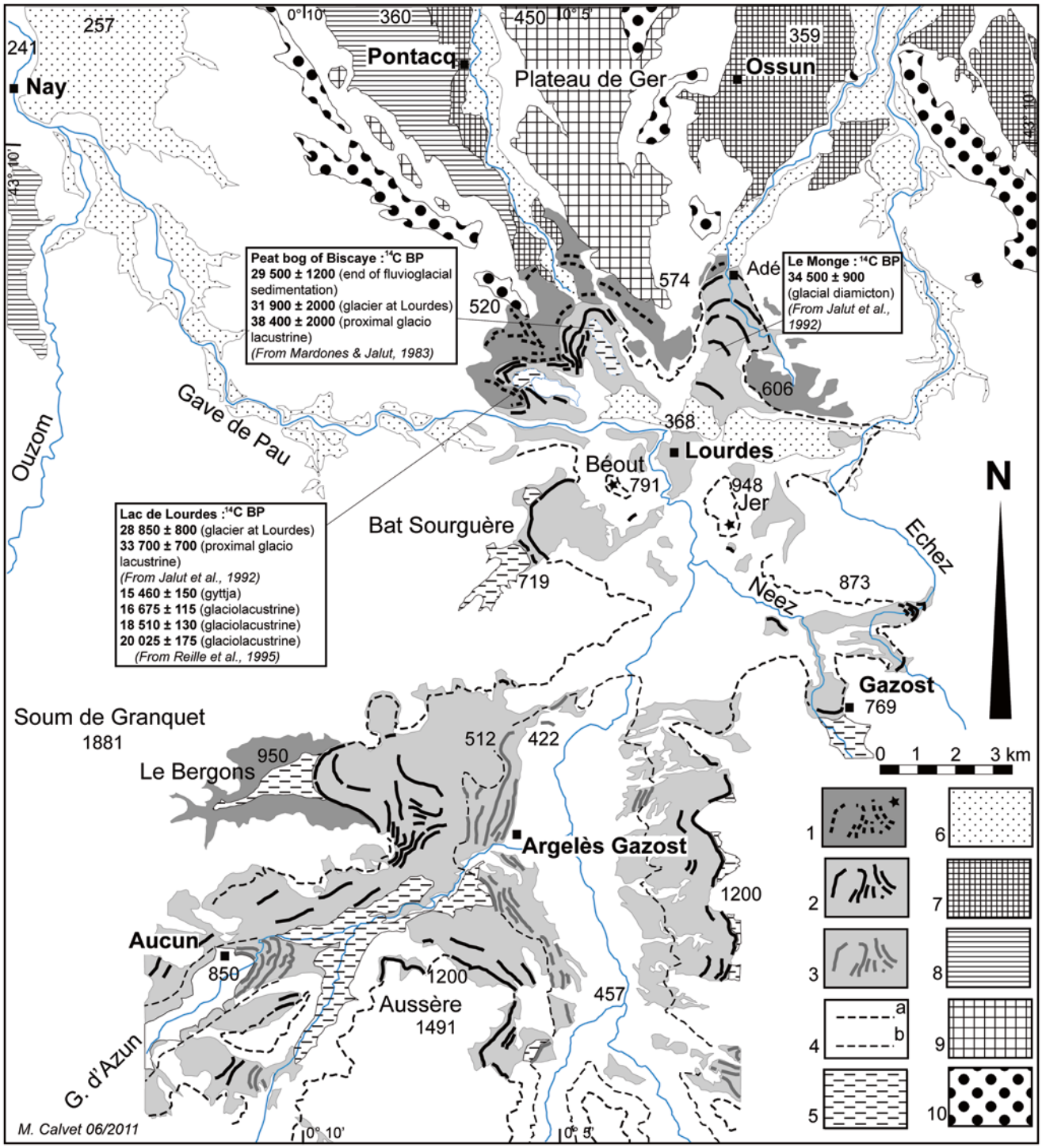

Fig. 12.6 Glacial extent in the Central Pyrenees, Gave de Pau lower valley around Lourdes (From M. Calvet, in Calvet et al. 2011b, with permission)

moraine-dammed lakes formed like the Lourdes Lake, while in the adjacent areas, glacial meltwaters deposited fluvioglacial sediments along the radiating valleys of the Plateau du Ger, north of Lourdes. The piedmont was probably ice-free at about 31 ka BP, but this phase was followed by a subsequent glacial readvance at 24 ka BP. This view was challenged by Reille and Andrieu (1995) who suggested that the ice cover lasted longer and vacated the piedmont zone between 16.67 and 14.46 ^{14}C ka BP only. It is most probable that glaciers advanced at different stages and reached similar positions repeatedly, as shown by clusters of very different ^{10}Be ages at about the same location (Rodés 2008). Then the

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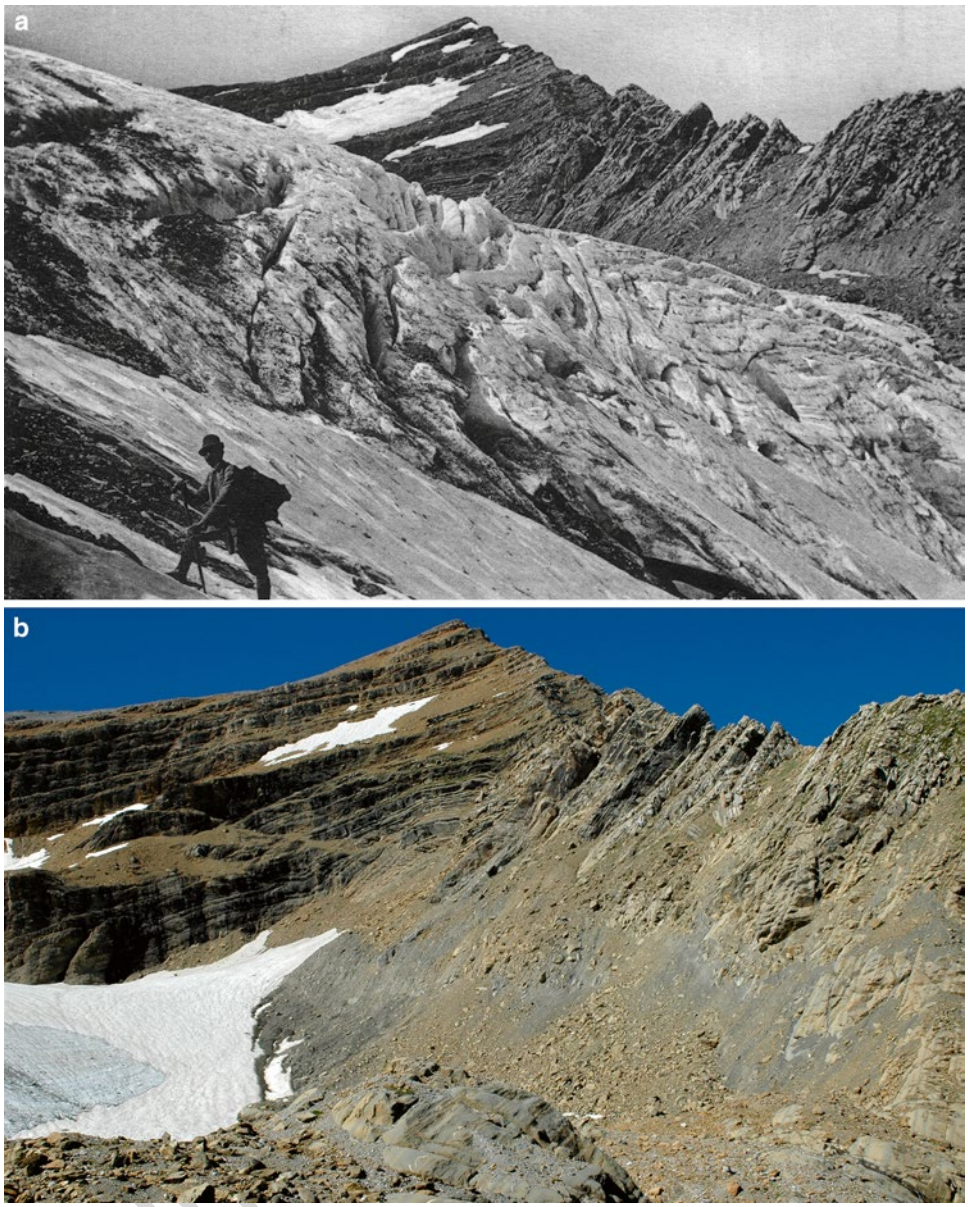

Fig. 12.7 Evolution of the Taillon Glacier (northern slope). (**a**) ~~(*left*)~~ ca. 1900, old postcard (Association Moraine, with permission). (**b**) ~~(*right*)~~ In 2010 (photo G. Nogué, Association Moraine, with permission). Note the readjustments (rockfall, scree, debris flow) of the rocky wall following deglaciation

glaciers receded rapidly, with a few traces of evidence left, such as lateral moraine of Argeles Gazost, because of their prompt removal by further erosion (Fig. 12.6). Yet, immediately below the crest zone, some traces of glacial fluctuations are preserved downvalley, suggesting the presence of Late Glacial and most probably Holocene moraines.

More recent Neoglacial events like in the Cirque de Troumouse have been recorded (Gellatly et al. 1992), between 4,955 ± 90 and 4,654 ± 60 BP, followed by more recent, yet still undated, events. Little Ice Age moraines are more frequently preserved in most massifs of the Central Zone. The modern glaciers disappear very quickly as observed in many places (René 2001). There are no more than 21 glaciers left in the Pyrenees, occupying a total area of 450 ha, whereas as recently as in 1870, the total glaciated surface amounted to 45 km^2. The gradual increase in temperature – a total of 0.9 °C from 1890 until now – implies that the Pyrenean glaciers will probably disappear by 2050 or even earlier. In the Gavarnie area, glaciers are essentially restricted to N to NE facing cirques at altitudes above 3,000 m a.s.l. (Mont Perdu or Taillon, 3,144 m; Fig. 12.7) or occur on high plateaus like in Ossoue–Vignemale. Nevertheless, glaciers are not what really have made the renown of Gavarnie site.

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12.4 "Nature's Colossus"

The most striking part of the Cirque de Gavarnie is its 1,500 m high amphitheatre shape, widening from 800 m at the bottom up to 3,000 m at the top, in a series of three giant vertical steps (Fig. 12.1). Generally interpreted as a result of glacial erosion, it is a much more complex form where limestone and underground waters have played an important role in the overall architecture of this unique scenery. Two outstanding features are the main attractions of the Gavarnie cirque: the Grande Cascade and the Brèche de Roland.

12.4.1 Waterfalls

One remarkable feature of the Cirque de Gavarnie is its waterfalls in two or three drops, with an overall drop of 420 m, "taller than the Eiffel Tower" as locals say. The Grande Cascade, the lower one, is 281 m tall, and the breaking fall turns often into mist. As Victor Hugo has written (1855, posthumously published in 1891) in his poem "God": "*The twelve waterfalls that shadow hears complaining in this terrible and whirling cylinder, the mountain streams exhausted of foam and fighting, and flow, top torrent and smoke down*". The water at the origin of the waterfall is coming from the snowmelt and from a frozen pond located in Spain near the Mont Perdu, with the waters seeping and finding their way underground through the Cretaceous limestone strata before resurging right on the cirque rim. The annual discharge of the waterfall varies between 3 and 200 m^3/s when snowmelt is at its maximum. Indeed, the waterfall accentuates the vertical dimension of the relief, all the more as the adjacent limestone strata are also overturned and nearly vertical along the "*Arête Passet*" (Fig. 12.8). The waterfall is the source of the *Gave de Pau* stream, which collects other *gaves* (torrential streams) originated from the Barèges and Cauterêts valleys, hence being transformed in a fast-flowing stream in Lourdes that can be subject to severe flooding like in autumn 2012.

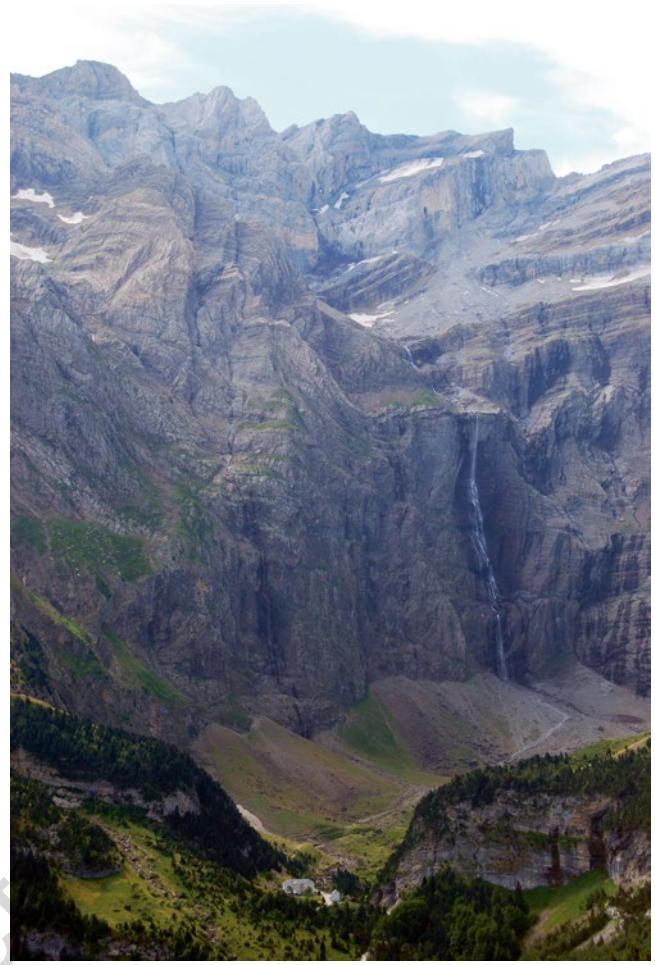

Fig. 12.8 Great Waterfall of Gavarnie. The water comes out of karstic network developed at the foot of the Grand Pic du Marboré (3,248 m). *Left* of the waterfall: note the folded, nearly vertical strata (Cretaceous limestones) of Arête Passet, a famous climbing road. Foreground: glacial rock-bar shaped into the Devonian sedimentary basement (Credit: M. Fort)

12.4.2 Brèche de Roland

The *Brèche de Roland* (2,807 m) is a natural gap, open in the upper layer of the cirque. The eye is attracted by its very spectacular geometry, 40 m across bordered by very slender walls over 100 m tall, cut into the Eocene limestone (Fig. 12.9). According to the legend, Roland, Charlemagne's nephew, threw his sword when he was mortally wounded in a battle against the Mores; the sword hit the cliff and opened the breach just at the border between France and Spain. In fact, this giant doorway is the result of a collapse of the rocky wall that was favoured by postglacial debuttressing. The pass is a classic way on its southern side to climb either Mont Perdu or the Taillon (3,144 m), which offers a vertiginous overlook down to the cirque bottom. It also marks the sharp contrast existing between the northern, moist Atlantic side of the mountain and the south, dry, and stony sloping plateaus of the Aragon, Mediterranean side, with their very deep canyons, that reveal natural geological cross sections cut into the multicoloured, Tertiary sedimentary strata.

12.5 Natural and Cultural Heritages

If the outstanding beauty of these landscapes has been celebrated for many centuries, the early occupation (40,000–10,000 BC) of these mountains is in fact testified by megalithic remnants, such as the Gavarnie stone circles (Fig. 12.1) and the Tella dolmen, or caves such as Anisclo or

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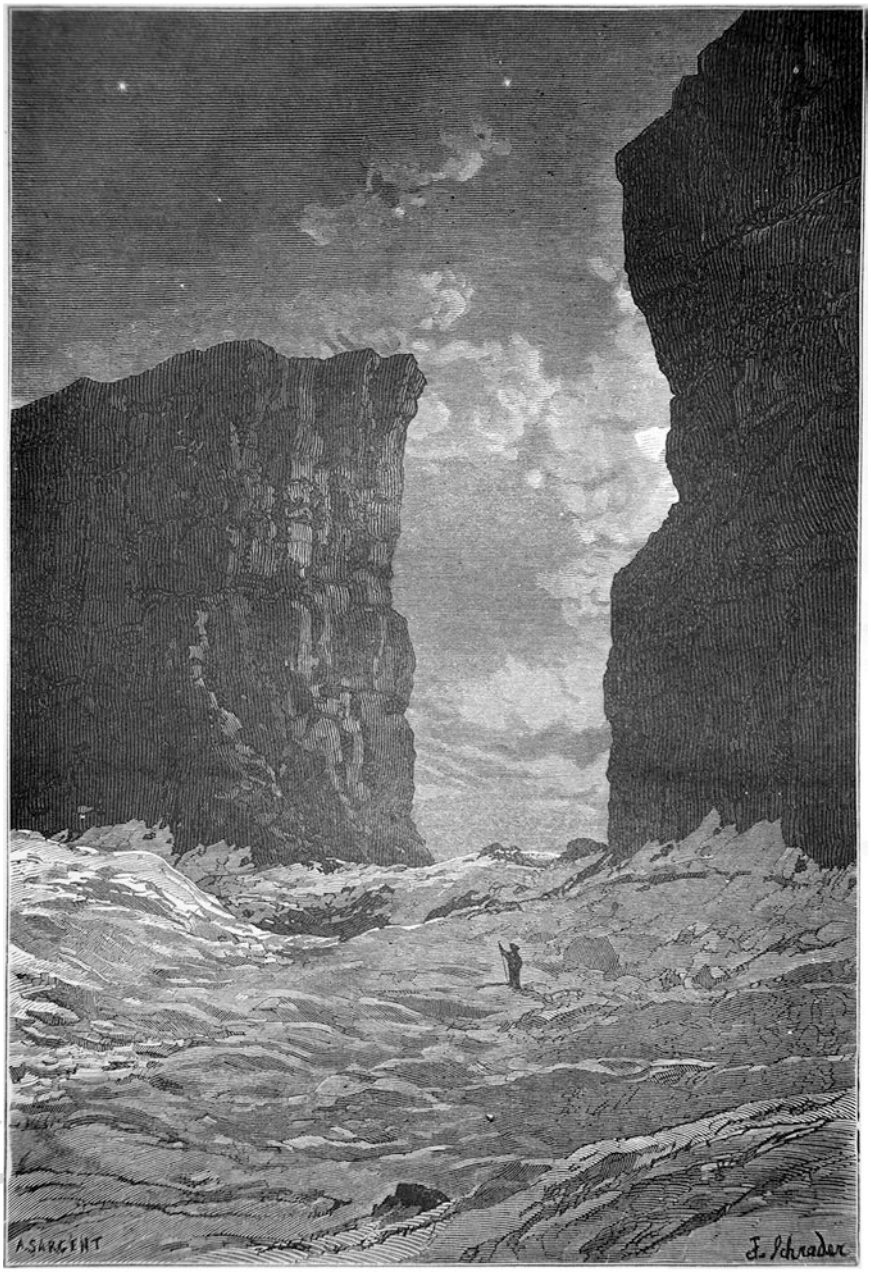

BRÈCHE DE ROLAND
Dessin de Fr. Schrader, d'après nature.

Fig. 12.9 Schrader's drawing of the Brèche de Roland (2,807 m) (In Reclus 1877, p. 25). Franz Schrader was among the very first to promote "pyreneism" and to draw attention to endangered species

Escuain in Aragon, shaped by karstic waters (Fig. 12.2). The elevations of the crest lines were never a barrier, and high passes (called "*ports*") linking Bigorre (France) to Aragon (Spain) bear evidence of their frequentation by shepherds and extensive livestock commuting from one side to the other for grazing and sheep breeding (Galop et al. 2007). The Port de Boucharo (Puerto de Bujaruelo) west of Gavarnie was traditionally crossed by shepherds on their transhumance way from the grand canyon of Ordesa to the Gavarnie meadows, with halts known as "*hospices*" such as the *espitau/hospitales* of Gavarnie (Fig. 12.10), and summer shelters of pastoralists called "*cabanes*" or "*coueyla*" (hut), like the Cabane de Tuquerouye (Fig. 12.11), used by hunters and now used by recreational walkers, or the Aires *coueyla* in the Troumouse cirque, considered as cultural heritage and now rehabilitated and protected. Indeed, as in many valleys in the Pyrenees, French and Spanish living on both sides of the mountain share many commonalities and customary rights on a local and trans-Pyrenean basis, and landscapes still present cultural similarities like the use of terraces fields.

On the French, Lavedan side, the paucity of arable lands in the valley bottom favoured the development of a social life

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Fig. 12.10 Gavarnie village. In the early days Gavarnie was a shepherd town and an important passage point between France and Spain (way to Boucharo port, Puerto de Bujaruelo). The hospitales is visible in the background (Early twentieth-century postcard, Public domain)

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based on community of land, with exchanges and shares of farming production and grazing time in alpine pastures (Galop et al 2007). This collective way of life persisted during the twentieth century when hydropower dams and tourist activity based on skiing development started providing a valuable, alternative income to villagers.

Actually, tourism started in the second half of nineteenth century, with mineral, sulphurous, often hot springs, mostly situated at the contact of the granitic basement and sedimentary rocks. Their exploitation as hydrothermal baths in Cauterêts, Barèges, Luz-St-Sauveur was largely popularised by Imperatrice Eugenie (1826–1920). Fairly differently, religious tourism is also a local specialty. The 18 apparitions of the Virgin Mary to Bernadette Soubirous young shepherdess, in 1858, changed the fate of the small town of Lourdes, which has developed into a major place of Roman Catholic pilgrimages. With good connection by rail and air, there are today millions of tourists who come each year to Lourdes. This attendance is beneficial to its hinterland of the Gave valleys, especially to the Cirque de Gavarnie, with two million tourists visiting the site each year. In wintertime, besides the Gèdre ski resort, Gavarnie has become famous for ice climbing on frozen waterfalls. In summertime visitors walk or ride a horse to discover the breathtaking walls and waterfalls issued from the bowels of the earth. In addition to the cirques, herding or hiking trails permit to discover the most striking geological and geomorphological features or to observe rare, protected species adapted to extreme environments, such as alpine rocky slopes near the Sarradets (plants *Androsace ciliata, Saxifraga iratiana, Artemisia genepi, Doroconum*) or caves (the endemic, cave-dwelling collembolan *Tricanthella frigida*). Edelweiss (*Leontopodium alpinum*) is the symbol of the Pyrenees National Park (PNP), whereas the local "isard" (*Rupicapra p. pyrenaica*), which had almost disappeared by dint of being hunted long, is again abundant since the PNP creation in 1967 and has become an integral part of the landscape (Fig. 12.2). On the Spanish side, in the Parque Nacional de Ordesa y Monte Perdido created in 1918 (2,100 ha, extended to 15,608 ha in 1982), the

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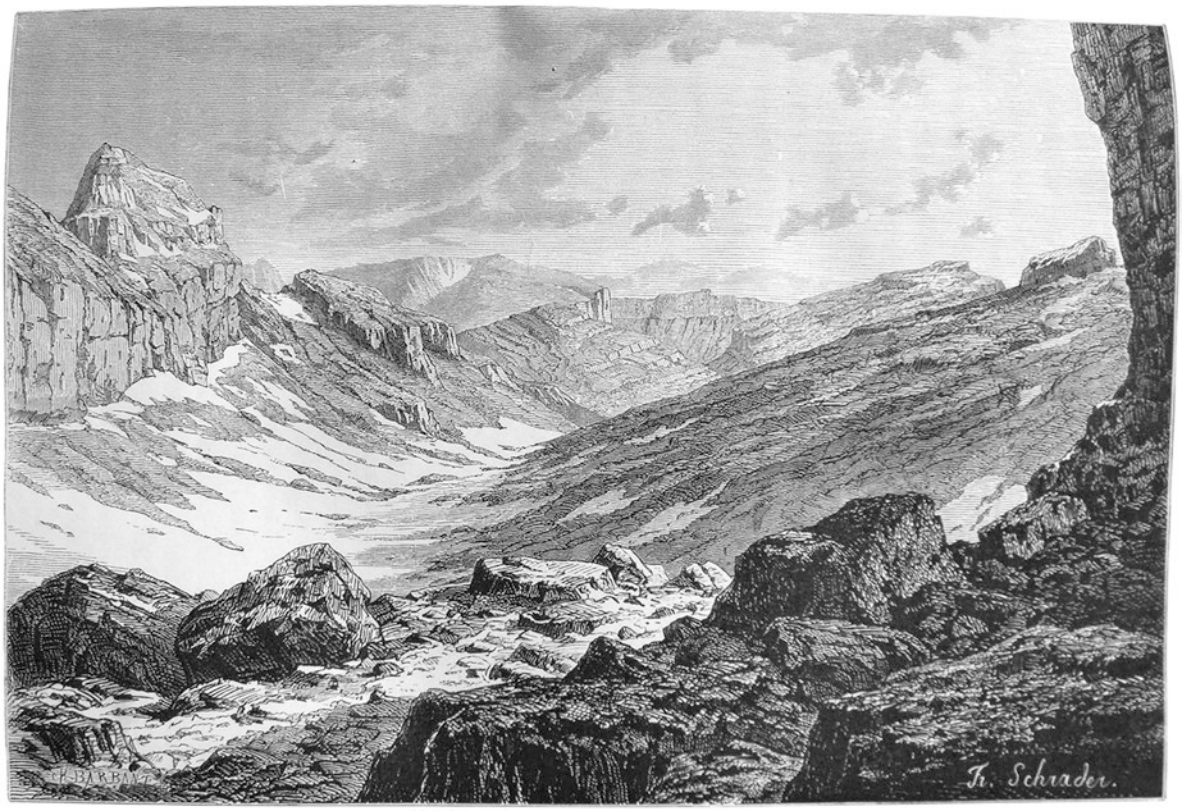
Fig. 12.11 Tuquerouye refuge (2,655 m) at Gavarnie. This entirely stone-built hut is located at the *port de Tuquerouye,* along the trail to Spain across Monte Perdido to the Aragon canyons of Añisclo, Ordesa, Pineta and Escuain (Early twentieth-century postcard, Public domain)



VUE PRISE DE LA BRÈCHE DE ROLAND

Dessin de Fr. Schrader, d'après nature.

[AU4]

Fig. 12.12 Example of the delicate and precise drawings by Franz Schrader: Spanish side of the Brèche de Roland (2,807 m), with dry, southeast dipping limestone plateaus overlooked by the Casque du Marboré (3,006 m) on the *left* (In Reclus (1877, p. 77); Public domain)

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lammergeyer (*Gypaetus barbatus*) is in decline because of its dependence on pastoralism. The two adjacent national parks, together with the Site Classé and Classified Reserve of the Gavarnie, Troumouse and Estaubé cirques, with the Ordesa–Viñamala Biosphere Reserve and a WWF/IUCN Centre of Biodiversity, fully justify the UNESCO World Heritage status.

The attractiveness of the Gavarnie cirque also gave rise to summer entertainments such as the theatre festival which takes place at the entrance of the cirque for the last 27 years and attracts 20,000 people over 2 weeks. Since the inscription of the area as a World Heritage property in 1997, the committee of UNESCO has requested relocation of the theatre festival, incompatible with the outstanding universal value of the site. Despite efforts to minimise the impacts by festival organisers, their resistance to move the festival elsewhere creates a risk for the decommissioning of Gavarnie site as a part of the Mont Perdu World Heritage. In the adjacent valley, Gèdre villagers have accepted to restrict road access to Troumouse cirque in order to help the recovery of natural landscape and wilderness.

12.6 Conclusion

Considered the archetype of glacial cirques, the Gavarnie cirque results from a combination of both karstic and glacial influences, in the context of plate tectonics and complex convergence between Spain and France. The exceptional size of the cirque, taller than wider, generated many tales and legends, attracted writers and artists. If Victor Hugo was fascinated by natural forces, Franz Schrader (1844–1924) was probably the most emblematic Gavarnie's lover: he not only sustained the Gavarnie myth but also was the first to explore and explain the interactions between geology and climate at the origin of these dramatic landforms and to decipher the human imprints on the overall landscape. His exceptional skills in geography, cartography, drawing, and painting definitely made him the first "Pyreneist", whose graveyard rests forever on the lower slopes of Gavarnie Cirque.

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Queries	Details Required	Author's Response
AU1	Please confirm the chapter title.	
AU2	The citation "Choukroune et al. 1989" has been changed to "Choukroune and ECORS team 1989". Please check if appropriate.	
AU3	Please confirm the captions of Figures 12.5 and 12.7.	
AU4	Please provide text-citation for Fig. 12.12.	

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