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The Gavarnie Cirque: a celebrated “nature’s colossus

Monique Fort

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	Given Name	Monique
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	Division	Department of Geography
	Organization	University Diderot-Sorbonne-Paris-Cité, UFR GHSS Case 7001 – CNRS UMR 8586 PRODIG
	Address	Rue Thomas Mann 5 , 75205, Paris, France
	Email	fort@univ-paris-diderot.fr
Abstract	<p>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 <i>Brèche de Roland</i>. 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.</p>	
Keywords (separated by “-”)	Calcareous cirque - Thrust nappes - Pyrenean glaciation - Waterfalls	

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

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Monique Fort

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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

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. Caunterêts valley,

M. Fort (✉)
Department of Geography, University Diderot-Sorbonne-Paris-Cité,
UFR GHSS Case 7001 – CNRS UMR 8586 PRODIG,
Rue Thomas Mann 5, 75205 Paris, France
e-mail: fort@univ-paris-diderot.fr



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

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

high elevation by extreme climate, steep landforms, and 59
bedrock nature (predominance of limestone). 60

42 **12.2.1 At the Crossing of Climatic Influences**

43 The Gavarnie cirque and adjacent landforms correspond to
44 the central part of the Pyrenees, where a number of >3,000 m
45 high peaks are present: Mont Perdu, Astazou (3,012 m),
46 Marboré (3,250 m), Taillon (3,144 m), and Vignemale
47 (3,298 m), to name a few (Fig. 12.3). This dominating relief
48 plays an important role in the climatic regime and determines
49 a sharp contrast between the influences from the Atlantic to
50 the North and the West and those from the Mediterranean to
51 the Southeast. In the Lavedan valley, westerlies command
52 humid fluxes and abundant precipitation, yet the topographic
53 contrasts may locally create rain-shadow effects and tem-
54 perature inversions. Mediterranean influences, locally known
55 as the “*balaguere*”, a foehn-like wind in Lavedan, bring
56 sudden heat that generally precedes heavy rains or snowfalls.
57 These contrasts are expressed in the rich, endemic flora and
58 fauna specific of each altitudinal belt and are accentuated at

12.2.2 Where Spain Tightens Against France 61

The east–west trending Pyrenean mountains represent the 62
westernmost end of the Alpine–Himalayan collisional system 63
(Fig. 12.4). They are the result of a long evolution during 64
which the boundary of the Iberian and European plates 65
evolved until the final compressional stage of the Pyrenean 66
orogenic growth (Late Cretaceous to Tertiary times), respon- 67
sible for the present-day asymmetry of the mountains. 68
Indeed, the steep, narrower (≈ 45 km) northern flank on the 69
French side contrasts sharply with the gently sloping 70
southern Spanish side, where ridges elevation progressively 71
declines down to the Ebro basin (≈ 100 km). 72

The general structure of the Pyrenees displays a fanlike, 73
flowerlike arrangement: large thrust nappes lean towards the 74
north on the northern side, while they lean towards the 75
south on the southern side. They are flanked on both sides by 76
two foreland basins, the Aquitanian and the Ebro basins 77

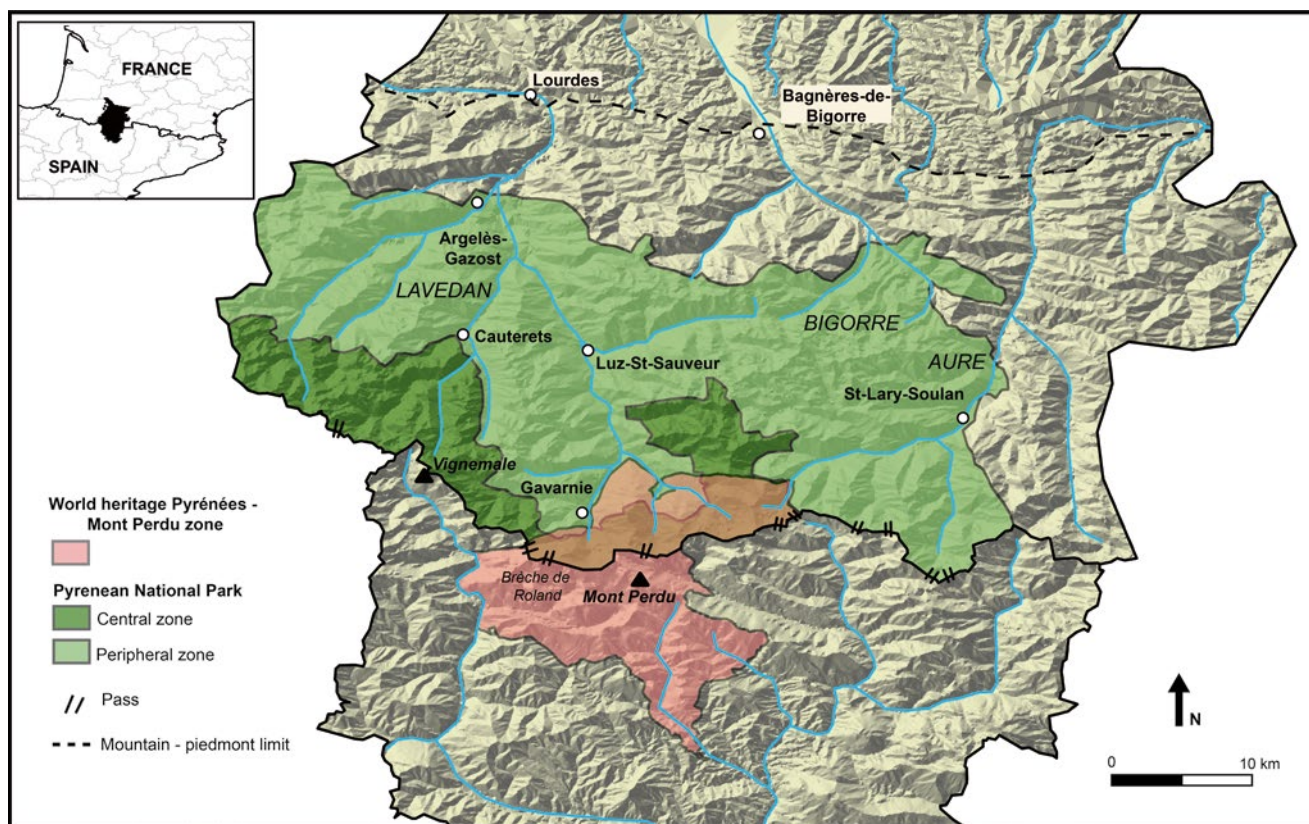


Fig. 12.2 Map of the UNESCO World Heritage zone: on the Spanish side, it includes the totality of Parque Nacional de Ordesa y Monte Perdido, whereas the French side extends over the core zone and the peripheral zone of the Pyrenees National Park. Thick solid line marks the international boundary

78 (Fig. 12.5a). In fact, as revealed by extensive seismic reflection
 79 profiling, the European wedge is overlain by the upper
 80 Iberian wedge, whereas at the lower crustal levels, the tec-
 81 tonic wedge of the European crust has indented the Iberian
 [A2] plate (Choukroune and ECORS team 1989; Teixell 1998).
 83 This tectonic wedging at different crust levels is one major
 84 thickening mechanism, at the origin of orogeny and uplift of
 85 the Pyrenees.

86 The Gavarnie cirque area is sited in a central position, the
 87 axial zone, where a maximum shortening occurred and
 88 where this geologic architecture is the most distinct and
 89 nearly horizontally emplaced. It is mostly composed of the
 90 Gavarnie–Mont Perdu nappe complex, a series of thrust units
 91 piled up on the autochthonous Palaeozoic crystalline rocks
 92 (migmatitic gneisses): this is particularly well expressed
 93 along the eastern side of the cirque (Fig. 12.5b). In detail, the
 94 Gavarnie–Mont Perdu nappe is composed of highly tecton-
 95 ised Palaeozoic material, with its tightly folded, Cretaceous
 96 and Eocene sedimentary cover that overthrusts to the south
 97 and culminates with *Cylindre du Marboré* and *Mont Perdu*.
 98 The extent of the Gavarnie nappe is very large, at least more
 99 than 50 km from north to south, and represents fairly well the
 100 tectonic forces that produced the Pyrenean range. Most of

peripheral zone of the Pyrenees National Park. Thick solid line marks the international boundary

the uplift appears to have started in the Eocene period, but it
 continued during the Oligocene when most of the deforma-
 tion 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

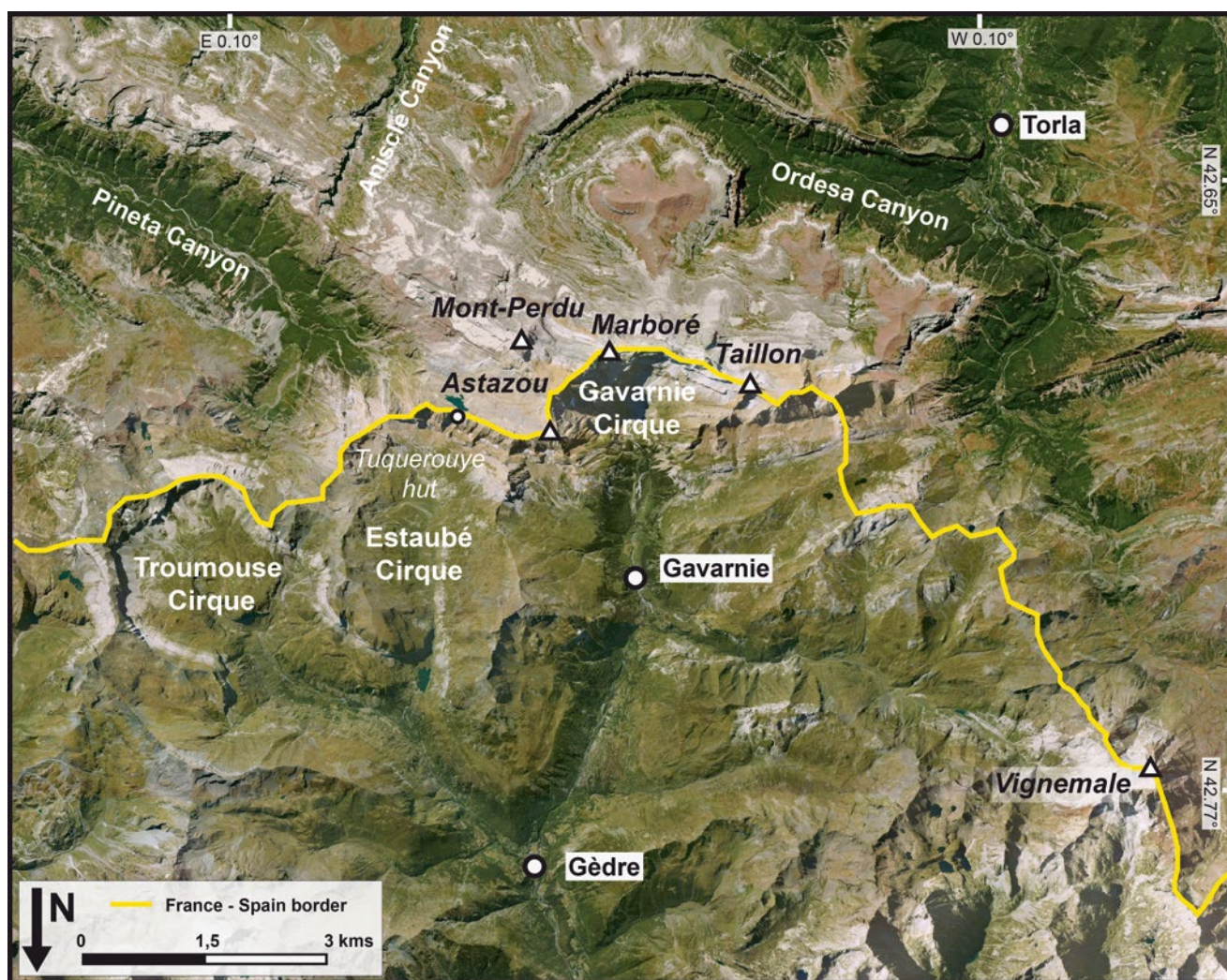


Fig. 12.3 The Gavarnie–Mont Perdu site includes spectacular cirque walls on the French side; two emblematic, still glaciated peaks (Mont Perdu and Vignemale); and three of the largest and deepest canyons

on the Spanish side (Google map in the background, North oriented towards *bottom*)

120 Pyrenean Zone (retro-side of the belt). This is where
 121 exhumation was centred at that time, before erosion migrated
 122 southwards by tectonic control, divide migration being
 123 achieved by captures of the southern drainage network by the
 124 northern rivers, in particular with the source of the Garonne
 125 River in Val d’Aran (Babault et al. 2011). In the adjacent
 126 Aure valley (Fig. 12.2), the Neste River was also quite active:
 127 the Lannemezan megafan is the topmost relief feature where
 128 more than 2,000 m thick sediments are piled up in the sub-
 129 siding foreland of the mountain, reflecting a significant inci-
 130 sion of the rivers, probably favoured by both the steepness of
 131 the French side of the Pyrenees and the dominant moisture
 132 supply from the northwest, then by glaciation. In both the
 133 Val d’Aran and Aure valleys, granitic, joint substrate was
 134 deeply incised. In contrast, in the Gave de Pau valley, the
 135 presence of the thick and massive calcareous Gavarnie–Mont
 136 Perdu nappe did not allow further significant retrogressive
 137 erosion in its upstream part due to karstic, underground drain-
 138 age 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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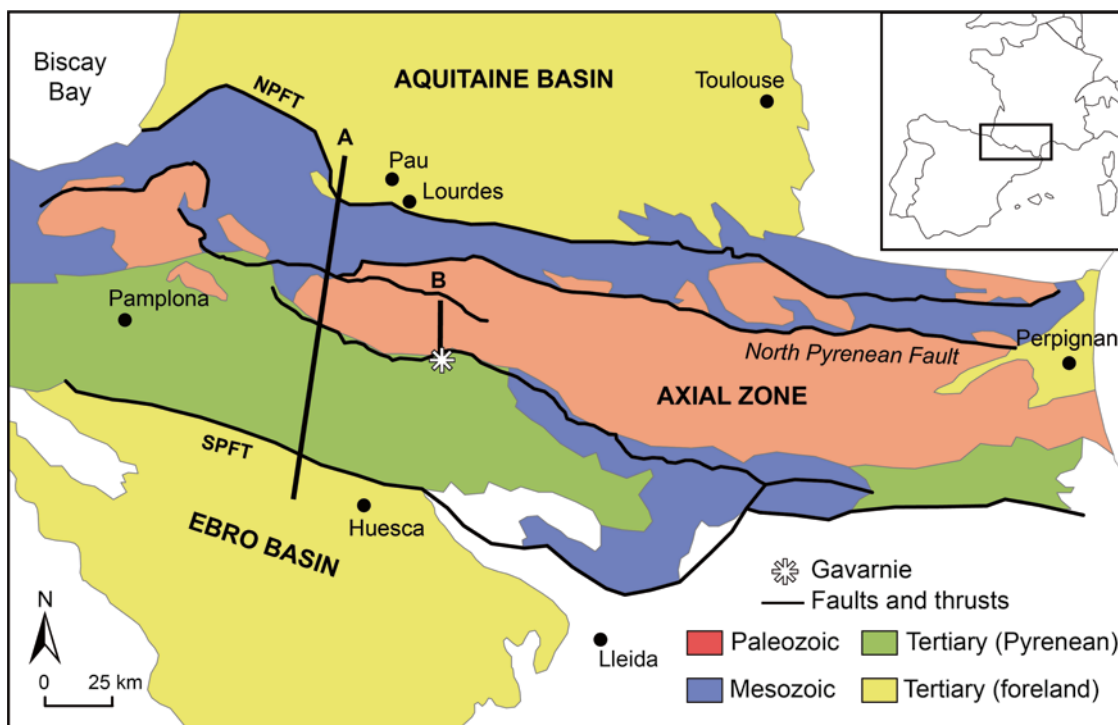
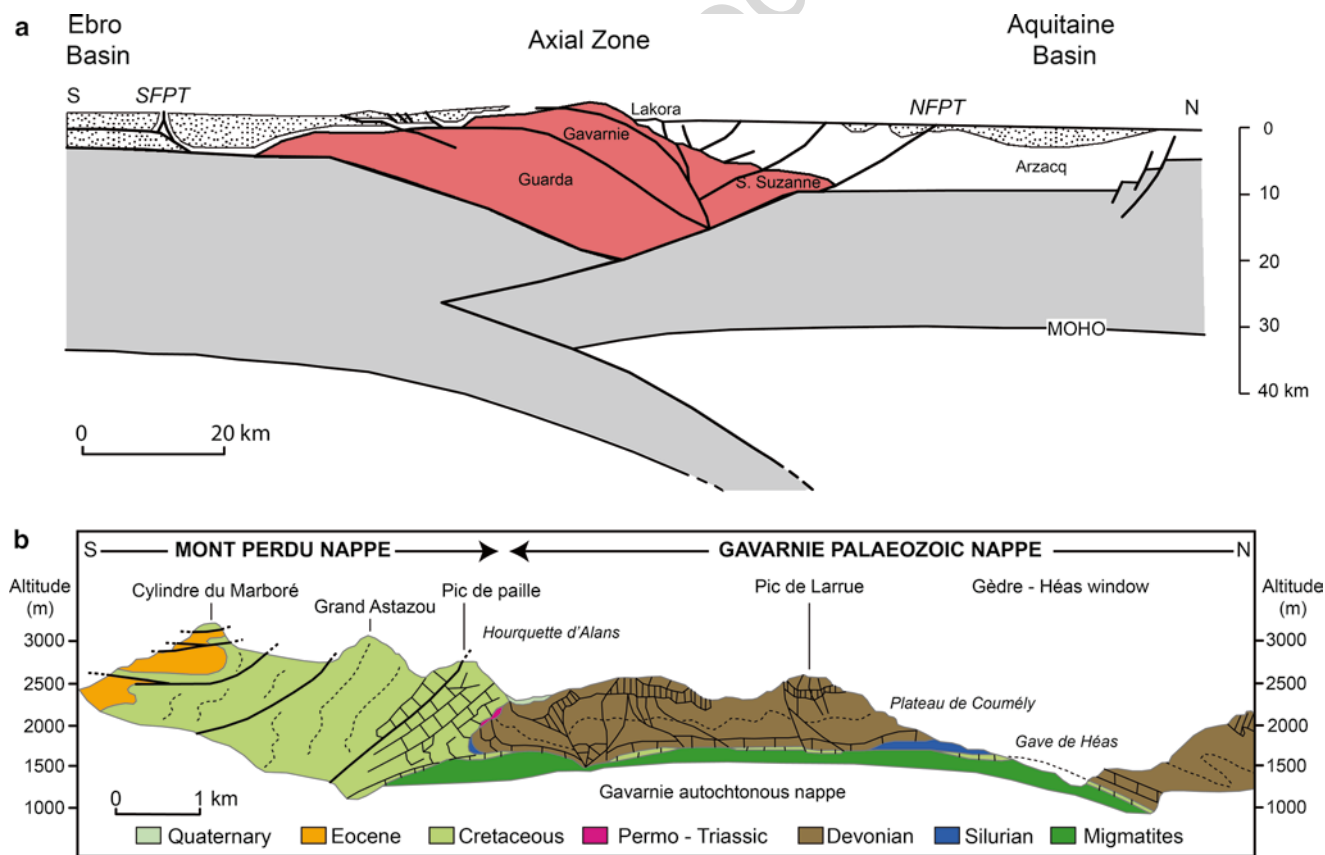


Fig. 12.4 Major geological entities of the Pyrenean range. A–A' and B–B' refer to the two cross sections of Fig. 12.5a, b



[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

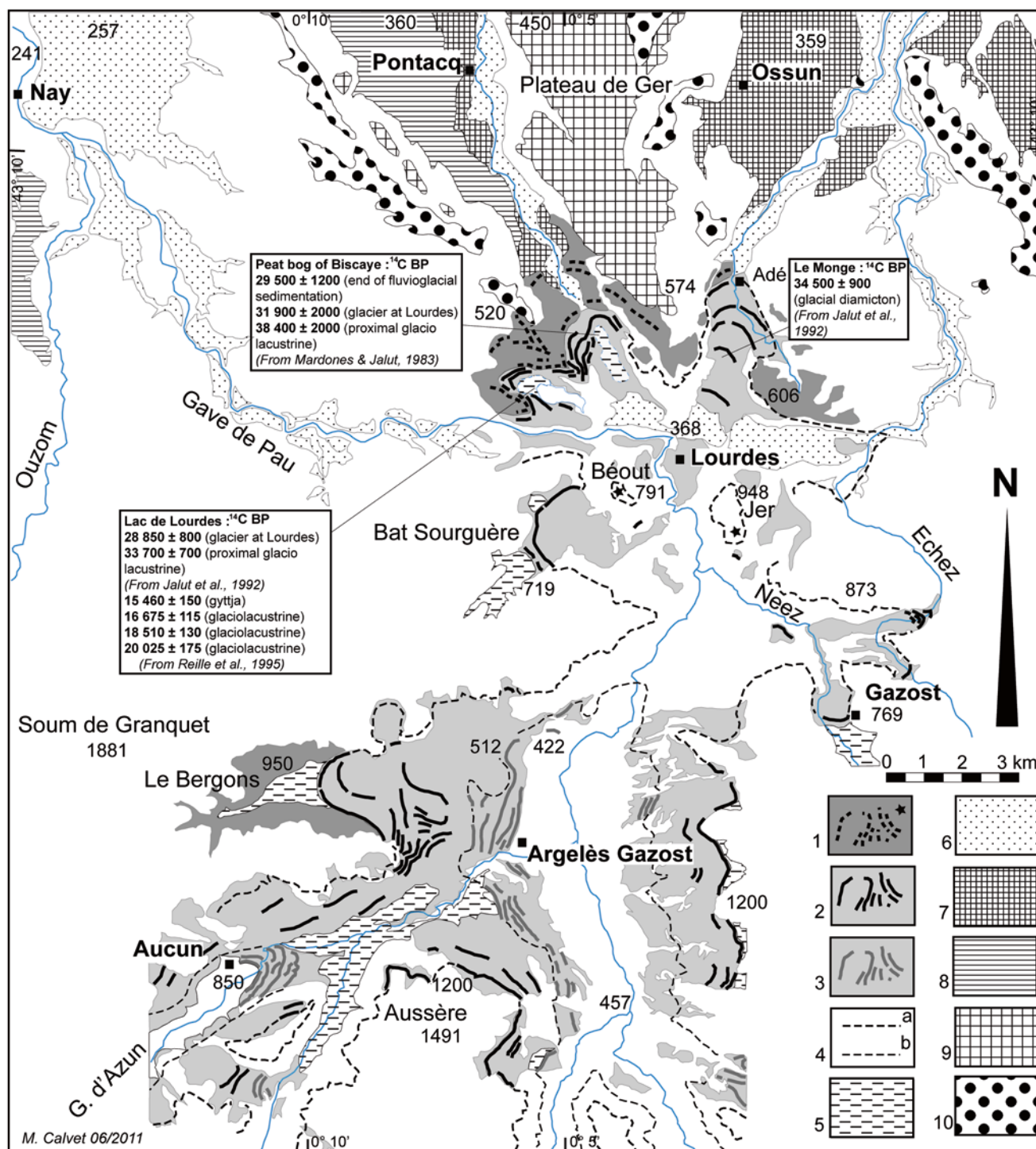


Fig. 12.6 Glacial extent in the Central Pyrenees, Gave de Pau lower valley around Lourdes (From M. Calvet, in Calvet et al. 2011b, with permission)

155 moraine-dammed lakes formed like the Lourdes Lake, while
 156 in the adjacent areas, glacial meltwaters deposited fluvio-glacial
 157 sediments along the radiating valleys of the Plateau du
 158 Ger, north of Lourdes. The piedmont was probably ice-free
 159 at about 31 ka BP, but this phase was followed by a subse-
 160 quent glacial readvance at 24 ka BP. This view was chal-

155 lenged by Reille and Andrieu (1995) who suggested that the
 156 ice cover lasted longer and vacated the piedmont zone
 157 between 16.67 and 14.46 ^{14}C ka BP only. It is most probable
 158 that glaciers advanced at different stages and reached similar
 159 positions repeatedly, as shown by clusters of very different
 160 ^{10}Be ages at about the same location (Rodés 2008). Then the
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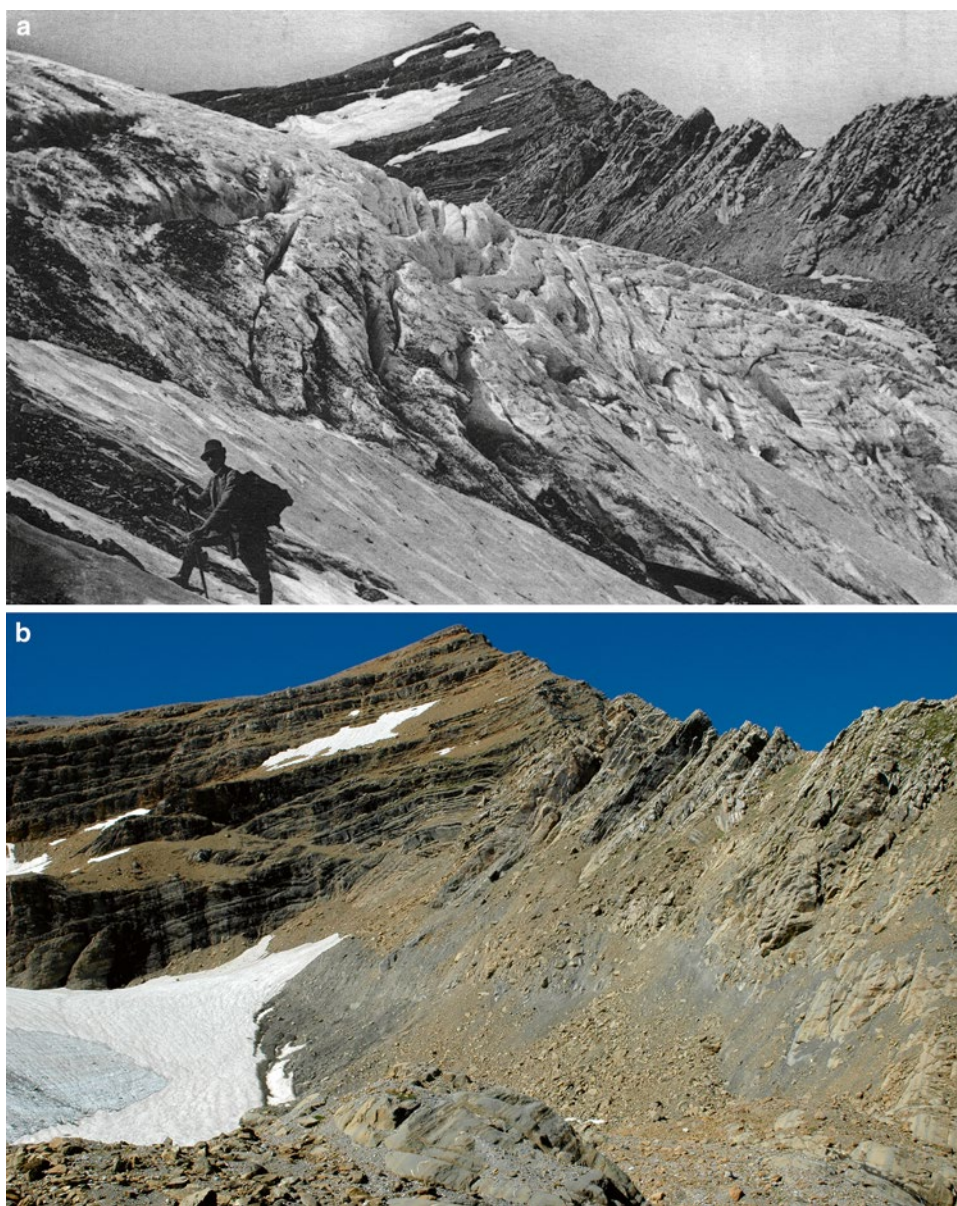


Fig. 12.7 Evolution of the Taillon Glacier (northern slope). (a) (~~left~~) ca. 1900, old postcard (Association Moraine, with permission). (b) (~~right~~) In 2010 (photo G. Nogué, Association Moraine, with permission). Note the readjustments (rockfall, scree, debris flow) of the rocky wall following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

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

173 More recent Neoglacial events like in the Cirque de
 174 Troumouse have been recorded (Gellatly et al. 1992),
 175 between $4,955 \pm 90$ and $4,654 \pm 60$ BP, followed by more
 176 recent, yet still undated, events. Little Ice Age moraines are
 177 more frequently preserved in most massifs of the Central
 178 Zone. The modern glaciers disappear very quickly as

179 observed in many places (René 2001). There are no more
 180 than 21 glaciers left in the Pyrenees, occupying a total area
 181 of 450 ha, whereas as recently as in 1870, the total glaci-
 182 ated surface amounted to 45 km². The gradual increase in
 183 temperature – a total of 0.9 °C from 1890 until now – implies
 184 that the Pyrenean glaciers will probably disappear by 2050
 185 or even earlier. In the Gavarnie area, glaciers are essentially
 186 restricted to N to NE facing cirques at altitudes above
 187 3,000 m a.s.l. (Mont Perdu or Taillon, 3,144 m; Fig. 12.7)
 188 or occur on high plateaus like in Ossoue–Vignemale.
 189 Nevertheless, glaciers are not what really have made the
 190 renown of Gavarnie site.

191 **12.4 "Nature's Colossus"**

192 The most striking part of the Cirque de Gavarnie is its
 193 1,500 m high amphitheatre shape, widening from 800 m at
 194 the bottom up to 3,000 m at the top, in a series of three giant
 195 vertical steps (Fig. 12.1). Generally interpreted as a result of
 196 glacial erosion, it is a much more complex form where lime-
 197 stone and underground waters have played an important role
 198 in the overall architecture of this unique scenery. Two out-
 199 standing features are the main attractions of the Gavarnie
 200 cirque: the Grande Cascade and the Brèche de Roland.

201 **12.4.1 Waterfalls**

202 One remarkable feature of the Cirque de Gavarnie is its water-
 203 falls in two or three drops, with an overall drop of 420 m,
 204 "taller than the Eiffel Tower" as locals say. The Grande
 205 Cascade, the lower one, is 281 m tall, and the breaking fall
 206 turns often into mist. As Victor Hugo has written (1855, post-
 207 humously published in 1891) in his poem "God": "*The twelve*
 208 *waterfalls that shadow hears complaining in this terrible and*
 209 *whirling cylinder; the mountain streams exhausted of foam*
 210 *and fighting, and flow, top torrent and smoke down*". The
 211 water at the origin of the waterfall is coming from the snow-
 212 melt and from a frozen pond located in Spain near the Mont
 213 Perdu, with the waters seeping and finding their way under-
 214 ground through the Cretaceous limestone strata before resurg-
 215 ing right on the cirque rim. The annual discharge of the
 216 waterfall varies between 3 and 200 m³/s when snowmelt is at
 217 its maximum. Indeed, the waterfall accentuates the vertical
 218 dimension of the relief, all the more as the adjacent limestone
 219 strata are also overturned and nearly vertical along the "*Arête*
 220 *Passet*" (Fig. 12.8). The waterfall is the source of the *Gave de*
 221 *Pau* stream, which collects other *gaves* (torrential streams)
 222 originated from the Barèges and Caunterêts valleys, hence
 223 being transformed in a fast-flowing stream in Lourdes that
 224 can be subject to severe flooding like in autumn 2012.

225 **12.4.2 Brèche de Roland**

226 The *Brèche de Roland* (2,807 m) is a natural gap, open in the
 227 upper layer of the cirque. The eye is attracted by its very
 228 spectacular geometry, 40 m across bordered by very slender
 229 walls over 100 m tall, cut into the Eocene limestone
 230 (Fig. 12.9). According to the legend, Roland, Charlemagne's
 231 nephew, threw his sword when he was mortally wounded in
 232 a battle against the Moors; the sword hit the cliff and opened
 233 the breach just at the border between France and Spain. In
 234 fact, this giant doorway is the result of a collapse of the rocky
 235 wall that was favoured by postglacial debutting. The pass

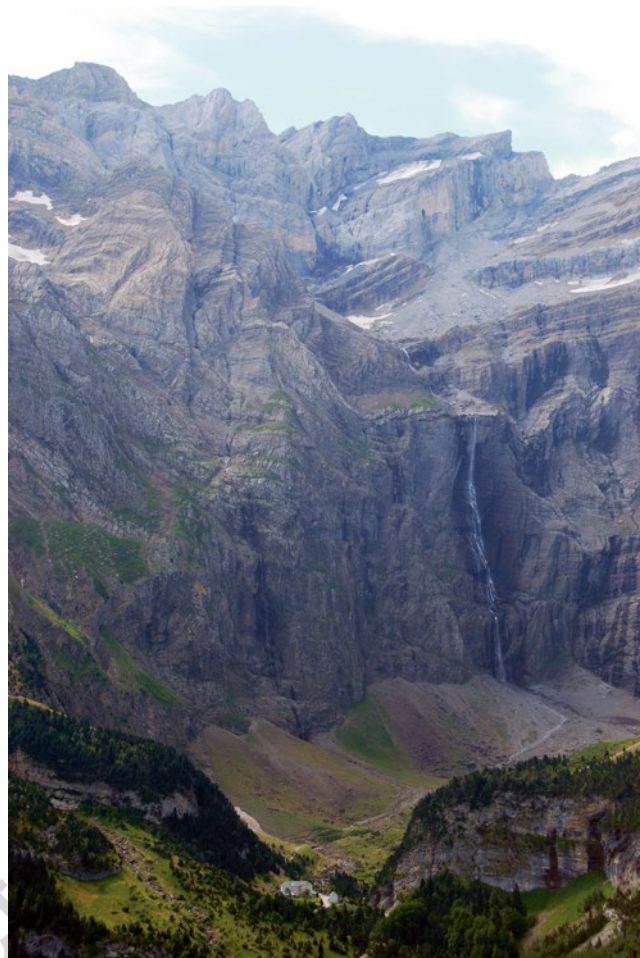


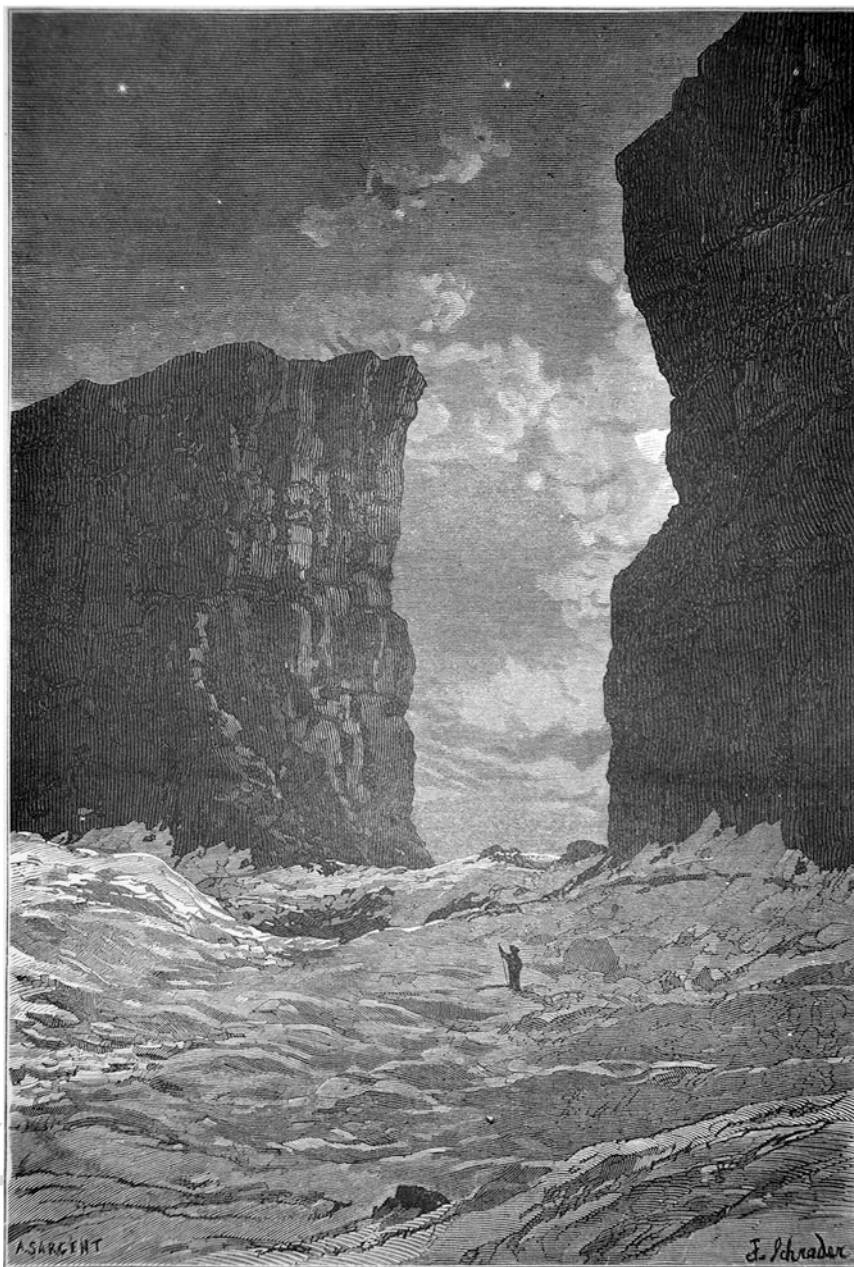
Fig. 12.8 Great Waterfall of Gavarnie. The water comes out of karstic network developed at the foot of the Grand Pic du Marboré (3,248 m). *Left* of the waterfall: note the folded, nearly vertical strata (Cretaceous limestones) of Arête Passet, a famous climbing road. Foreground: glacial rock-bar shaped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

is a classic way on its southern side to climb either Mont 236
 Perdu or the Taillon (3,144 m), which offers a vertiginous 237
 overlook down to the cirque bottom. It also marks the sharp 238
 contrast existing between the northern, moist Atlantic side of 239
 the mountain and the south, dry, and stony sloping plateaus 240
 of the Aragon, Mediterranean side, with their very deep can- 241
 yons, that reveal natural geological cross sections cut into the 242
 multicoloured, Tertiary sedimentary strata. 243

12.5 Natural and Cultural Heritages

If the outstanding beauty of these landscapes has been cele- 245
 brated for many centuries, the early occupation (40,000– 246
 10,000 BC) of these mountains is in fact testified by 247
 megalithic remnants, such as the Gavarnie stone circles 248
 (Fig. 12.1) and the Tella dolmen, or caves such as Anisclo or 249

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



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

250 Escuain in Aragon, shaped by karstic waters (Fig. 12.2). The
 251 elevations of the crest lines were never a barrier, and high
 252 passes (called "*ports*") linking Bigorre (France) to Aragon
 253 (Spain) bear evidence of their frequentation by shepherds
 254 and extensive livestock commuting from one side to the
 255 other for grazing and sheep breeding (Galop et al. 2007). The
 256 Port de Boucharo (Puerto de Bujaruelo) west of Gavarnie
 257 was traditionally crossed by shepherds on their transhu-
 258 mance way from the grand canyon of Ordesa to the Gavarnie
 259 meadows, with halts known as "*hospices*" such as the *espi-*
 260 *taul/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 hospitaies is visible in the background (Early twentieth-century postcard, Public domain)

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

278 Actually, tourism started in the second half of nineteenth
 279 century, with mineral, sulphurous, often hot springs, mostly
 280 situated at the contact of the granitic basement and sedi-
 281 mentary rocks. Their exploitation as hydrothermal baths in
 282 Cauterêts, Barèges, Luz-St-Sauveur was largely popular-
 283 ised by Imperatrice Eugenie (1826–1920). Fairly differ-
 284 ently, religious tourism is also a local specialty. The 18
 285 apparitions of the Virgin Mary to Bernadette Soubirous
 286 young shepherdess, in 1858, changed the fate of the small
 287 town of Lourdes, which has developed into a major place of
 288 Roman Catholic pilgrimages. With good connection by rail
 289 and air, there are today millions of tourists who come each
 290 year to Lourdes. This attendance is beneficial to its hinter-
 291 land 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 geo-
 morphological features or to observe rare, protected spe-
 cies 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 disap-
 peared 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)

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

319 The attractiveness of the Gavarnie cirque also gave rise to
 320 summer entertainments such as the theatre festival which
 321 takes place at the entrance of the cirque for the last 27 years
 322 and attracts 20,000 people over 2 weeks. Since the inscrip-
 323 tion of the area as a World Heritage property in 1997, the
 324 committee of UNESCO has requested relocation of the the-
 325 atre festival, incompatible with the outstanding universal
 326 value of the site. Despite efforts to minimise the impacts by
 327 festival organisers, their resistance to move the festival else-
 328 where creates a risk for the decommissioning of Gavarnie
 329 site as a part of the Mont Perdu World Heritage. In the adja-
 330 cent valley, Gèdre villagers have accepted to restrict road
 331 access to Troumouse cirque in order to help the recovery of
 332 natural landscape and wilderness.

333 12.6 Conclusion

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

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Author Queries

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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.	

Uncorrected Proof