Glacial Imprint on the Main Ridge of the Vosges Mountains

16

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Abstract

In this paper we provide an example of a widely studied landscape where conflicting observations in geomorphology lead to opposite interpretations. The central Vosges Mountains consist of a multi-tilted fault block, covered by an ice cap during each Quaternary cold period. After the Last Glacial Maximum, deglaciation began on the main ridge, leaving periglacial formations on low-relief highland or "old surface" and young valley glaciers or cirque glaciers with their associated moraines. The bald summital part of the Vosges Massif, which is known as the Hautes Chaumes, is of disputed origin. Whereas the occurrence of typically alpine soils supports a primary origin of heathland and meadows at some places, recent archeobotanical studies indicate that most of these vegetal communities result from deforestation since the Bronze Age period. The protection of this natural heritage is organized at two levels, a nature park (*Parc Naturel des Ballons des Vosges*) in an integrated rural and natural landscape, which is visited each year by five million persons, and four nature reserves, which guarantee the overall preservation of the landscapes and associated threatened fauna and flora. On the western gentle slope of the Vosges Mountains, a geomorphic feature corresponding to the maximum extension of the Würmian glaciers (the Noirgueux end moraine) benefits from a specific protection.

16.1 Introduction

As an intraplate aborted ocean, the Rhine graben is limited on the west side by the Vosges Mountains and on the east side by the Black Forest. The Vosges Mountains are a midlatitude (48°N, 7°E) granitic Hercynian shield lifted up since the Mio-Pliocene time. As other rift margins, the Vosges are characterized by a very pronounced dissymmetry, a long "gentle" slope to the west and a steeper one on the east side. This organization has strongly influenced the development of the valley glaciers and river network (André 1991; Flageollet 2002). The axis of the range strikes NNE (N110°); the elevation ranges from 1,424 m in the south to the 700 m plateau in the north. Moreover, the main ridge is shaped into a smooth convex upland.

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During the Quaternary, this mountain range, situated in the 48–53°N corridors between the former Scandinavian and Alpine ice sheets, was completely covered by a local ice cap. It represents a common geomorphological situation in Central Hercynian Europe.

A specificity of this small mountain is the interest by academics since 170 years to this landscape including the upper flat area known as the *Ballons* or *Hautes Chaumes* and the collection of glacial cirques on the east and west sides (Fig. 16.1). During a century, the upper part of the Vosges has been described as – or derived from – an "old planation surface," the post-Hercynian or pre-Triassic peneplain. The aim of this chapter is to describe the main feature of this landscape, that is, the contrast between the so-called old smooth main ridge and the recent glacial cirques and moraines of valley glaciers on both sides of the massif. If the more recent cirques are hanged in the upper valleys, the majority of them are associated to deeply incised ones. This area has suitable characteristics for paleoweathering, paleosurface, and glacial studies.

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Fig. 16.1 Facing west, the smoothly undulated main ridge. Typical landscape of *Ballons* and *Hautes Chaumes* in the upper Fecht valley from *right* to *left*, the Kastelberg (1,350 m), the Rainkopf (1,305 m), and the Rothenbachkopf (1,318 m) in a porphyroïde granite. The Altenweiher cirque, the lake (930 m), is installed on a moraine and a *roche moutonnée* (Credit: Y. Kohler)

16.2 The Vosges Mountain Main Ridge: The *Ballons*

Along 80 km from the south culminating at the Grand Ballon at 1,424 m to the north at Tête des Faux reaching 1,219 m (Fig. 16.2), the topography of the crest is smoothly undulated (Fig. 16.1). The continuity of this ridge associated to the convexity or the *Ballon* shape of the summits is strongly opposed to the vertical glacial cirques walls.

16.2.1 The Ridge Around "Le Hohneck"

In the center of the ridge, the altitude is continuously high associated with a small variability; Le Hohneck (1,363 m) is the highest point of a 25 km crest, the other summits range within 144 m. The central ridge is a kind of Hercynian granitic horst lifted in altitude with its Mesozoic sedimentary cover. The erosion during the Cenozoic destroyed the Jurassic and Triassic deposits and exhumed the buried pre-Triassic topography. The latter has been eroded on the sides of the blocks, leaving the central *Ballon*-shaped part as a remnant of the paleotopography. This evolution gave rise to multi-paleosurface theories.

From north to south and orthogonal to the main ridge, faults and fractures individualized block units which evolved as *Ballons* separated by erosion gaps or incipient gaps. At a smaller scale, each *Ballon* has a slightly different shape, according to the effects of petrography, tectonics, and associated fracture patterns. Avoiding monotony each summit can be perceived differently, with more or less aesthetic pleasure, according to everyone's sensitivity (Fig. 16.3).

Recent work on the Ringelbach experimental catchment issued from a 150 m drilling core facies analysis shows a paleoweathering record on the upper part of the granite buried below the Triassic sandstones and below the post-Hercynian paleosurface. The weathering observed in this drilling core has a thickness of 100 m (Baltassat et al. 2005; Wyns 2012). This ante-Triassic weathering mantle produced specific horizons: arenaceous residuals on the upper part, planar fissures, and fractured granites. First observed in the Rhine graben (Carozza 2013), these resulting weathered levels have been used as proxies of the pre-Triassic topography to infer the location of paleotopography, as well as to highlight the influence of tectonics on the tilted blocks.

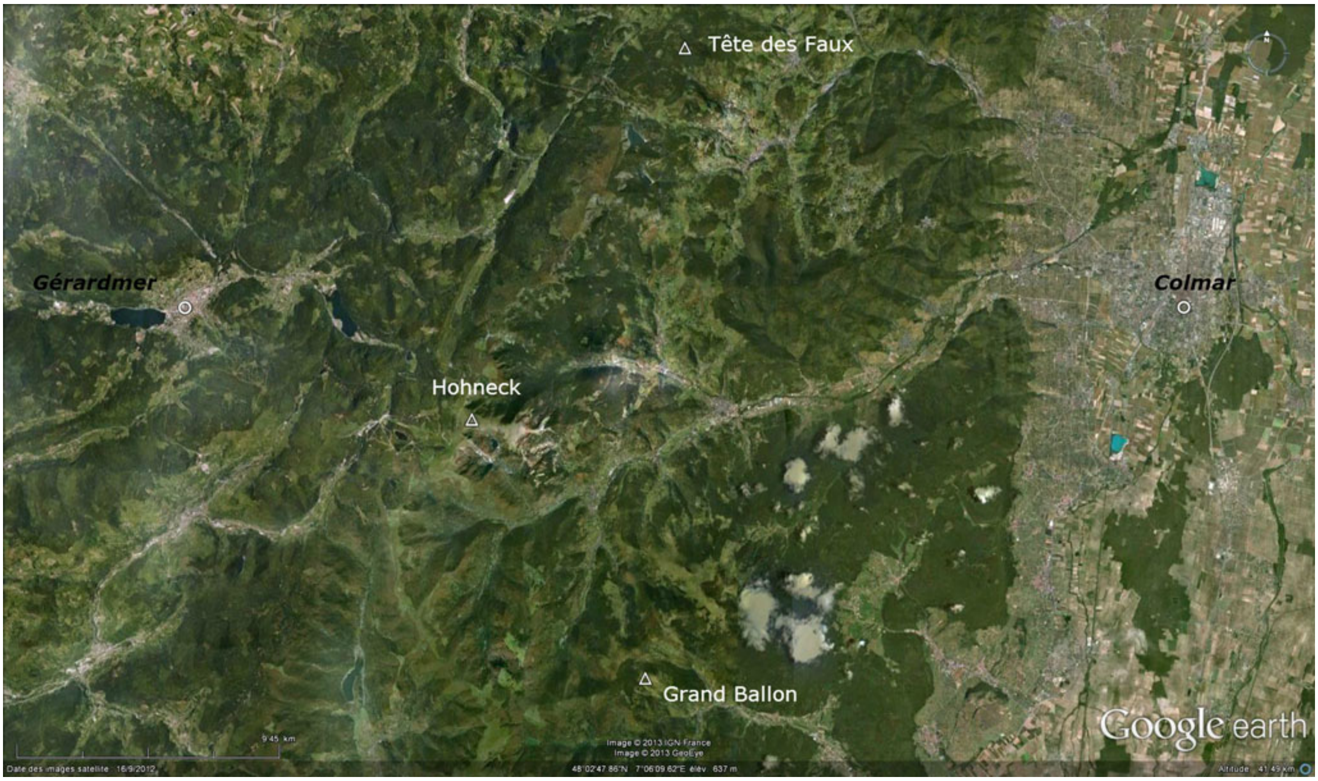

Fig. 16.2 The Vosges main ridge: Grand Ballon, Hohneck, and Tête des Faux, between two cities, Colmar and Gérardmer. Image Google Earth

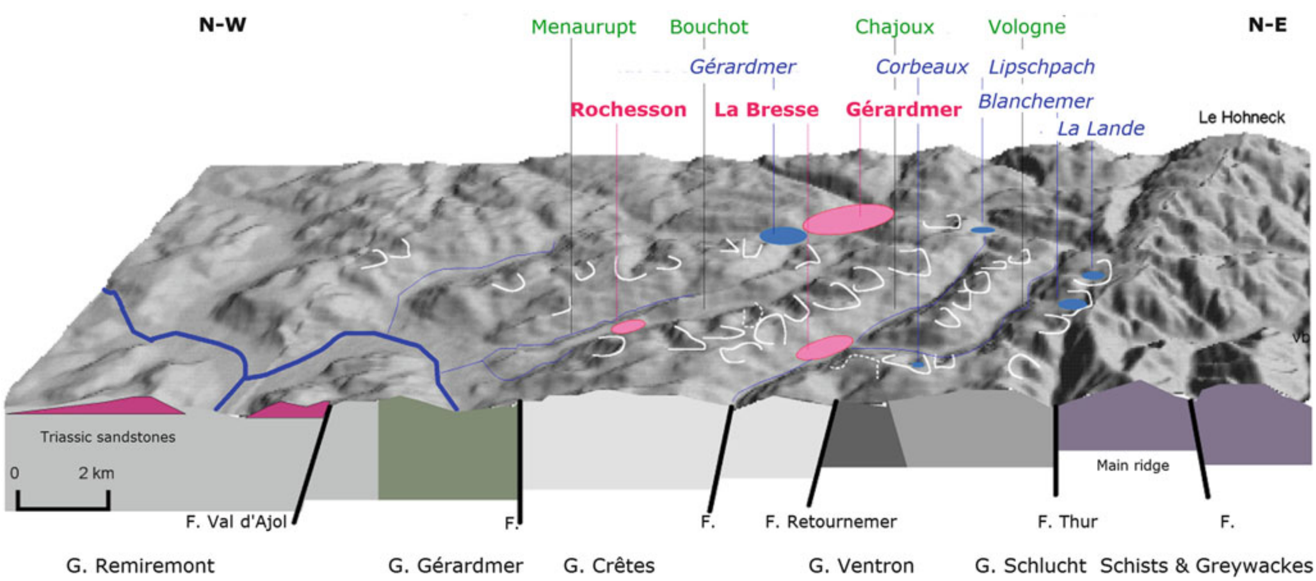

Fig. 16.3 South of main ridge and western side (Lorraine) in the Hohneck area (*F* fault, *G* granite, *Bold pink* cities, *Blue italic* lakes, Green: valleys). The blocks are steps from Paris Basin to the horst. The glacial cirques are facing west; on the horst they are carved on opposite sides. The Grande Pile peat bog (Woillard 1978) is on the far southwest of this area (Adapted from Flageollet 2008)

The Vosges' topography has a strong influence on the local climate, being the first main orographic barrier from the Atlantic; the annual precipitation increases slowly from the Paris Basin to the main ridge with a mean annual rainfall of 2,000–2,200 mm over half a year. The reverse occurs on the eastern lee side with fast decreasing precipitations toward the Rhine graben with a gradient of 150–200 mm/km due to the foehn effect resulting from the steep N–S topography and westerly winds. The main ridge is cold, windy, and foggy. The annual mean temperature is 5 °C at 1,200 m and exceeds

Fig. 16.4 Snow patches and vegetation of the main ridge. Facing south, in the center, the Hohneck (1,363 m), the bald effect is illustrated by the density of the vegetation: (*A*) *Chaumes* heather, blueberry, and broom, (*B*) stunted beech, (*C*) upland beech, and (*D*) beech-fir mixed forest (Credit: Y. Kohler)

10 °C during 4 months only; the frost occurs 160 days/year; these local edaphic conditions limit the vegetation; the wind was noticed by the first botanists (Mappi 1742) and later (Jenik 1958; Carbiener 1963) proposed the concept of anemo-orography to describe the canalized winds and interpret the spatial distribution of the vegetation of the *Hautes Chaumes* on the main ridge.

But the same processes have similarly shaped the asymmetry of the landscape; the wind blowing from the west accumulated snow in leeward positions with resulting firn and glacier masses progressively transforming the east-side depression into cirques.

16.2.2 The Main Ridge: A Bald Mountain of Disputed Origin

Hautes Chaumes is the local name for the summit, encompassing the local ecology, including petrography, geomorphology, and the vegetation, as well as postglacial and human impact on these mountains. On gentle slopes, the vegetation of the *Chaumes* mainly consists of a mosaic of heathland with low shrubs (heather, blueberry, and broom), grasses (matt grass, fescue, and other Poaceae), and moorland (peat mosses and Cyperaceae).

The bald effect is emphasized by the contact between the *Chaumes* vegetation and upland beech forest (beech and pioneer species, like maple, willow, mountain ash), where trees become stunted, loaded with epiphytic lichens and mosses (elfin woodland or *Krummholz*). In some sites, peat bogs tend to be colonized by Norway spruce.

The vegetation is a consequence of geomorphology, soil, climate, and man. During many years, the convex *Ballons* of the main ridge were described as upper and lower *Chaumes* according to altitude or primary vs. secondary *Chaumes* according to natural vs. anthropic origin. Did the forest ever colonize this upper part of the Vosges Massif, or are these bare landscapes of the *Hautes Chaumes* of primary origin? The occurrence of cryptopodzolic rankers, evolving typically under alpine meadows, which are found in some parts of the *Chaumes,* support their primary origin (Fig. 16.4; Guillet 1972).

For a long time, the *Chaumes* of the upper area (Gazon de Faing, Gazon Martin) were considered as primary and the *Chaumes* below 1,250 m (Haut Fourneau, Tanet, Wurzelstein) as secondary (Carbiener 1963). Recent historical, biogeographical, and anthracological works have provided new insights in this question (Goepp 2007). Some arguments show that deforestation begun during the Bronze Age and that heathland is resulting from anthropic activity. Following this author, all summits of the area would have been grazed during several centuries before this activity disappeared in recent decades. This explains why, from Col de la Schlucht to Tanet, the summits harbor forest with pioneering species like Norway spruce, mountain ash, and maple, from the edge of the beech high forest (Wlodarczyk 1992). These recent woodlands have replaced previous heathland and meadows, which have almost disappeared from La Schlucht to Missheimle. At Haut Fourneau and Tanet, Norway spruce and mountain ash are firmly established over the *Chaumes*, preparing the new naturally forested area. All in all, some *Chaumes* may have retained their primary nature until now in very limited areas, but most of them are certainly anthropogenic to some extent.

16.3 The Glacial Cirques

Because climate is dependent on topography, we hypothesize that climatic processes acting on vegetation occurred also during the cold periods of Pleistocene. The present-day position of the permanent snow line is above the Hohneck (1,363 m) while the lowest snow line position was approximately at 900 m during the last glaciation. The main consequence of the snow accumulation is the incision and deposition in the valleys. The western valley glaciers were 30–40 km long; the maximum extension of the Würmian glaciers (the Noirgueux end moraine) benefits from a specific protection. On the eastern side, the end moraines are located at 5–10 km from the main ridge. On the east and west sides, 23 and 19 cirques are respectively located along the main ridge.

16.4 The Eastern Cirques

The smooth convex upper summits and bare mountains *Ballons* contrast strongly with the steepness of the limiting hillslopes and east-facing cirque headwall. Two examples to illustrate the incision of the valley originated from the main ridge. After only 4 km the Thur River at Wildenstein flows 670 m down the Schweiselwasen (main ridge). In the upper Fecht valley at Erbersch, the flat valley bottom is situated at 3 km from the Kastelberg (main ridge).

The principal evidences of the Pleistocene Vosges Mountain glaciation are cirques, steep-sided valleys, hanged valleys, overdeepened basins, glacier accumulations, and fluvioglacial sediments. The valleys are mainly controlled by morphostructural features (Flageollet 2008). The dissected valleys are characterized by abrupt slopes of 500–700 m. This glacial erosion is due to the *excess* of snow accumulation on the lee side and by ice movement. The lower parts of valleys were occupied by the ice and end moraines.

Many glaciologists have been intrigued by the size of the moraines in the Vosges: "Why these huge moraines for such a small mountain?" Some new observations have recently clarified the point. The question is not related to climate, latitude, or petrography but could be probably reduced to the origin of the accumulated glacial sediments. To accumulate, the morainic sediments had to be easily removed and transported. Two hundred million years after their production, the three-level weathering mantles have provided sands, pebbles, and boulders. In the valleys, the till deposits are known as water reservoir since the nineteenth century; the thickness of the glacial and fluvioglacial sediments can reach up to 40 m in the Fecht valley near Metzeral, 30 m at Stosswihr, 20 m at Munster, and 20–60 m at Turckheim.

The youngest glacial cirques associated with periglacial forms are located in altitude around the *Ballons*. Several valley closures below the ridge show features of a remodeling by nivation processes. In some of these nivation cirques, accumulation characters, altitude, and valley exposition suggest the occurrence of firn glaciers.

Among a series of beautiful cirques, such as those of lac Blanc (Fig. 16.5), lac des Truites (Fig. 16.7), Missheimle (Fig. 16.8), lac Vert, and lac Noir, some were occupied by peat bogs and some of them have been turned into artificial lakes. The lac Blanc cirque is more impressive by its size, the cirque headwall, and the moraine closing the lake. The lac Blanc and lac Noir are easily reached by car and were recognized in the 1870s by Charles Grad as suitable for hydroelectricity, it will be done 60 years later. Since the 1930s, *lac Blanc* is flowing into *lac Noir* situated 1 km and 120 m below during the day, producing electricity, and during the night water is refueled into the upper lake.

16.5 The Western Cirques

With its valleys, vales, and cirques, the western slope is the counterpart of the eastern side. Due to the rifting, on this side, the topography is less carved, the glacial valleys are less incised, and the slopes are smoother. This results in the past and nowadays a greater accessibility to the main ridge. The mean altitude of the western slope is greater than the eastern one; the extension of the ice cap was also greater, reaching 30–40 km, and the deglaciation left a great variety of moraines, peat bogs including the "Grande pile" (Woillard 1978), rock bars, and contributed

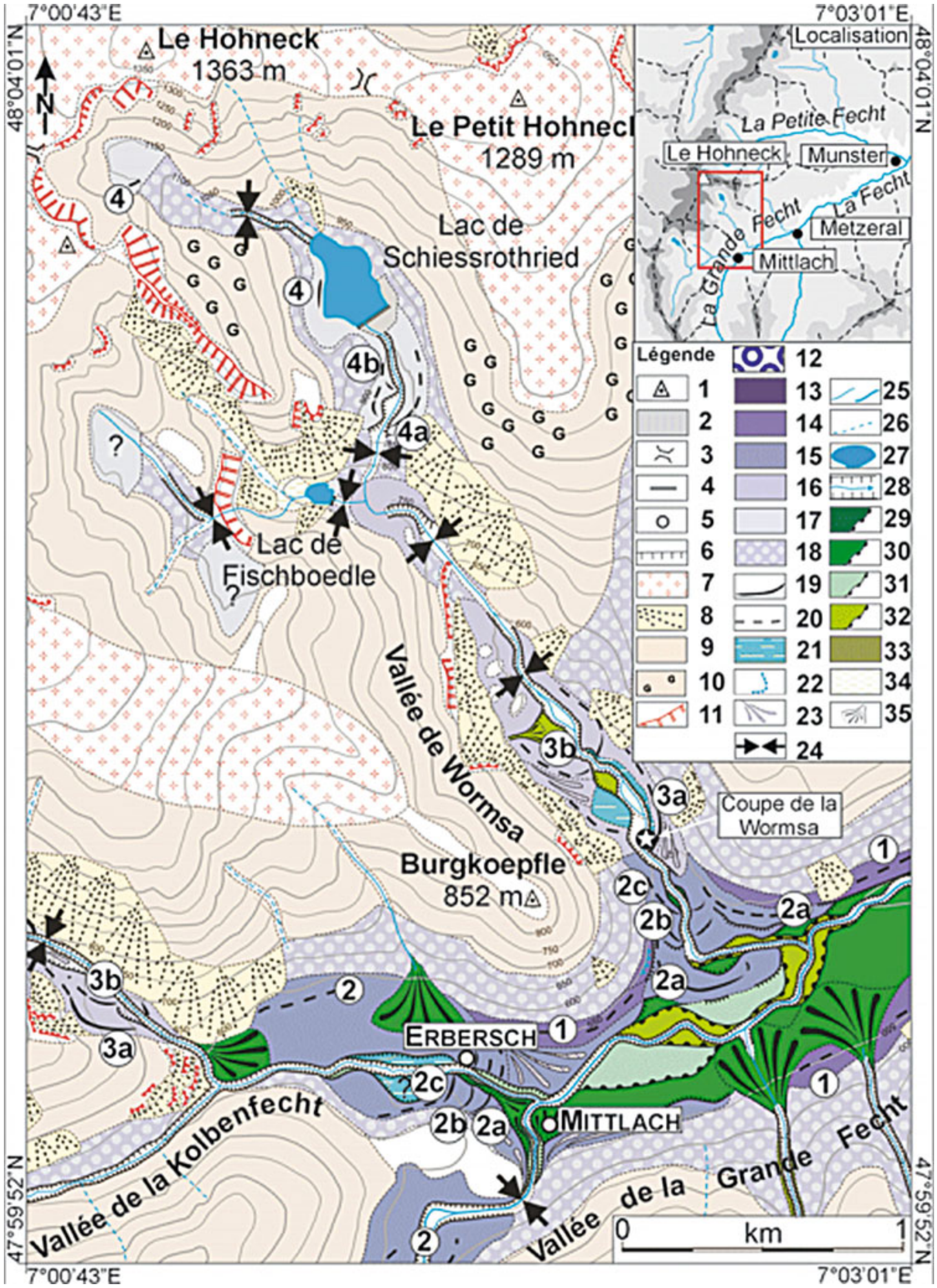

Fig. 16.5 Map of the Wormsa valley field (Vosges, France). *1* Summit, *2* backfill, *3* pass, *4* dam, *5* locality, *6* bank, *7* Grus, *8* bouldery talus, *9* undetermined or polygenic periglacial deposits, *10* gelifluxion, *11* steep slope, *12* till (Riss), *13* till (middle Würm), *14* stage 1 till, *15* stage 2 till, *16* stage 3 till, *17* stage 4 till, *18* reworked till, *19* morainic ridge, *20* discontinuous morainic ridge, *21* fluvioglacial and glaciolacustrine deposits indicating ice retreat, *22* ice contact valley-side terrace or kame delta, *23* proglacial fan, *24* rock bar, *25* river, *26* ephemeral stream, *27* lake, pond, *28* present-day riverbed, *29* fluvioglacial terrace T1a, *30* fluvioglacial terrace T1b, *31* fluvioglacial terrace T1c, *32* post-glacial terrace, *33* torrential deposits, *34* peat bog, and *35* alluvial or torrential fan (Adapted from Andréoli et al. 2006)

to the beauty and diversity of the landscape. In this area, human activity deeply transformed the natural environment by dams, artificial lakes, electric hydropower, ski resorts, snow gun towers, and ski lifts. Nowhere else in the massif is the impact of human activities on wildlife so visible (Fig. 16.6).

16.6 Deglaciation of the Cirques and Main Ridge

The local deglaciation, which is documented by tors, erratic blocks, moraine boulders, and *roches moutonnées,* is similar to other deglaciations in Central Europe (Bourlès et al. 2004).

Fig. 16.6 Western side (Lorraine), one of the more impressive ski runs at Artimont-Belle Hutte ski resort, on the land dependant of the municipality of La Bresse. Snow will have to cover these slopes to hide the heavy destruction of the natural environment aimed to serve the needs of private interests. It clearly shows how difficult it can be to share a common space (Credit: J-L Mercier)

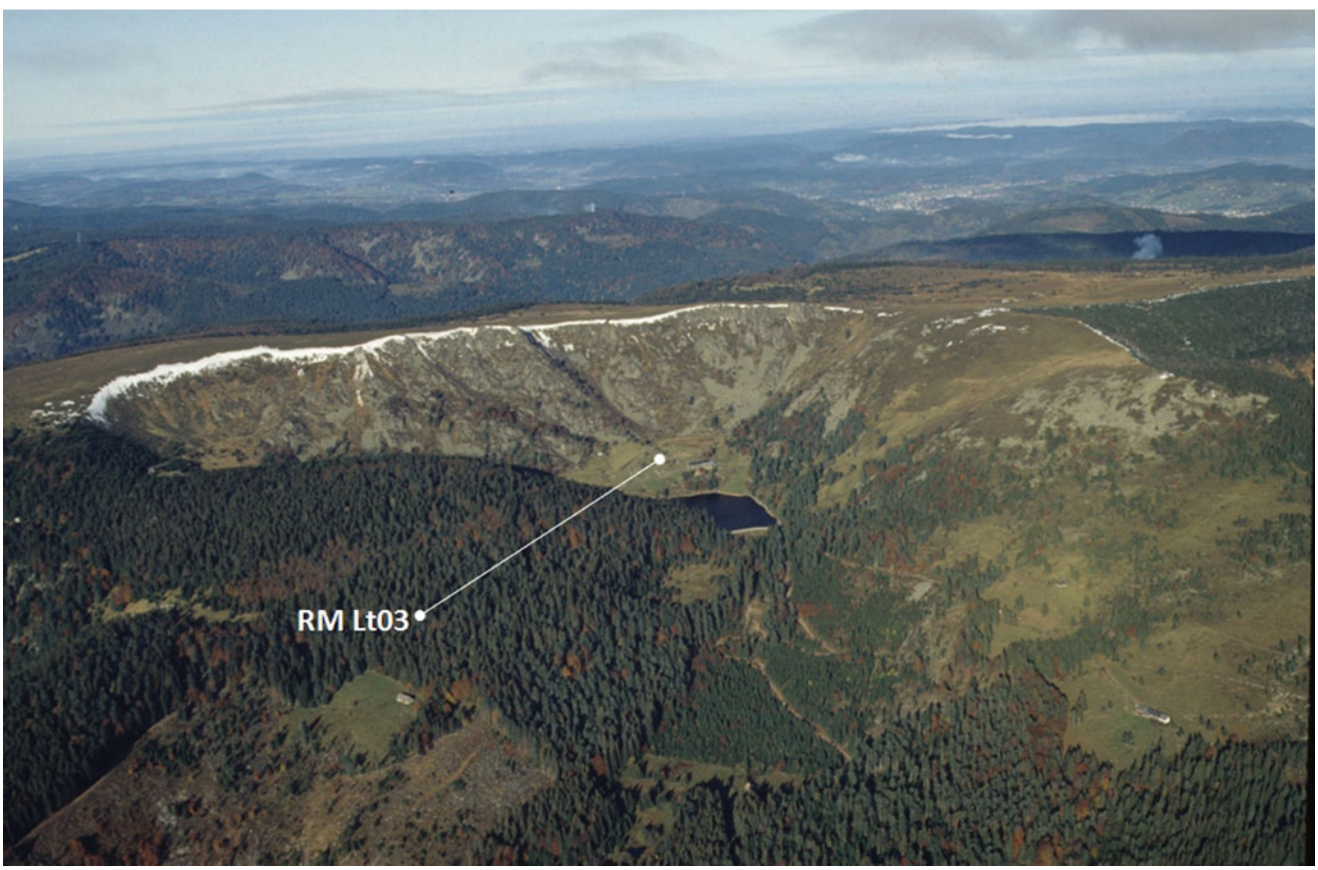

Fig. 16.7 The "lac des Truites" and cirque, on a *roche moutonnée* (48°06′12 N, 7°04′25 E, 1,110 m): sample RM Lt03 gives an exposure age of (9.5 ± 1.7 ^{10}Be ka; Mercier et al. 1999; Mercier and Jeser 2004)

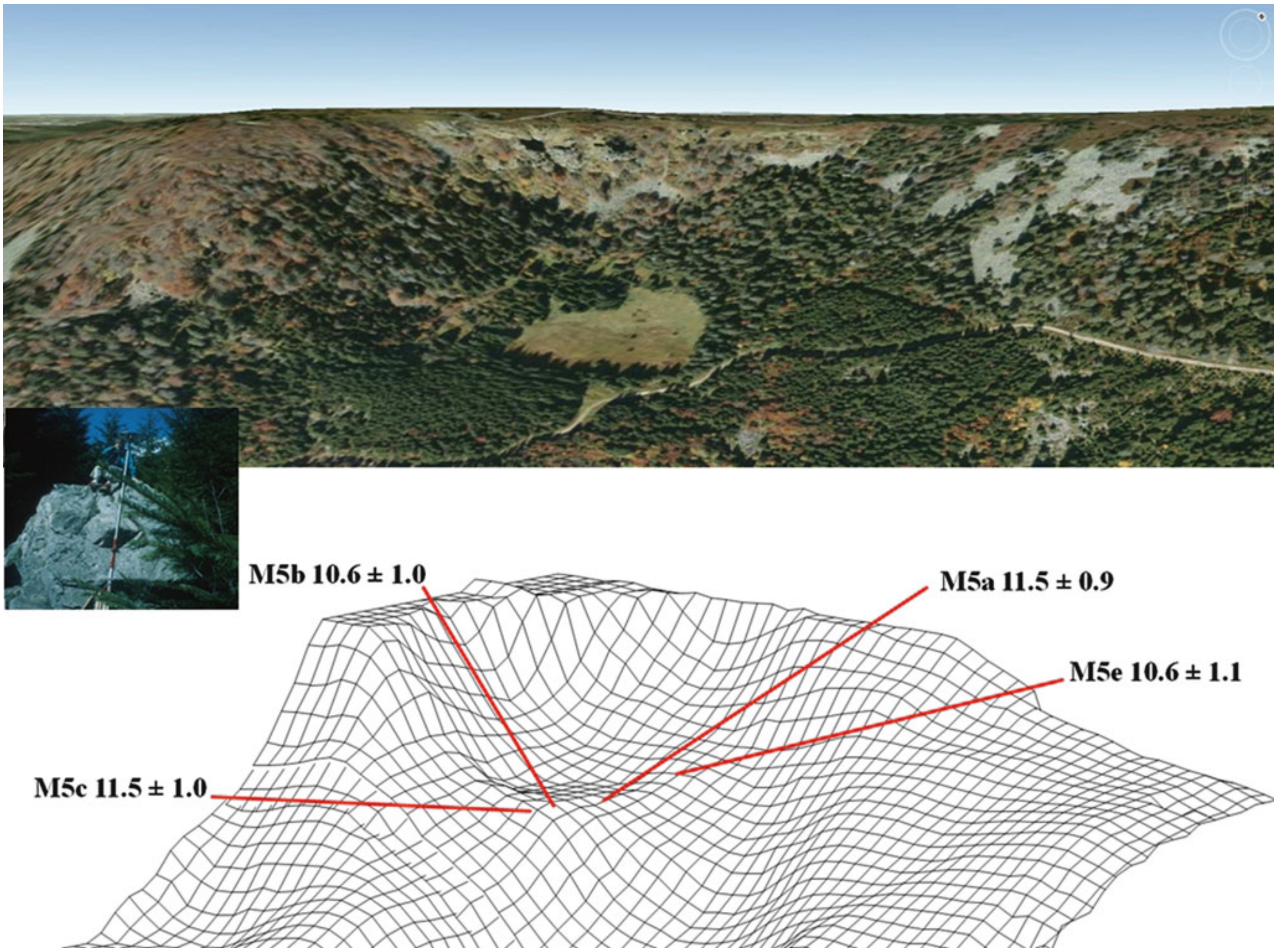

Fig. 16.8 Missheimle (48°04′31 N, 7°02′25 E), a cirque limited by two moraines. Four erratic boulders (1,102 m) (Insert: student for scale). Boulders are dated (^{10}Be ka) from the Younger Dryas (Mercier et al. 1999; Mercier and Jeser 2004; Image Google Earth)

After the Last Glacial Maximum, the deglaciation was not simply a smooth warming, because cold events also occurred. The ^{10}Be datings of moraine boulders provide exposure ages attributed to the Younger Dryas ((Fig. 16.8, Mercier et al. 1999). During the Early Holocene, decaying glaciers occurred in the Vosges Mountains, especially in the upper cirques and within shallow depressions of the main ridge above 1,100 m. A peat bog has developed in the La Lande valley (924 m) after closure by the *Belle Hutte* end moraine; the lower part of the peat has been dated with four ^{14}C dates ranging from 8,300 ± 50 to 6,600 ± 40 years in the Boreal (Walter-Simonnet et al. 2008) and an indirect older age for the *Belle Hutte* end moraine. Exposure age of deglaciated *roches moutonnées* (Fig. 16.8) was obtained at 9.5 ± 1.7 ^{10}Be ka (Mercier et al. 1999; Mercier and Jeser 2004), and a cold event was evidenced at 8.3 ± 1.1 ^{10}Be ka in the Wormsa valley (Fig. 16.5, cf. supra) (Figs. 16.7 and 16.8).

Permanent ice and firn fields possibly persisted in relief positions suitable for snowdrift accumulations until as recently as 5,000–6,000 years ago (Mercier and Jeser 2004). Other snow-ice patches were still present (Mappi 1742), i.e., during the Little Ice Age and near the Kastelberg in 1860 (Wahl and David 2007), and also persisted in 1978 for more than a year.

16.7 Conclusion

With a bit of irony, some authors explained that the number of scientific works and disputes is related to the quality of the landscape; if this assertion proves true, the beauty of the Vosges landscape is well ranked. It is vital to preserve these unique features: the *Hautes Chaumes*, the upland beech forests, the old maple forests on scree slopes, the endemic floristic association encountered on the upper part of the cirque headwall, and the peat bogs in the cirques. At higher altitude, the conservation of the *Hautes Chaumes* and the upper part of the main ridge is in peril because of climatic change. The invasive plants in the valleys and the lower parts of slopes threaten the autochthonous flora and modify the natural landscape. The winter snow leisure industry, an unsustainable development activity in a natural paradise, should be reconsidered in the realm of climate change and conservation of a natural heritage.

The legacies of the past did not have the same weight in geomorphology and in phytogeography. The climatic factor has been a major driver for the evolution of both the relief and the vegetation. The landscape encountered in the Vosges main ridge acted as a strong amplifier on the climate, the vegetation cover as well as land use by rural population. The burden of the past is extremely strong in geomorphology, as noticed with the main ridge, its shape and extension, its discussed and disputed origin, and its cirques and moraines. It is less pronounced on the more flexible vegetation cover able to adapt to climate variability and human activity. These natural processes are fully expressed where human footprint is limited as in the *Hautes Vosges*. The overall preservation of the natural heritage of the Vosges Massif is currently ensured by the existence of a Nature Park (*Parc Naturel des Ballons des Vosges*) and four Nature Reserves.

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