GLACIAL FORMS AND ICE DISTRIBUTION IN THE NORTHERN VOSGES DURING THE LAST ICE AGE[1]

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ABSTRACT

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During the last ice age, the Northern Vosges have been intensely glaciated. The climatic snow line was at an altitude of approximately 700 m. Nevertheless, the floors of some typical cirques do lay at even lower altitudes, as a result of important snow drift by SW winds. Comparison of snow drift mechanisms and of the loess distribution pattern in the Alsatian graben suggests frequent anticyclonic conditions during winter in Central Europe. This was probably in the form of a high pressure bridge linking the early autumn. High temperatures resulted in more abundant precipitation, mostly snow which played a major role in the glaciation, principally replenishing glaciers on leeslopes, facing NE, in the Buntsandstein plateau area.

Nevertheless, 'typical' glacial landforms are uncommon. They are restricted to cirques. This suggests that the so-called 'typical' glacial landforms are an extreme case, their occurrence depending on specific lithological characteristics.

INTRODUCTION

The Northern Vosges consist of the Champ du Feu Massive, a Hercynian association of granite intrusions and of older geosynclinal rocks which have undergone metamorphism, and its discordant cover of Permian and Lower Triassic sediments (Buntsandstein), most of which are detritic. The Lower Trias consists of sandstones and conglomerates, but their degree of consolidation varies extremely, ranging from unconsolidated clayey sands and pebbles to quartzitic sandstones and conglomerates. They are 500-800 m thick and form an extensive plateau that terminates in a cuesta above the Bruche valley. Permian sediments are generally unconsolidated clays and sands with interbedded volcanic rocks. There are unconformities between the Permian and the Hercynian Massive and between the Permian and the Lower Triassic. The Permian, which is softer, has been excavated at the foot of the Triassic sandstone cuesta. For orographic reasons, glacial landforms have been sculpted either in the Hercynian basement or in the Triassic sediments.

Typical glacial landforms were observed more than a hundred years ago in the Southern Vosges ('Hautes Vosges'), in the Hohneck Massive, but as recently as 1967 ZIENERT counted 8 cirques in the Triassic Plateaus, NW of the Bruche valley. More detailed field observations by DARMOIS-THEOBALD (1972) resulted in a more extensive inventory of glacial forms in the same area. In basement rocks, for instance, ZIENERT (1967) quoted only one cirque. Typical glacial landforms are rather scarce and they have not drawn the attention of earth scientists.

Professor J. Zonneveld directed many students in the study of Quaternary glaciations in the mountainous French areas, including the Southern Vosges and we are glad to dedicate this paper to him. It is based on detailed geomorphic mapping of the Saverne, Molsheim, Selestat, Cirey sur Vezouze, and St. Die sheets which form parta of the 1:50 000 geomorphological map of France.

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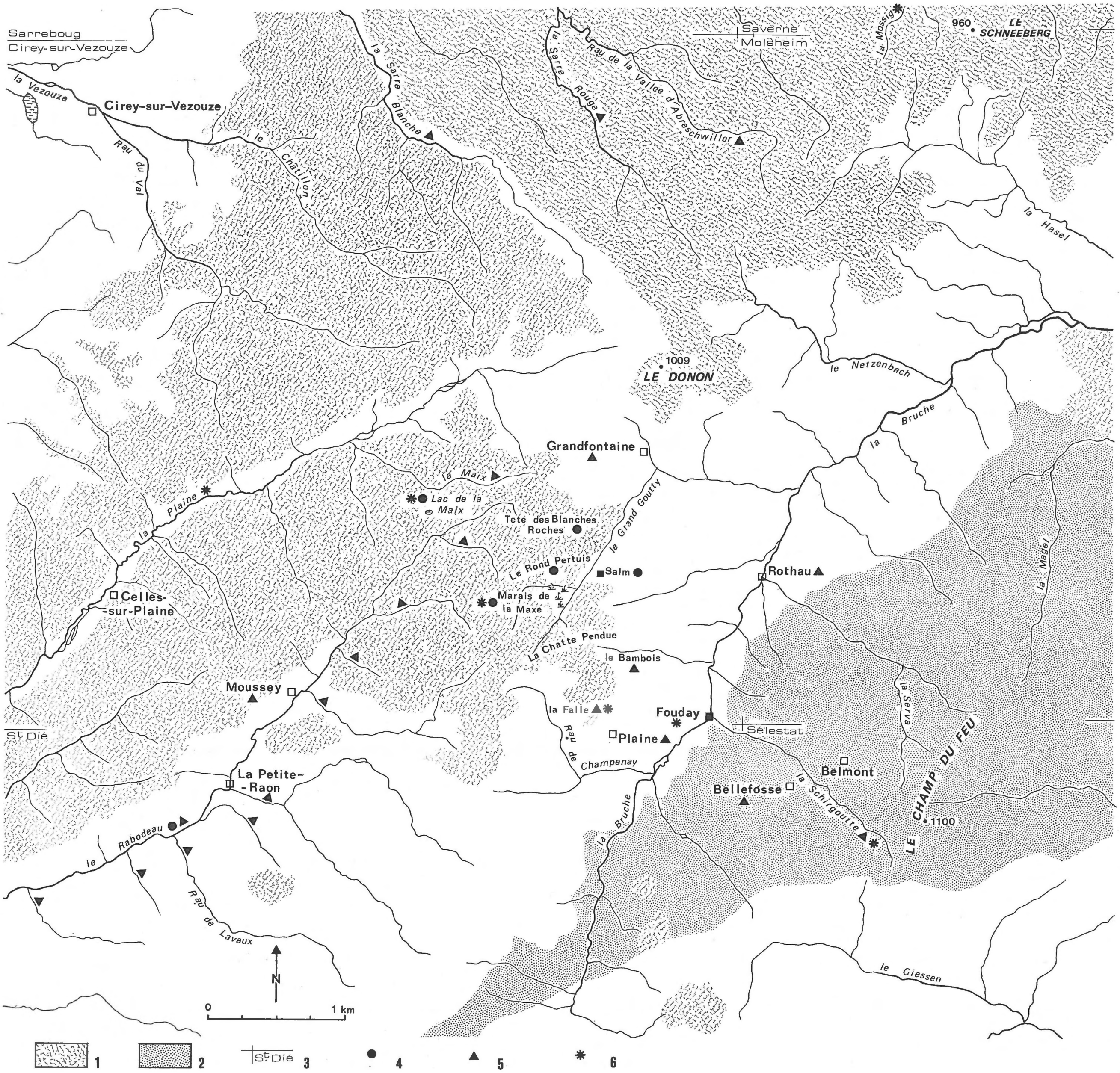

Fig. 1
Legend
1. Buntsandstein plateau and cuesta; 2. Champ du Feu Hercynian massive; 3. 1:50 000 sheet limit; 4. cirque; 5. glacial tongue; 6. moraine.

THE NATURE OF GLACIAL EVIDENCE: LANDFORMS AND DEPOSITS

The types of glacial landforms which are commonly described as typical in textbooks (cirques, troughs, moraine ramparts etc.) are far from being the most common ones in the field. They are extreme landforms. They are formed by efficient ice action in particular types of rocks, generally hard rocks with clear low density jointing, which are very suitable for quarrying. Typical moraine ramparts are mainly formed during phases of glacial readvance and are usually push-moraines. In the Hautes-Vosges, for instance, all the typical well-known cirques were excavated along a Hercynian lineament which can be clearly identified on Landsat imagery. Massive granite intrusions occur along this lineament which shows orthogonal jointing every few metres. Moraine ramparts are very few and are not usually typical. Trough valleys are even scarcer. The most spectacular one is the Thur valley, which was formed along a Hercynian tectonic accident, where granite is densely jointed and where remnants of metamorphozed acid volcanics of Devonian age persist. Because of their very high resistance to abrasion, the latter form bars. In the valleys around the Hohneck, the complete absence of moraine ramparts and of glacial troughs makes attempts to delimit the former extension of glacial tongues very difficult.

This problem is exacerbated in the Northern Vosges by the predominance of soft rocks in the sedimentary cover, by the marked heterogeneity of the basement, and by extensive and intensive ancient weathering in most of them. During cold periods of the Quaternary, morphogenetic actions essentially consisted of the sweeping out of weathered rocks, the sculpturing in the Hercynian basement of landforms which are not specific to any well-defined morphogenic system, but which, on the contrary, were polygenetic and untrustworthy as such in the identification of glacial processes. This situation is responsible for ZIENERT's (1967) drastic underestimation of Quaternary glaciation in the Vosges, where he simply focussed his attention on cirque landforms. ZIENERT (1967) did not notice any cirque in the Champ du Feu Massive and we are in complete agreement with him; there are none. Nevertheless, we did find other evidence of a former glaciation, possibly two. Paradoxically, it is in Triassic sediments that typical cirques can be identified. Some of them, such as the Lac de la Maix or the Marais de la Maxe (Cirey sur V.)[3], would make quite suitable textbook illustrations. They occur where deep valleys with steep slopes are cut in beds of sparsely jointed hard quartzites or of conglomerates. But, because of the great lithological heterogeneity that characterizes the area, such a coincidence is uncommon.

'Typical' glacial landforms cannot be used as a sound criterion for identifying the extension of former glaciation: such an exercise requires a careful combination of various types of arguments. Geomorphological mapping provides an excellent opportunity for bringing out and evaluating such evidence. Usually, gelifluxion does not result in the displacement of boulders over great distances. In the Hercynian basement, where a relative abundance of loamy and silty material enhances this process, we have seldom observed boulders of 1 m in gelifluxion slope deposits. Probably, intensive frost shattering destroyed them. They are commonly observed only in talus at the foot of fresh rock scarps, which occur frequently and which consist generally of metamorphic volcanics. Glacier ice, on the contrary, easily swept away the weathering products of granite and gneiss, cleaning out fresh or relatively fresh residual rock which could then be excavated. During ice transport, they have been protected against frost shattering and have suffered negligeable comminution along their way. An accurate knowledge of the distribution of the different rock types is necessary to identify boulders which have been transported over a certain distance, either on the slopes or in the valleys, and in evaluating this distance. In the Hercynian basement, attempts at evaluation are made easier by the greater variety of rock types. Acid volcanic rocks of the Devonian, for instance, remain quite easy to identify, even when they have been metamorphosed. Commonly, because of their exceptional resistance to weathering and their sparse jointing, they crop out as small hogbacks, which can be easily located. The boulders they engender are usually more than 1 m long. When they have been transported some kilometres along slopes and valleys, one can be sure that only glacial tongues have been able to move them. The glacial tongue of the Schirgoutte valley has been identified using this criterion. In the other cases, it is a different type of granite with limited outcrops that can be used for the same purpose.

[3] For location, we give the name of each corresponding sheet of the 1:50 000 map in brackets.

In the Lower Trias, identification of former glaciation is more difficult. In these sandstones, fine particles are usually too scarce to allow an important development of gelifluxion. Steep slopes have been shaped mainly by gravity and mantled by screes. Each resistant bed has been broken into angular boulders which have slid some metres downslope. All transitional stages between the bed in situ and the downslope blocks can be observed. The screes which mantle some high slopes consist of a succession of numerous local talus which have been generated 'step by step', their material having been transported short distances, of only a few metres. The differences in rock types from one bed to the other can be used to support this view.

In contrast with this type of slope, a tongue of boulders can be observed in a slope concavity consisting of boulders of different rock types that are mixed together and which can be assumed to have been deposited by a glacial tongue. The same applies when this boulder tongue is continuous along a slope where sandstone beds alternate with sand.

Terminal moraines are uncommon. Frequently, the extreme advance of glaciers in valleys is just characterized by a tongue-shaped accumulation which has been smoothened by melt waters either during the period of its deposition or later on, during glacial recession. The Schirgoutte valley, at Fouday, is a good example (Cirey sheet). The only well shaped moraines are associated with some typical cirques.

In most characteristic cirques, a moraine rampart closes the cirque floor on its distant edge (Lac de la Maix, Marais de la Maxe, Trou du Cuveau, etc.). The same can be observed in the Hautes Vosges, where glaciers had a much greater extension. These so-called 'Moraine Ramparts of the Cirques' have a chronological significance: they attest a lateglacial readvance. In the lower part of the peat accumulated on the floor of some cirques, pollen of Boreal age have been identified (BECKER & SITTLER, 1952; HATT, 1937). An altitude of 800-850 m of the snowline has been proposed by DARMOIS-THEOBALD ET AL. (1976) for this lateglacial stage.

A cirque has been excavated in the sandstone plateaus NW of Champ du Feu Massive in Trou du Cuveau. A rampart divides this cirque floor in two parts, but nearer to the back slope of the cirque, and has been identified as a protalus rampart by DARMOIS-THEOBALD (1972). It should be even more recent in age (Upper Dryas?). There are too few typical end moraines to use them as a sound criterion for reconstructing former glacial extensions, disregarding their important chronological value. Nevertheless, more pollen analytical studies are urgently needed.

DISTRIBUTION OF GLACIAL FEATURES

Evidence of glaciations older than the last Würm-Weichsel maximum is scanty and partly questionable. The lowermost moraines in the Schirgoutte valley, at Fouday, or some moraines along the left bank tributaries of the Plaine River are all that remain. As the snowline was very low during the last glacial maximum, most older moraines have been reworked and fossilized during this period which makes identification difficult. Examples of this have been observed in the upper Mossig valley, at the Western floor of the Schneeberg and in the St. Quirin, Abreschwiller and Sarre Blanche valleys (Saverne, Cirey).

Triassic Plateaus

Several small glaciers have grown along the front scarp of the Buntsandstein cuesta, in the SE part of the Cirey sheet, on the municipal territories of Plaine, Rothau, and Grandfontaine. They occupied very steep valley heads and most of them have been mapped on the geological map at the scale of 1:50 000. Only a few of them have sculpted a typical cirque, and have been described by ZIENERT (1967). This is the case of Marais de la Maxe, already quoted, the floor of which is at an altitude of only 635 m. On the SW of the cirque, a convex sandstone ridge has its highest point slightly above 860 m. On the lower slopes of Rond Pertuis, NW of Salm (Grandfontaine), looking NE, two other cirques can be seen with floors at 700 and 650 m. Just N of them, at the foot of the Tête des Blanches Roches, another cirque floor has been carved between 670 and 650 m, but it is not as typical as the former ones. A glacial tongue, coming from these different cirques, has reached an altitude of about 550 m in the valley. At Plaine, near the Southern edge of the same sheet (Cirey), a typical end moraine has been built at La Falle, under the Maison Forestière, by a glacier coming from the group of small valleys converging there, at an altitude of 430-440 m. This valley is open to the SE, but its SW divide consists of a sandstone plateau slightly above 840 m. All the valley slopes are mantled with moraines, whose extension is much greater than that shown on the geological map. On the northern side of the same valley, the eastern slope of the Chatte Pendue ridge has been covered by ice. It came as low as 490 m at Bambois.

Further to the NW, the Lac de la Maix cirque floor has an altitude of 675 m, on a steep N-looking slope. The highest point on the S edge of the plateau, in the SW of the cirque, reaches an elevation of 812 m. In the Vallée de la Maix, the ice that flows out of the cirque joined another glacier tongue coming from the E, and the divide culminates at an altitude of 899 m. Where the dipslope plateaus of the Buntsandstein cuesta reach an altitude above 750-800 m, glacier tongues have been formed in the valleys and have reached rather low elevations. This can be seen in the Rabodeau valley where moraines can be observed as low as 400 m, and in the valleys of the Sarre Blanche, the Sarre Rouge, and Abreschwiller.

We can draw the following conclusion for the last glacial maximum which probably occurred around 18 000 BP:

a) The snow line was at a low altitude, not higher than 650-700 m, as can be deduced from the altitude of the cirque floors. If we reconstruct it using the mean between the highest point of the divide and the lowest altitude of the moraine, we obtain similar values for small glacial tongues: about 600 m for the right slope of the Rabodeau Valley near Moussey, 650 m for Plaine (La Falle) for a small composite glacier, 695 m for the Bambois and the Rabodeau glaciers.

b) The arrangement of the cirques is quite characteristic. The more typical ones all face NE or E. All E-facing cirques are situated along the cuesta front whose orientation is determined by structure. There is no structural bias commanding the orientation of the cirques sculpted in the valley slopes of the left tributaries of the Rabodeau: they are all facing NE. It is the same for the Lac de la Maix. In spite of its intense glaciation, there is no cirque in the Falle valley catchment where no slope faces NE. We can conclude from this pattern that snow drift by SW winds resulted in a overfeeding of glaciers on the lee slopes, i.e., NE facing slopes. The anomalous low altitudes of some cirque floors, like Lac de la Maix and Marais de la Maixe can be explained by this process. This was suggested many years ago to explain the carving out of great cirques on the eastern slope of the main divide in the Hautes Vosges (Lac Blanc, Lac Noir, Lac Vert, Lac des Truites). The mechanism is still active as shown by large remnants of snow drifts which can be observed in spring on the upper backslopes of these cirques.

Further evidence for the importance of snow drifts appears in the distribution of the larger glacial tongues and of the typical cirques with low floors: all of them are located on the lee or NE side of extensive plateau remnants. The extent of such landforms seems even more important than their altitude: at the foot of the Corbeille (899 m) and of the Tête des Blanches Roches (908 m), relatively high but limited in area, no typical cirques can be observed and there is no depression of the altitude of the cirque floors. It seems that at higher altitudes lower temperatures were able to rapidly freeze the snow after its fall and thus reduce the formation of snow drifts.

We can conclude that exposure has played quite an important role in the glaciation of the area and that, as at present, the heavier snow falls came with SW winds. They probably prevailed during the autumn, when temperatures were still relatively mild. It is well known that autumn snow falls are more efficient for glacier feeding than spring ones, as the snow freezes hard during winter and melts more slowly during summer. Loess distribution in the Alsatian graben, suggests that during the winter low-water period, which is favourable for deflation, predominant (or morphogenetic efficient) winds blew from the NE and ENE.

All loess covered areas lie SW and WSW of extensive sandy alluvial accumulations and an important granulometric gradient is usually observed from the NE to the SW, with the following sequence: deflation and wind worn pebbles, sand dunes, sandy loess and loess becoming finer and finer and discontinuous before becoming completely absent. Such features suggest a frequent occurrence, during winter, of high atmospheric pressures in Central Europe. This could be explained by the extension of the Fennoscandian inland ice and of the Alpine ice-cap, during pleniglacial periods.

Champ du Feu Massive

We now consider the Champ du Feu Massive glaciation. Obviously, there is a drastic difference in orography and hypsometry between this Massive and the Plateaus. Culminating at exactly 1100 m, the Massive is definitely higher. Above all the dissection pattern is quite different. The Plateaus form narrow remnants between deep valleys with steep sides, which do not favour the generation of extensive glacial tongues, as the ice reaches low altitudes after a short distance and melts. On the contrary, during recent Tertiary and old Quaternary periods of subtropical climate, the crystalline rocks of the Champ du Feu Massive have suffered intense weathering and have been sculptured in the form of basins ('alvéoles'). The flanks of the Massive, immediately below the summit, present a succession of gentle convex ridges and of smooth concave hollows, with extensive areas above the glacial snow line. Such conditions have been highly favourable to the formation of large glaciers.

On the higher part of the Champ du Feu an ice cap has been formed. The ice movement was too slow to permit the sculpture of any typical glacial landform and, even, to clean the older weathering products completely. Gradually, on lower slopes, the weathering profile was truncated deeper, so that, in places, core stones crop out. Progressively, these core stones have been mixed with the finer fraction of the weathering products by glacial transport and transformed into moraines. These 'embryonic moraines' gradually change into more typical ones, core stones being reshaped into glacial boulders, with rounded edges. In some cases, as in the Serva valley, on the Northern slope of the Massive, ice flows were channelled in steep and narrow rocky valleys, which were cut during interglacial periods, not infrequently along more densely jointed strips of rock. Quarrying was active and fresh boulders predominate in the moraines, with quite typical glacial shaping.

More frequently, glacial tongues flowed along weathered basins and no typical glacial landform has been sculptured. At Belmont (Sélestat), for instance, the concentration of the ice occurred, above 650 m, in a smooth, spoon-shaped, concavity of the slope. No cirque can be identified. Nevertheless, this landform crosses a ridge of Devonian acid volcanics, which resisted weathering. At an altitude of 800 m, morainic material became quite typical, consisting of an unsorted mixture of crystalline and volcanic boulders in a sandy-clayey matrix of weathering products. Volcanic boulders are an excellent natural tracer: they reach Fouday (Cirey) where the snout ended, within a few hundred metres of the confluence of the Schirgoutte and Bruche rivers. Below Belmont, this glacial tongue effectively joined the Schirgoutte glacier which has accumulated moraines along the valley, that probably formed during recession. Another affluent glacier came from Bellefosse (Sélestat), where the ice mantled the scarp of the Château de la Roche, consisting of Devonian volcanics, at an altitude of 770-720 m, before flowing through a weathered basin formed in granite. Using the 'mean method' for determining the altitude of the snow line, we arrive, for the western flank of the Champ du Feu Massive, at a value of 750 m, which is in agreement with the figures obtained for the Buntsandstein Plateaus. This catchment faces W and SW and has not been replenished by snow drifts. Furthermore, a good proportion of the slopes, mainly near Belmont, face S and SSW and enjoy a very good insolation, which is not favourable to glaciation.

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