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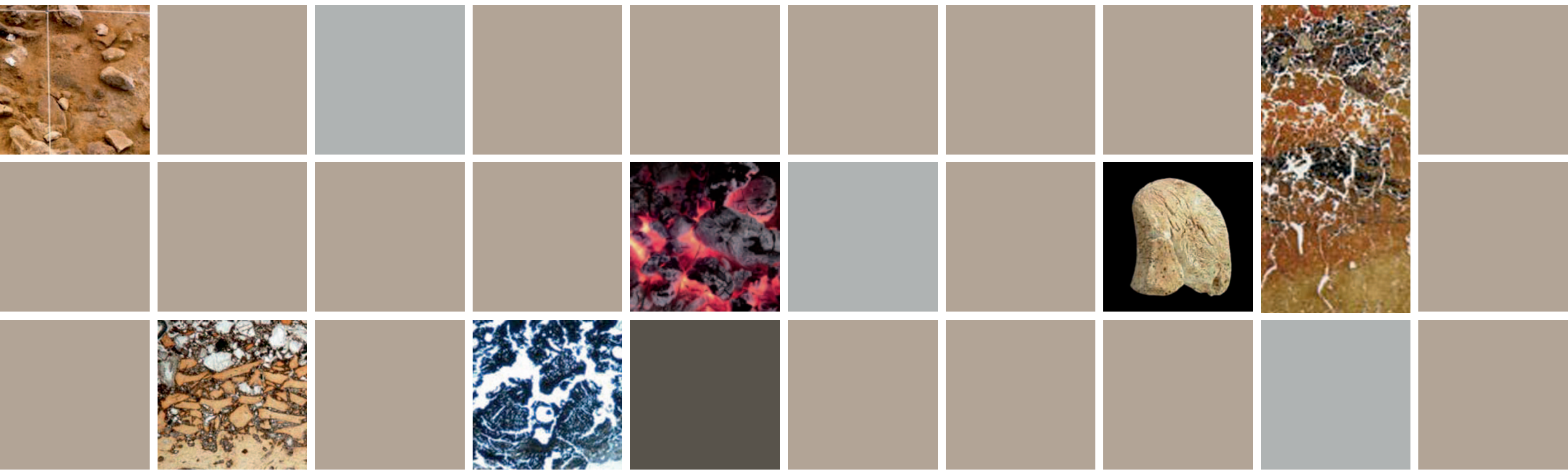
THE TAPHONOMY OF BURNED ORGANIC RESIDUES AND COMBUSTION FEATURES IN ARCHAEOLOGICAL CONTEXTS



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COMBUSTION FEATURES AND PERIGLACIAL STRUCTURES: A NEW TAPHONOMIC ANALYSIS OF MOUSTERIAN COMBUSTION FEATURES AT SAINT-VAAST-LA-HOUGUE (50)

Bertrand MASSON

Abstract

The Mousterian site of Saint-Vaast-la-Hougue (Manche), excavated by Gérard Fosse in the early 1980's, has yielded around thirty combustion features. These features were excavated, described and interpreted without sufficient consideration of the periglacial processes that occurred during and after the human occupations. Based on observations of modern periglacial processes in active contexts, archaeological examples from sites in the Nord-Pas-de-Calais region and experiments conducted at high altitudes by A. Pissart (1973 to 1987) and researchers in the ACR program "Taphonomy of Middle Palaeolithic assemblages in periglacial contexts" and "The Palaeolithic in the Quercy" (2004-2007), we reveal evidence of formal convergences between the periglacial structures and the forms and functions of the combustion features attributed to the Mousterian at Saint-Vaast-la-Hougue.

Keywords : cryoturbation, cryoexpulsion, gelifluction (periglacial solifluction), Mousterian, periglacial, cryostatic pressure, solifluction, polygonal ground, combustion feature, taphonomy

Introduction

The Mousterian site of Saint-Vaast-la-Hougue is located in the Nord Cotentin, on the eastern coast of the Hougue peninsula (fig. 1). It was excavated by Gérard Fosse from 1978 to 1984. Several essential elements characterize this site, whose occupations extend from the end of the Eemian (stage 5e) to the beginning of the Weichselian periglacial (stage 4). First, the combustion features are exceptional for this period in terms of both their number and their formal diversity. Second, the site is spatially structured into two distinct zones separated by a granitic butte: one is a "habitat" zone, while the other is exclusively devoted to fire-related activities. Finally, a remarkable number of periglacial phenomena are present at this site. This last aspect was not considered in previous interpretations of the features and it thus appeared necessary to conduct new analyses of them in light of studies (in which the author of this paper is a participant) conducted in the context of the ACR programs "Taphonomy of Middle Palaeolithic assemblages in periglacial contexts", directed by L. Vallin and "The Middle Palaeolithic in the southern Aquitaine: taphonomic studies in modern periglacial contexts", directed by P. Bertran and J.-P. Texier.

Fig. 1 - Location of La Hougue Island.

Topographic situation and chronostratigraphy

Topographic situation

La Hougue was a small island until the end of the 17th century when a military engineering project reattached it to the mainland (fig. 2). It is composed of a granitic bedrock base covered with late Quaternary formations that surround and connect three granite outcrop buttes:

- to the north, an elongated butte, oriented N-S, 20 m NGF at its highest point;
- to the south, two buttes, one with a very steep profile, the other larger and with a weaker slope. Their highest points are 22 and 18 m respectively.

Fig. 2 - Areal view of La Hougue Island with the location of the two principal excavation sites.

The Mousterian site studied is located at the foot and to the southwest of the southernmost butte (fig. 3). The archaeological excavation is located at the top of the current beach on a strip of land (3 m wide) preserved by the 17th century construction work.

Chronostratigraphy

The excavation of around fifteen test pits distributed over the entire surface of the island (fig. 3) allowed J.-P. Lautridou, J.-P. Coutard, B. Van Vliet-Lanoë and J.-C. Ozouf of the *Centre de Géomorphologie du CNRS* in Caen to define the chronostratigraphy summarized in figures 4 to 8.

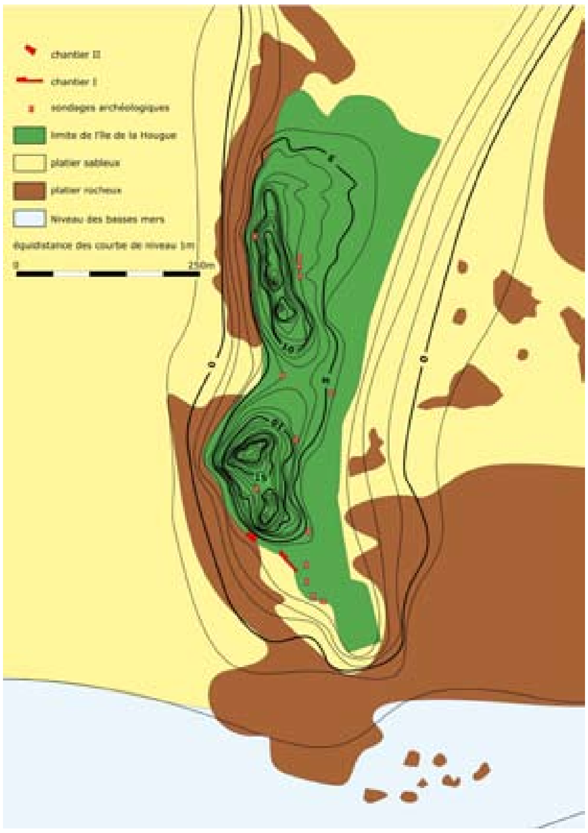

Fig. 3 - Location of the archaeological excavations overlaid on a map of La Hougue Island before the military construction work, reconstructed based on ancient maps (CAD Bertrand Masson).

The Mousterian occupations

With no apparent discontinuity, the Mousterian occupations are contained in the horizons from the top of the low level beach and the base of headlands D1-D2. These horizons correspond to the climatic degeneration during which periglacial conditions slowly developed at the beginning of the Weichselian. The state of preservation of the industry allowed the distinction of two large groups (Fosse 1982):

- the lower horizons, which contain a lithic assemblage with numerous cores and tested nodules, along with a few tools consisting mostly of notches, denticulates and scrapers. The objects have a thick, white patina and frequent alterations caused by freezing. The Mousterians knapped mediocre quality flint nodules from the beach. The features include a knapped flint concentration, unworked stones arranged in half circles and combustion features.
- the upper horizons, which contain an assemblage that is slightly modified by frost action and has a thin patina. The raw material is of a better quality and does not come from the beach, but from sedimentary contexts exposed by retreating sea levels. Scrapers are dominant in this Levallois-type industry, which can be attributed to the Typical Mousterian. The only features are knapped flint concentrations. The two *loci* studied (ChI et ChII) are near one another (around 40 metres apart) and are situated on either side of a small granite butte (fig. 9). Even if the narrowness of the excavated zones prevents us from reliably interpreting the site (fig. 10 and 11), a few ethnographic observations can be made. Though the occupations of the lower levels (beach horizons and C1) are similar, the occupations of level C2 are different. In Chantier (Site) I, the isolated combustion features are associated with knapped flint concentrations, numerous tools and granite blocks arranged in a half circle, suggesting a domestic activity zone and probably a habitat. The organization of Chantier II is different. Up against the dune (level C1) an ensemble of combustion features is superimposed over a depth of nearly one meter. Next to ashy pockets, there are true organized, which are bordered by granite stones. The lithic industry is poor and often reduced into debris by fire. This part of the site of "La Hougue" was dedicated to specialized activities related to fire (Fosse *et al.*, 1986), (Thiébault *et al.*, 1988).

The combustion features

Numerous combustion features were identified: 14 at Chantier I, over a surface of 18 m^2, and 20 at Chantier II, over 30 m^2. These are minimum numbers since several features, particularly at Chantier II, are interpreted as combustion complexes composed of several indistinct hearths. These features were classed into four types (Thiébault *et al.*, 1988).

Agglomerations of ash and charcoal

These are simple pockets of ash and charcoal materials. Some of these features are rather thin and

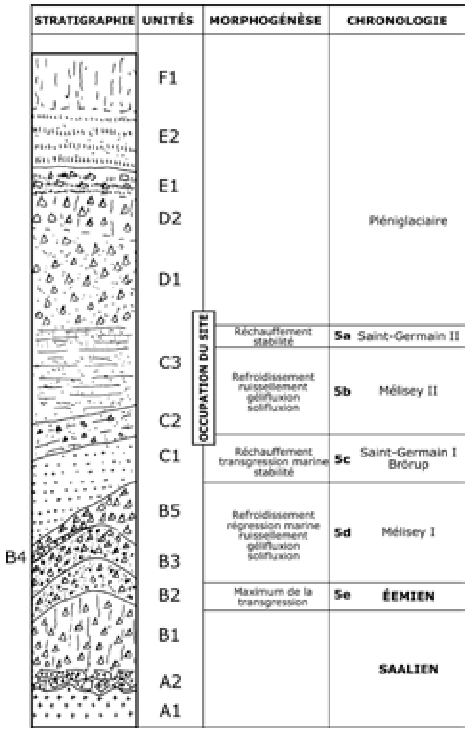

Fig. 4 - Synthetic stratigraphic sequence of the Saint-Vaast-la-Hougue peninsula, based on the work of J.-P. Lautridou, J.-P. Coutard, B. Van Vliet-Lanoë and J.-C. Ozouf of the Geomorphology Center of the CNRS in Caen.

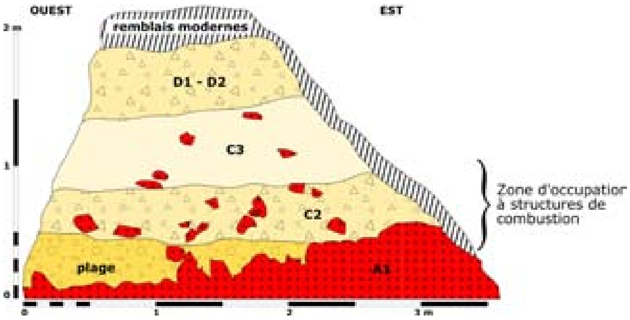

Fig. 5 - Stratigraphic sequence of Chantier I: the legends are in the text (CAD Bertrand Masson).

Fig. 6 - Photo of the stratigraphic profile of Chantier I (Photo Gérard Fosse).

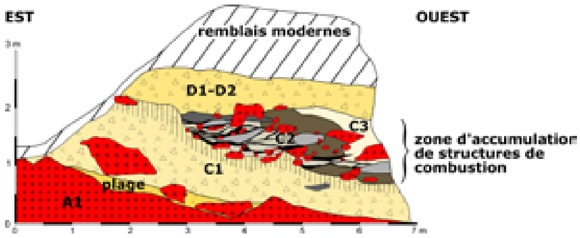

Fig. 7 - Stratigraphic sequence of Chantier II: the legends are in the text (CAD Bertrand Masson).

Fig. 8 - Photo of the stratigraphic profile of Chantier II (Photo Gérard Fosse).

Fig. 9 - View of Chantiers I and II taken from the beach (photo Gérard Fosse).

Fig. 10 - View of Chantier I in the process of excavation, showing the narrow surface of the preserved site. The excavated surface covers 18 m^2 (photo Gérard Fosse).

Fig. 11 - View of Chantier II in the process of excavation. The excavated surface is 30 m^2 (photo Gérard Fosse).

composed of sediments that are slightly darker than the surrounding sediments and contain wood charcoal (fig. 12 and fig. 14). The most evident agglomerations cover a surface of up to 1 m^2 and consist of a coalescence of different types of ashes containing varied amounts of charcoal (fig. 15 and fig. 16). The absence of a zone of rubified sediment under the ashes led the excavators to interpret these as dumping zones.

Fig. 12 - Agglomeration of thin ash and charcoal materials that are characterized by a darker and redder sediment colour and accompanied by wood charcoal fragments and balls of hard red sediment (photo Gérard Fosse).

Fig. 13 - Pocket of wood charcoal in an ashy gray silt (photo Gérard Fosse).

Fig. 14 - Pocket of large wood charcoal fragments in a whitish silt (photo Gérard Fosse).

Fig. 15 - Ensemble of white to grey ash zones (photo Gérard Fosse).

Fig. 16 - Zone of ashy silt (photo Gérard Fosse).

Simple hearth

These are hearths with no border, composed of an accumulation of combustion materials in a simple depression in the ground. These features have an ovular to circular form and are shallow (between 10 and 15 cm deep). They have a diameter of 30 to 100 cm (fig. 17 to fig. 20).

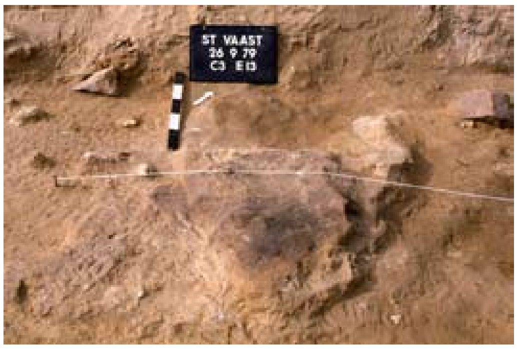

Fig. 17 - View of hearth DE13 when it was discovered. This is a large sub circular hearth approximately 1 m in diameter in a shallow (10 cm) intentionally dug pit (photo Gérard Fosse).

Fig. 18 - View of hearth at the end of its excavation: the ashy fill was removed (the solid line indicates the upper limits of the pit); the flint cobble in the middle was fractured by the fire. In the 1980 report, Gérard Fosse noted that “the whitish materials visible (to the right, outside of the hearth), have not yet been explained, but seem to be related to fire” (photo Gérard Fosse).

Fig. 19 - Small hearth in a pit: located on the border of the slope, half of the hearth was eroded by the sea. In the photo, the pit has been half emptied (photo Gérard Fosse).

Fig. 20 - Small hearth in pit D18: located on the border of the slope, half of the hearth was eroded by the sea (the arrow indicates an older combustion feature). All of the ash has been removed from the pit (photo Gérard Fosse).

Hearth with a stone border

Gérard Fosse (*in* Thiébault *et al.*, 1988) describes these hearths as “Hearths with a border of granite blocks simply pushed into place in order to obtain a central space that is ovular or circular and free of stones”. “This concerns nearly all the hearths constructed in the heterometric slope deposit of Chantier II; these fire places almost always include a deepened area” (fig. 21 to fig. 23).

Fig. 21- A constructed hearth in Chantier II : the granite blocks of the headland were pushed away in order to free a central space that has traces of combustion (ash and charcoal) (photo Gérard Fosse).

Fig. 22 - A constructed hearth in Chantier I with granite blocks pushed to the periphery and forming a circle (photo Gérard Fosse).

Fig. 23 - Hearth constructed in the headland of Chantier II (photo Gérard Fosse).

Combustion complex

These are extended combustion features with unclear limits, making them difficult to excavate and interpret.

They are composed of strongly imbricated and overlapping combustion zones. Only one such feature was found at Chantier I, while they are the most frequent type found at Chantier II (fig. 24, fig. 25 and fig. 26).

The periglacial processes

Solifluction

The features were excavated, described and interpreted without sufficient consideration of the periglacial processes that occurred during and after the human occupations at Saint-Vaast-la-Hougue. For example, Gérard Fosse, Dominique Cliquet and Gérard Villegrain wrote in 1986 that "...the archaeological levels were not disturbed by natural phenomena posterior to the human occupation, as they were in the silts of the northern Paris Basin, or were at most affected by "frost-creep", which resulted in only minor disturbances, and [...]the "features" were consequently preserved" (Fosse *et al.*, 1986). Recent studies, especially since the experiments conducted by "TRANSIT" in modern, active periglacial contexts (Texier *et al.*, 1998), have shown that modifications to prehistoric assemblages in periglacial contexts can be rapid and significant and that they can deform anthropogenic features both horizontally and vertically (Texier, 2001). The different processes, which rarely act alone, can result in the creation of anthropogenic pseudo-features (Texier, 2000). New analyses of the Palaeolithic sites of Baume-Vallée (Bertran, 1994), Combe-Capelle (Texier & Bertran, 1995) and La Ferrassie, (Texier, 2001) showed the presence of periglacial phenomena at these sites. Therefore, contrary to previous interpretations, these were not simple gravitational deposits and their development had consequences for the preservation of the archaeological levels.

At some point during their history, most Palaeolithic sites contemporary with periglacial climates met the conditions necessary for the functioning of periglacial processes that could modify their contents. A geomorphological study of Saint-Vaast-la-Hougue showed that this site does not escape this rule. It thus appeared necessary to conduct new analyses of its features in order to determine the possible effects of periglacial phenomena.

Fig. 24 - Combustion complex in Chantier I: extended combustion zone with numerous combustion pits that could have been used successively (photo Gérard Fosse).

Fig. 25 - Combustion complex in Chantier II (photo Gérard Fosse).

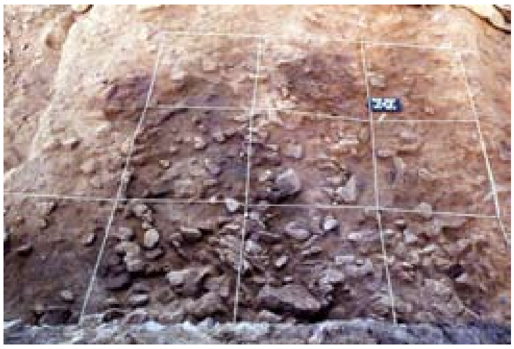

Fig. 26 - Combustion complex in Chantier II (cliché Gérard Fosse).

Definition and modern examples

Solifluction (figs. 29 and 30) is a slow, downslope mass movement of loose detrital materials under the action of freeze-thaw cycles (Bertran & Coutard, 2004). It is the result of several processes:

Frost creep: a mass movement of sediments that occurs when they are lifted perpendicular to the slope as a result of an increase in the volume of ice during its crystallization, followed by their more or less vertical subsidence as the ice thaws (Washburn, 1967).

Pipkrakes (needle ice): ice needles that form on the ground surface, perpendicular to the slope, under stones, vegetal fragments or blocks of sediment. These materials can be uplifted by the pipkrakes during their formation. A pipkrake can lead to the vertical tumbling an object in front of its original position, caused its displacement (Washburn, 1973, 1979). Pipkrakes are responsible for the movement of large materials on the surface of solifluction flows (fig. 27).

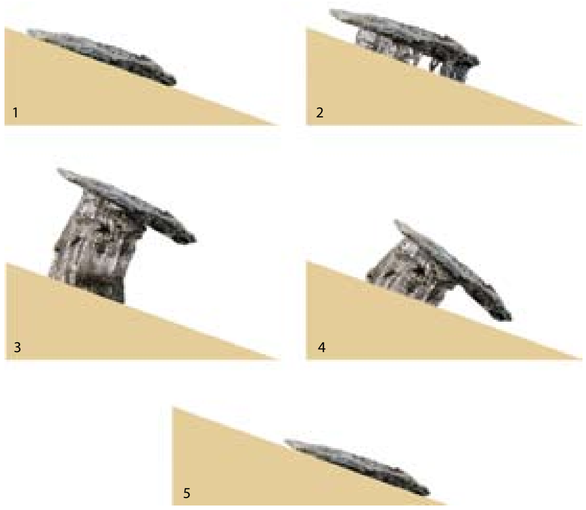

Fig. 27 - Schema explaining the movement of a stone by pipkrakes: 1 – initial position of the stone; 2 – beginning of the uplifting of the stone, perpendicular to the slope, by a pipkrake; 3 – end of the uplifting; 4 – thawing and vertical subsidence of the stone; 5 – final position of the stone, which was moved forward (CAD Bertrand Masson).

Periglacial solifluction (gelifluction): sediment flow that occurs during thawing when water is liberated faster than it can be drained (Baulig, 1956).

Solifluction flows that form on slopes between 2° and 35° progress slowly and in the same manner as the tracks of a tractor (Bertran, 2004). The distribution of movement rates, which are faster on the top and central part of the flow, than at its base, edges and front, result in a progressive rolling of the front into the form of a lobe (Bertran & Coutard, 2004; Coutard & Ozouf, 1996; Francou & Bertran, 1997) (fig. 28). One of the consequences of this type of movement is that stones can be stood up vertically at the front of the flow (figs. 31 and 38). At the front of the flow, we can thus expect to find semi-circular assemblages of vertically positioned stones.

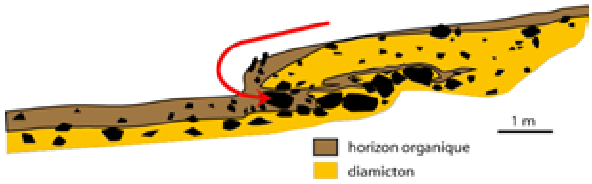

Fig. 28 - Schematic profile of a solifluction flow after Bertran & Coutard, 2004.

Fig. 29 - Lobed solifluction flow, Massif du Chambeyron, French Alps, altitude 2600 m, (photo Bertrand Masson).

Fig. 30 - Layered solifluction flow, Massif du Chambeyron, French Alps, altitude 2800 m, (photo Bertrand Masson).

Archaeological example: the Mousterian site of Saint-Amand-les-Eaux

This site was excavated by Philipe Feray in 2007. It is located on the eastern part of the Scarpe plain at the foot of a hill (Mont-des-Bruyères) composed of Eocene sands. Its maximum altitude is 30 m.

Since the study of this site is still in progress and the excavation has not yet been published, I will only briefly describe it here. According to current knowledge, it appears that the main function of this

Fig. 31 - Close-up of a solifluction flow showing the vertically positioned stones at the front of the flow, Massif du Chambeyron, French Alps, altitude 2600 m (photo Bertrand Masson).

Fig. 32 - Close-up of a solifluction flow showing the vertically positioned stones at the front of the flow, Massif de Rubren, French Alps, altitude 2600 m (photo Bertrand Masson).

Fig. 33 - View of the site of Saint-Amand. Note the front of the solifluction layers that traverse the site (photo Philippe Feray).

Fig. 34 - Profile view of the front of the solifluction layer at Saint-Amand-les-Eaux (photo Philippe Feray).

Fig. 35 - Close-up of the front of the solifluction layer at Saint-Amand-les-Eaux (photo Philippe Feray).

site was as a biface production workshop dated to stage 4 (Deschodt *et al.*, 2006). The average slope is 2.43° and it is traversed by a solifluction level (fig. 33). The meticulous excavation of this level revealed its organization, including the half-circle arrangement of stones at the front flow and the vertical position of sandstone blocks (figs.34 and 35).

Formal convergences

It is difficult, 30 years after an excavation, to re-examine a site from a different perspective as some data is forcibly lacking. The excavation of Saint-Vaast-la-Hougue was realized by successive horizontal levels, or *decapages*, a few centimetres deep and the ensemble of artefacts of natural and human origin were recorded and removed after each horizontal stripping. These conditions do not allow us to observe certain phenomena, such as a solifluction flow, in three dimensions. The object orientations (Bertran & Lenoble, 2002), which could have been used to distinguish the levels disturbed by solifluction, were not recorded. Nonetheless, comparisons of photos of the features at Saint-Vaast-la-Hougue with modern and ancient solifluction structures show formal convergences. Though not sufficient to deny the role of humans in the realization of partitions around the hearths, these formal convergences suggest the possibility of a natural process. Under certain conditions, such as those at Saint-Vaast-la-Hougue, natural phenomena can produce arrangements of vertical stones in a half-circle, which we can thus call “pseudo-features” (fig. 36).

Polygonal grounds

While archaeologists are beginning to recognize the role of solifluction in the disturbances of some prehistoric sites, the action of polygonal grounds in the redistribution of archaeological artefacts is still rarely considered, even if their effects can be quite significant (Masson & Vallin, in press).

Definitions and modern examples

The formation of polygonal grounds requires a very weak slope, a heterometric superficial formation and a high water content. Under these conditions, patterned grounds (in the geomorphological sense) result from the combined actions of the processes:

Segregation ice: in soils, water crystallizes in a discontinuous manner, forming ice lenses parallel to the freeze front. These lenses increase in size as water migrates toward the freeze front (cryosuction), thus causing the ground to swell (Pissart, 1987; Van Vliet-Lanoë, 1988). The ancient presence of segregation ice is shown by the leaflike structure of the sediment (fig. 38).

Cryoexplusion: in soils subject to freeze-thaw cycles, stones tend to be expulsed toward the surface (Pissart, 1987; Coutard & Van Vliet-Lanoë, 1994). The speed of the phenomenon is related to the number of freeze-thaw cycles and the size of the objects. The largest objects are cryoexpulsed the fastest, as has been shown in laboratory experiments by Coutard and Van Vliet-Lanoë (Coutard & Van Vliet-Lanoë, 1994).

Pipkrakes : see above.

Patterned grounds « appear as polygonal forms outlined by stony elements surrounding “islands” of finer materials. Within the rows of stones, which are often vertically positioned, there is sometimes a very clear granulometric sorting” (Pissart, 1987, p. 56), (fig. 39 and fig. 40). Experiments realized by Albert Pissart from 1968 to 1975 to identify the evolutionary processes of polygonal grounds showed that:

- the displacement rates on the surface due to the action of pipkrakes could attain 4 cm in 2 years;

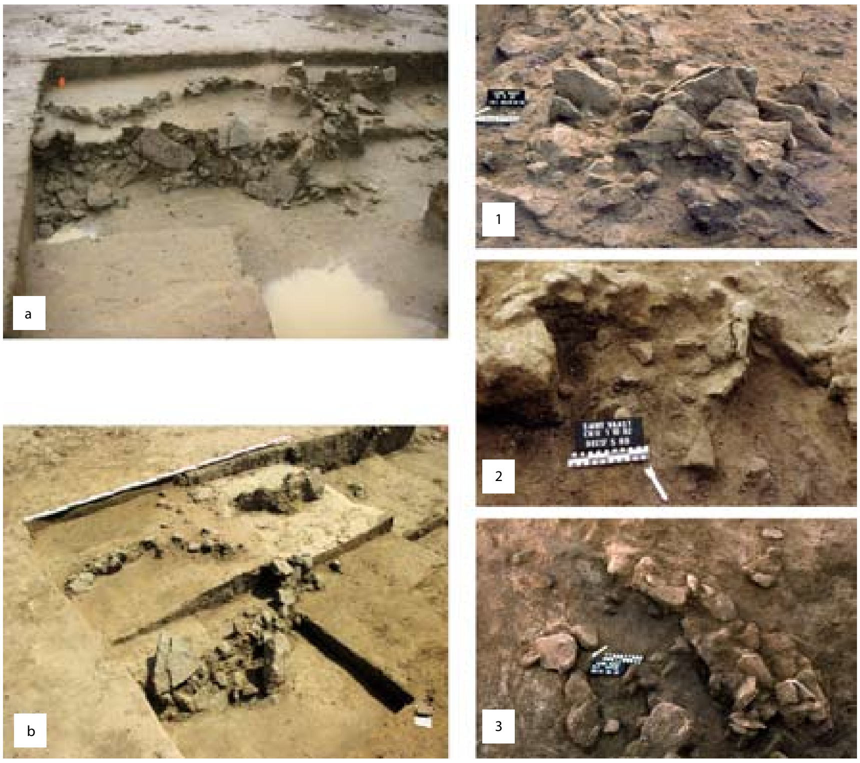

Fig. 36 - Comparison of the front of the solifluction layer at Saint-Amand-les-Eaux, on the left (photo Philippe Feray), and the constructed hearths at Saint-Vaast-la-Hougue (photo Gérard Fosse) on the right. Photo b clearly shows that a flat excavation in this type of level can result in the creation of false features.

- the speeds of the cryoexpulsion of buried stones was proportional to their size and attained 1 cm per year for gravels;
- a field of polygons destroyed by mixing could be reconstituted in 7 years.

Fig. 37 - Polygonal grounds on the Massif du Chambeyron, French Alps (photo Luc Vallin). Three generations of polygons are imbricated, the smallest measuring around 30 cm in diameter, the middle ones around 1 m and the largest between 2 and 3 m.

Fig. 38 - Saint-Amand-les-Eaux, profile of the archaeological level. The ancient presence of segregation ice is shown by the presence of iron oxides. The tag indicates the leaf-like structure of the sediment (photos Bertrand Masson).

Fig. 39 - Polygon of the Massif du Chambeyron, French Alps (Photo Luc Vallin). The vertical position of the stones in the walls of the polygon is clearly visible in this photo.

Fig. 40 - Polygon of the Massif du Chambeyron, French Alps (photo Luc Vallin). The granulometric sorting is visible in this photo.

Fig. 41 - Saint-Amand-les-Eaux, surface of the solifluction layer. The leaching of the fine sediments by rain allows us to observe the polygonal grounds that formed on the gravel surface of the solifluction flow (photo Philippe Feray).

Archaeological example: the Mousterian site of Saint-Amand-les-Eaux

There are numerous periglacial structures at the Mousterian site of Saint-Amand-les-Eaux. In addition to the solifluction level and segregation ice lenses already mentioned, several polygonal networks formed within the silt-sand sediment (fig. 42) at the surface of the solifluction level (fig. 43). These small polygons, 10 to 30 cm in diameter, modified the archaeological level (fig. 44).

Experimental demonstration

In order to better understand the redistribution of artefacts by polygonal grounds and to determine the speeds of these transformations, an experiment was realized at the Gavarnie Massif (Pyrenees) as part of the ACR program entitled « Taphonomy of Middle Palaeolithic lithic assemblages in periglacial contexts", directed by Luc Vallin (Masson &

Fig. 42 - Saint-Amand-les-Eaux, surface of the solifluction layer. Close-up of the polygons; the vertical position of the sandstone blocks and the granulometric sorting are clearly visible (photo Philippe Feray).

Fig. 43 - Saint-Amand-les-Eaux, surface of the archaeological level. Close-up of the polygon network of frost cracks (photo Philippe Feray).

Fig. 44 - Saint-Amand-les-Eaux, biface fabrication concentration disturbed by the polygonal network. The flakes are pushed into the walls of the polygons (photo Philippe Feray).

Vallin, in press). A pit measuring 1 m^2 and 10 cm deep was dug into the location of five small polygons (0.2 – 0.6 m diameter) and filled with silt (fig. 45). In 2005, 326 knapped flint flakes were regularly distributed over the surface of the pit so that they uniformly covered the silt fill (fig. 46). The object positions realized in 2006 show a reorganization of the objects that suggest the formation of polygons, more or less following the ancient pattern (fig. 47). The average object displacement, 8.25 cm, is much higher than that recorded by Albert Pissart. This could be explained by the high frost susceptibility of silt and a large number of freeze-thaw cycles (between 30 and 45 freeze-thaw cycles recorded by the team directed by P. Bertran and J.-P Texier on their nearby experimental sites).

Fig. 45 - Gavarnie experiment, initial polygonal ground: the polygons are small (20 to 60 cm diameter), the granulometric sorting is slight and the network is enhanced by the vegetation that is growing only in the walls (photo Luc Vallin).

Fig. 46 - Gavarnie experiment, september 2005, view of the silt pit covered with knapped flint (photo Luc Vallin).

Fig. 47 - Gavarnie experiment, september 2006, view of the pit after around 40 freeze/thaw cycles. The artefacts have moved and are now located along the walls of the ancient polygons (photo Pascal Bertran).

Formal convergences

Revealing a polygonal pattern is not an easy task as it implies detecting not concentrations of objects, but the empty spaces around them. Visual discrimination remains the most reliable method (Masson & Vallin, in press). In figure 48, a comparison of modern and fossil polygonal grounds with the constructed hearths at Saint-Vaast-la-Hougue shows formal convergences and tends to invalidate the implication of humans in the realization of the circular, granite borders around the hearths. This invalidation is supported by the study of artefact distribution maps.

Analysis of the distribution of fire-modified granites near the bordered hearth (ST66) of Chantier II, shon in figure 48 (2), shows that there is no correspondence between the burned granites and the hearth borders. The burned granites are distributed over the entire excavated surface with no particular organization, which appears to indicate that the archaeological level was disturbed (fig. 49). On this same map, we can also see numerous empty zones surrounded by granite blocks. If we do not take into account the ash fillings, it is visually possible to fabricate other structures with forms equivalent to those of the bordered hearths (fig. 50). The ensemble of these pseudo structures belongs to a polygonal network (fig. 51).

Based on an analysis of the vertical distributions of refits, Gérard Fosse identified three occupation levels in the upper horizons of Chantier I (Fosse, 1983). The plans of the spatial distributions of artefacts in each level reveal several empty spaces outlined by artefacts (for example, level III, fig. 52). As in the preceding plan of Chantier II, it is possible to visually trace an ensemble of cells that form a polygonal ground (fig. 53). The walls of cells in this network are randomly constituted by worked flint and natural stones (granite, sandstone and schist).

These two examples show that the sub circular arrangements of stones found in several levels of Chantiers I and II, are independent of the elements that compose their walls or centre. A natural origin, such as a polygonal ground, is the best explanation for this type of artefact distribution.

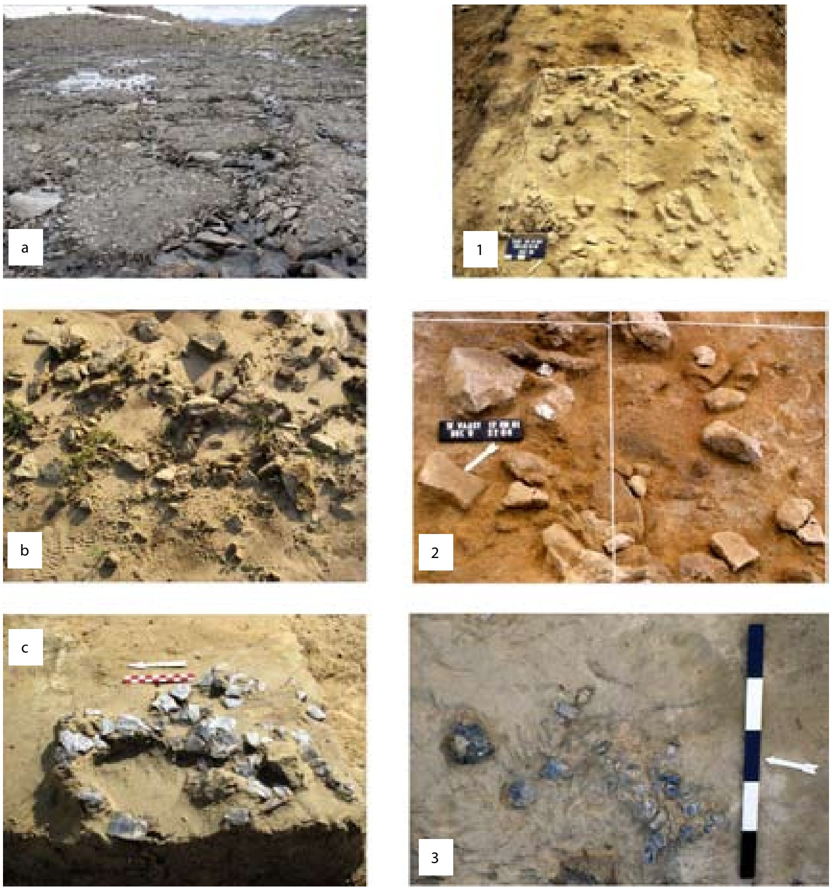

Fig. 48 - Comparison of natural (photo a) and fossil (photo b, Saint-Amand-les-Eaux, photo Philippe Feray) polygonal grounds and constructed hearths at Saint-Vaast-la-Hougue (photos 1 and 2, photos Gérard Fosse). The two bottom photos show the formal convergence between a concentration disturbed by the polygonal structures at Saint-Amand-les-Eaux (photo Philippe Feray) and a concentration at Saint-Vaast-la-Hougue (photo Gérard Fosse).

Cryoturbations: experiments by Albert Pissart (1973-1984)

Between 1968 and 1975, Albert Pissart conducted a series of experiments in a natural context (Massif du Chambeyron, 3000 m altitude) and in a laboratory with

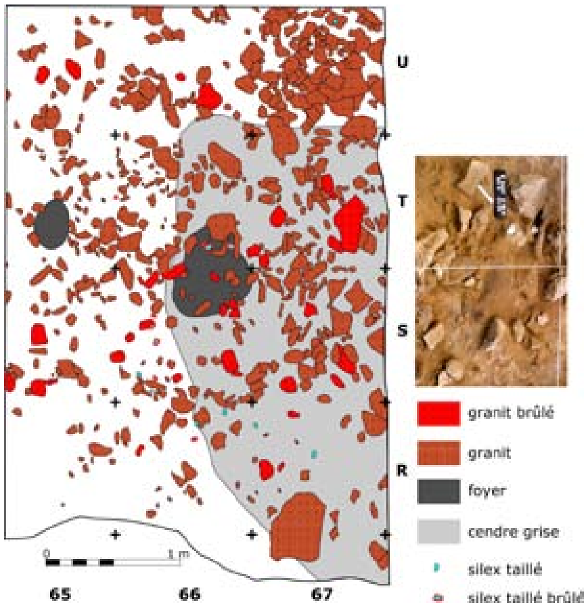

Fig. 49 - Plan of the hearths of decapage 9 at Chantier II at Saint-Vaast-la-Hougue (CAD Bertrand Masson).

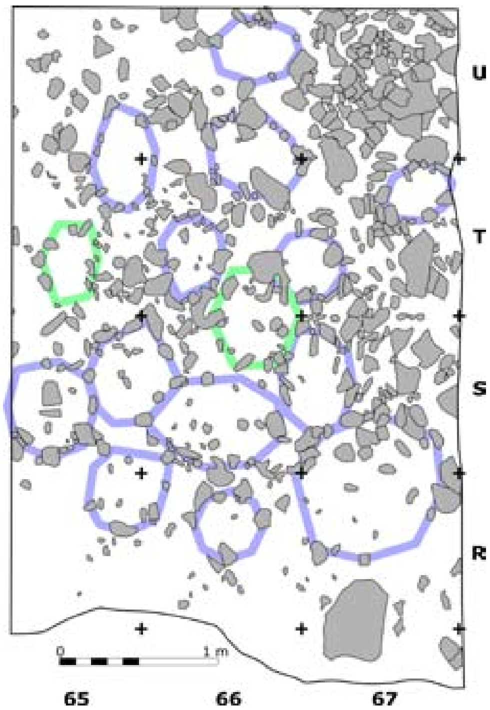

Fig. 50 - Plan of the artefacts (indistinctly represented) of decapage 9 at Chantier II at Saint-Vaast-la-Hougue, on which is indicated an ensemble of polygonal cells (in blue) identical to the hearth (in green) composed of an empty space surrounded by stones. This ensemble forms a polygonal network comparable to that recorded on the Massif du Chambeyron (fig.51), (CAD Bertrand Masson).

the goal of identifying the processes of the formation and evolution of periglacial ground structures (Pissart 1987). The method of study he employed consists of

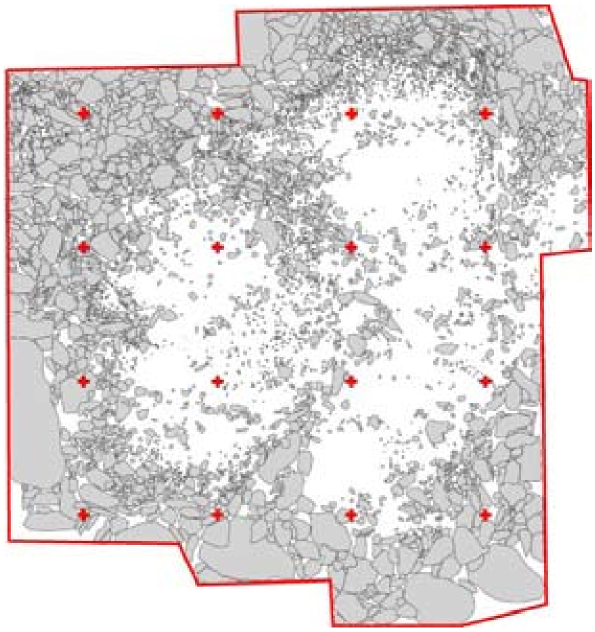

Fig. 51 - Plan of a polygonal ground on the Massif du Chambeyron (CAD Bertrand Masson).

observing the movements of coloured stones or the deformations of coloured silt blocks. In 1972 Albert Pissart thus buried levels of coloured earth, which were deposited horizontally in the centre of small, sorted polygons of the Chambeyron massif. This experiment showed that the modifications within polygons are not homogeneous and that the lateral intrusions at the limit between the fine and coarse materials, caused by freezing, more strongly deform these levels at the edges of the polygons (fig. 55A). Another similar experiment was realized in 1973 at the Col de la Gypière (2900 m, French Alps), on a slope of 3 to 6° within sorted soils (polygonal grounds modified along a slope, Fig. 54). Here, Albert Pissart in 1975, followed by Brigitte Van Vliet-Lanoë in 1984, observed the modifications made to a parallelepiped of coloured silt buried in the centre of a fine band of striated earth (fig. 55 B). This experiment showed that the rate of movements (maximum recorded by Albert Pissart: 7 cm/year) varies according to the depth of burial. The levels near the surface, which are subject to a greater number of freeze/thaw cylces, are the most deformed. Such cryoturbations could explain the form of some ashy levels on the periphery of hearths and the mixture of different types of ashes within them (fig. 55).

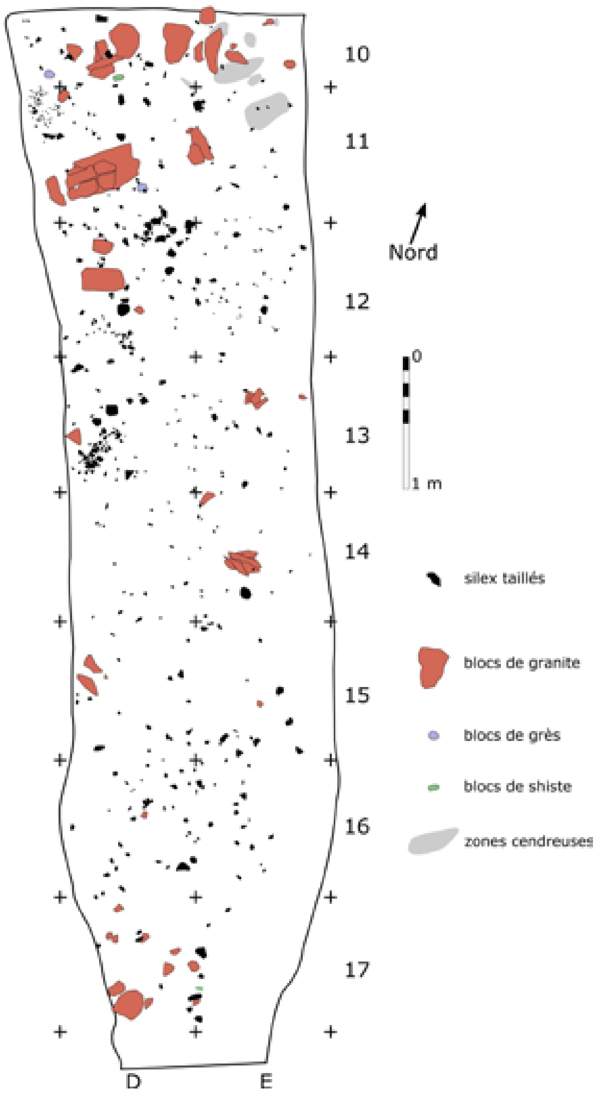

Fig. 52 - Spatial distribution map of the artefacts of level III of the upper horizons of Chantier I at Saint-Vaast-la-Hougue (CAD Bertrand Masson).

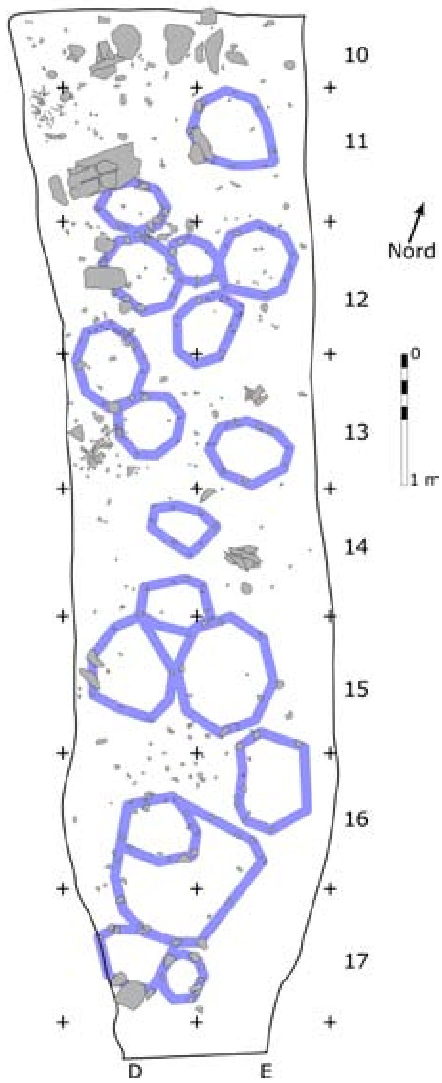

Fig. 53 - Spatial distribution map of the artefacts of level III of the upper horizons of Chantier I at Saint-Vaast-la-Hougue, on which an ensemble of polygonal cells (in blue) composed of an empty space surrounded by stones has been drawn (CAD Bertrand Masson).

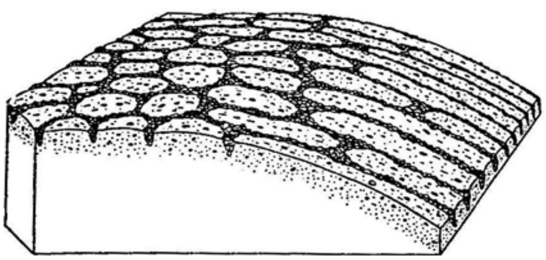

Fig. 54 -Passage, on a convex slope, from sorted polygons to striated sols (after Cotton, 1948, *in* Pissart 1987).

Cryostatic pressure

Experiments by Albert Pissart (1973–1984)

Still in the context of his work realized from 1973 to 1984, Albert Pissart conducted a series of experiments to demonstrate the unequal swelling of sediments with different granulometric dimensions during freezing. In a container with its walls inclined at 45° and covered with grease to avoid "wall effects", he deposited three cylinders of silt composed of six alternately coloured and non-coloured layers. One was placed on top of a layer of river sand and the two others on the bottom of the container and surrounded by 5 to 10 mm gravels (fig. 56 A and B). These experiments showed a progressive descent of the silt cylinders into the underlying sands. This descent increased with the number of freeze/thaw cycles (fig. 56 C).

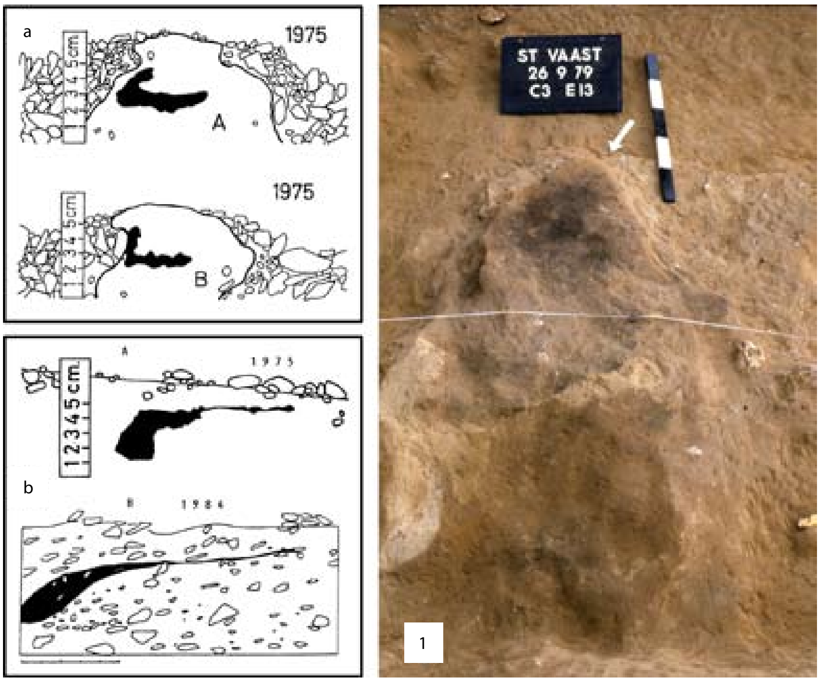

Fig. 55 - A – Profile of sorted polygons showing the deformation, after 2 years, of coloured layers deposited horizontally in 1973 (after A. Pissart, 1987). B – Deformation of a parallelepiped of coloured silt, placed vertically in 1973 within a fine band of striated soil, profile view (A. Pissart 1982 and B. Van Vliet-Lanoë 1988). 1 – Plan view of hearth DE13 when it appeared (photo Gérard Fosse). The forms of the ashy level, especially those on the periphery, could be explained by cryogenic deformations.

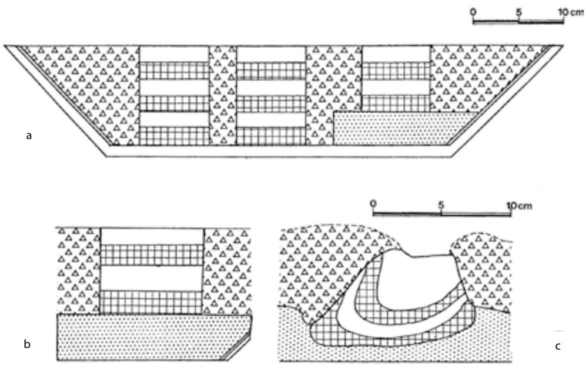

Fig. 56 - a – Schema showing the experimental apparatus employed by Albert Pissart to show the influence of cryostatic pressure in the deformation of soils (Pissart 1987). b – View of the silt cylinder, 73 mm in diameter, placed on coarse sand and surrounded by gravel before freezing.
c – Profile through the same cylinder after 15 freeze/thaw cycles, showing the descent of silt into the sand and the deformation of the coloured layers.

Archaeological examples

In the silts of northern France, examples of cryoturbated levels are frequent. We present here two examples that illustrate our topic. The first photo (fig. 57) shows a stratigraphic profile in levels attributed to the Weichselian early glacial period in Onnaing (Nord); despite a small granulometric difference, the gley soil horizons and those underlying them (humus-bearing at the base and loess at the top) are deformed by cryostatic pressure.

The second example comes from water-washed silts of the Weichselian early glacial at Hermies “Champ Bruquette”; the beds constituting these water-washed horizons, formed in humus-bearing and loess levels, were deformed by cryostatic pressure.

Formal convergences

Lacking an experimental reference base on the behaviour of hearths subject to freeze/thaw cycles, it is difficult to prove that cryostatic pressure can deform them. We saw before that small granulometric differences were sufficient for freezing to deform sediments. We can thus propose the hypothesis that the different sediments that compose a hearth—ashes, depending on their charcoal and organic material contents, rubified levels, and the surrounding sediments—do not have the same frost susceptibility, which could result in

Fig. 57 - Profile in the silts of the Weichselian early glacial at Onnaing (Nord), showing the cryostatic deformations suffered by the different horizons (photo Luc Vallin).

Fig. 58 - Profile in the water-washed silts of the Weichselian early glacial at Hermies «Champ Bruquette» (Pas-de-calais), showing the cryostatic deformations suffered by the different beds. The lightest beds are silty, the darkest are more clayey and humus-bearing (photo Luc Vallin).

their cryoturbation. As with the preceding examples, though a visual comparison is insufficient to affirm the role of freezing in the transformation of features, the formal convergences, visible in figures 59 and 60, show that a cryogenic origin can not be excluded.

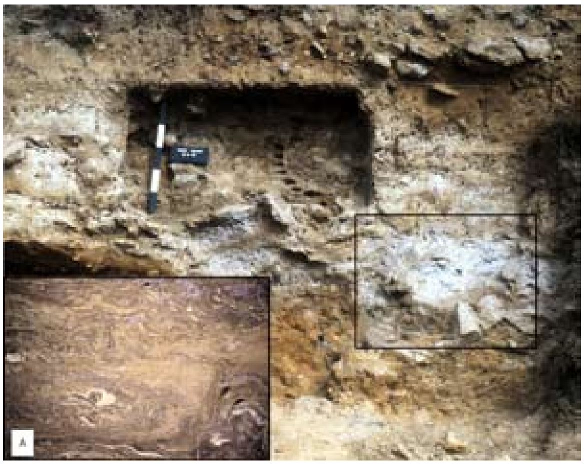

Fig. 59 - Comparison between a profile in the complex hearths at Saint-Vaast-la-Hougue (photo Gérard Fosse) and the water-washed and cryoturbated silts at Hermies "Tio-Marché", box A (photo Luc Vallin). We observe a similarity of form between the two boxes.

Conclusion

Researchers are now beginning to consider the influence of periglacial phenomena on lithic and osseous remains, notably in the context of research programs such as TRANSIT, experiments conducted in natural contexts (Gavarnie, Massif du Chamberyon) and in the laboratory as part of the "Taphonomy of Middle

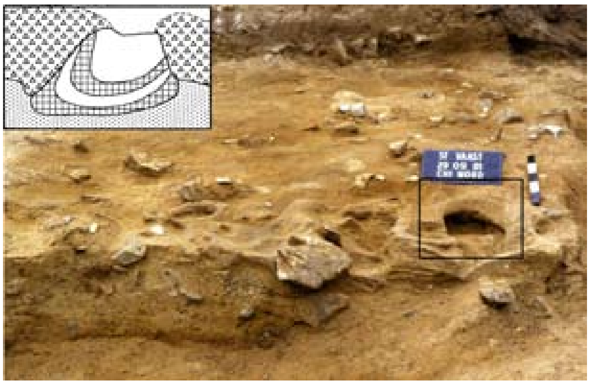

Fig. 60 - Comparison between a complex hearth at Saint-Vaast-la-Hougue (photo Gérard Fosse) and the forms obtained by Albert Pissart during laboratory experiments. The ashes of hearth D13 were emptied. The photo shows its hardened base composed of a coalescence of pits that were interpreted as successive reutilizations. Considering the formal convergence between the framed part, for example, and the forms obtained by Albert Pissart, a cryogenic origin cannot be excluded.

Palaeolithic assemblages in periglacial contexts" and "The Palaeolithic in the Quercy" research programs. However, to my knowledge, there have been no studies of the evolution of hearths in environments subject to freeze/thaw cycles. Due to the lack of an experimental reference base concerning the behaviours of combustion features subject to freeze/thaw alternations, it is not possible to make reliable interpretations of Mousterian combustion features in silt contexts in northern France.

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I particularly thank Gérard Fosse (Regional Archaeology Service of Nord-Pas-de-Calais) who allowed me to study the hearths of Saint-Vaast-la-Hougue, as well as Philippe Feray (Inrap) who provided me with the unpublished data from Saint-Amand-les-Eaux. I also thank all the researchers who intervened in the context of the research programs "Taphonomy of Middle Palaeolithic assemblages in periglacial contexts" directed by L. Vallin and "The Palaeolithic in the Quercy" directed by P. Bertran an J.-P. Texier. Experiments concerning the influence of periglacial phenomena are difficult to realize as their analyses require enormous amounts of time and their results are available only after many years of effort.

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