Holes and grooves: the contribution of microscopy and taphonomy to the problem of art origins

Optical and scanning electron microscopy, comparative anatomy, data from modern and Pleistocene carnivore accumulations, and analysis of archaeological materials show that some of the pieces interpreted by various scholars as engraved or perforated bones from European Lower and Middle Paleolithic sites (such as Pech de l’Azé II, Stránska Skála, K ulna, Bois Roche and Cueva Morín) are not early manifestations of non-utilitarian behavior. Putative engravings are in fact vascular grooves, while perforated pieces are partially-digested bones regurgitated by hyenas. The current debate on art origins has often been centered on the symbolic value and cognitive implications of these and similar pieces without a first-hand analysis of the objects to provide convincing demonstration of the human origins of the marks. Such demonstration is a necessary prerequisite to any discussion of their significance for the evolution of symbolic behavior.

Introduction

Two opposing hypotheses have been proposed to account for the origins of symbolic behavior: on one side, there are the partisans of a symbolic explosion corresponding, in Europe, with the Middle to Upper Paleolithic transition; on the other side, there are those who believe that acquisition of modern cognitive abilities took place gradually and that evidence of symbolic behavior is already present in the Lower and Middle Paleolithic.

Proponents of gradualism find support in such evidence as ochre or hematite use, collection and transport of crystals and fossils, and perforated and engraved portable objects of stone and bone found in several Lower and Middle Paleolithic sites in Europe, Africa and Asia. There is, however, no consensus on the nature and the significance of this evidence. Some scholars not only believe that humans made, collected, or used most of these objects, but are also ready to lend a symbolic or non-utilitarian value to them (e.g., Marshack, 1976, 1988, 1991; Bednarik, 1992, 1995; Bahn, 1996; cf. also Simek, 1992; Hayden, 1993; Wolpoff & Caspari, 1996). Others do not systematically question the artefactual nature of the objects, but reject their supposed symbolic meaning, proposing instead a utilitarian function, or deny their value as expressions of a symbolic or artistic tradition by stressing the sparsity and heterogeneity of the sample compared with the artefactual richness of the Upper Paleolithic (Chase & Dibble, 1987, 1992; Bar Yosef, 1988; Davidson & Noble, 1989; White, 1992, 1995; Stringer & Gamble, 1993; Mellars, 1989, 1996; Byers, 1994). A few reject the idea of human manufacture for several of these objects, and proposed natural causes, such as carnivore gnawing, rootmarking, erosion or chemical deterioration (Binford 1981; Davidson 1990; Chase 1990; d’Errico, 1991). In sum, this topic has attracted a great deal of attention and has inspired heated debates. In spite of the variety of views expressed, many of these claims have remained unexamined.

Although various alternative interpretations have been proposed, criteria to differentiate between human-made engravings and perforations and those produced by other causes have never been established; interpretations have remained at the level of conjecture (for an exception concerning perforations produced by carnivore puncture, see Chase, 1990). The
The purpose of this paper is to develop criteria for recognizing naturally-produced perforations and engravings by combining optical and scanning electron microscopy, comparative anatomy, and data from modern and Pleistocene bone accumulations. We have found these criteria useful for interpreting putative engravings and perforated bones from a number of Lower and Middle Paleolithic sites.

**Lower and Middle Paleolithic engraved and perforated bones**

**Grooves**

Engraved bones have been claimed for at least 16 Lower and Middle Paleolithic sites in Europe (Table 1). This sample, by no means complete, is composed of a variety of objects: several long bone and rib fragments, one ivory tusk (at Bilzingsleben), one vertebra (at Stránska Skála) one scapula (at La Quina) and one horse canine (at Prolom II). The "engraved motifs" are also variable, consisting of notches (e.g., Suard), rectilinear grooves in parallel (e.g., La Quina) or radial sets (e.g., Bilzingsleben, Stránska Skála) and curvilinear grooves (e.g., Pech de l’Azé, Cueva Morin). In the following sections we review a number of purported engravings with a particular arrangement or groove morphology for which we have been able to develop specific explanatory hypotheses.

**Pech de l’Azé II (Dordogne, France).** François Bordes (1969, 1972: p. 62) described an ox rib carrying on its internal face "a series of lines and incisions which are clearly intentional, not the random lines left by a flint cutting off the meat. . . . It seems to be by far the oldest engraving known." The bone (Figure 1) comes from the top of level 8, considered by Bordes as
Acheulian, and dated to the end of “Riss I”; level 8 has now been assigned an estimated age, using electron spin resonance (ESR), of about 150,000 BP (corresponding to isotope stage 6; Grün et al., 1991). Marshack (1976: p. 278) accepted the intentionality of the markings and after microscopic analysis asserted that “the image had been made sequentially as a series of connected, festooned double arcs, beginning at left and ending at right with a multiple marking”. He suggested (1977: p. 292) that this “meandering or serpentine image” involved “cognitive strategies” comparable with those on the Romanelli and Parpalló engraved slabs of Upper Paleolithic age.

The intentional nature of the Pech de l’Azé II engraving is accepted by various authors (e.g., Delporte, 1990; Bednarik, 1992, 1994, 1995; Valoch, 1994; Cremadés et al., 1995; Wolpoff & Caspari, 1996); the object is cited as a precursor of symbolic representations (Donald, 1991). Other authors are ready to accept the human-made origin of the markings, but express doubts as to the representational or symbolic value of the artefact (Chase & Dibble, 1987; Bar Yosef, 1988; Stringer & Gamble, 1993). Binford (1981) questioned the artefactual nature of the object, suggesting that the engravings were root marks. Later, Marshack (1991) suggested a parallel between the Pech de l’Azé and Cueva Morin meander (see below). These markings should, he says, be interpreted as the result of “partial and limited deterioration of some of the bone surface under particular conditions of moisture, drainage, acidity . . . chemistry and perhaps bacterial action”. However, he did not provide a definite interpretation nor diagnostic features supporting his new ideas. More recently, d’Errico (1995) has proposed that markings such as those from Pech de l’Azé, Cueva Morin and the Tagliente rock shelter (Leonardi, 1988) should be interpreted as blood vessel impressions. These preliminary observations and comparisons are more fully developed in the present paper.
Cueva Morin (Santander, Spain). Echegaray & Freeman (1971) reported 11 bones from the Mousterian level 17 of Cueva Morin with meandering marks (Figure 2). They interpreted these as intentional engravings, pushing back the origins of artistic behavior to the Middle Paleolithic. Later Freeman (Echegaray & Freeman, 1973; Freeman, 1978) suggested that portions of these marks may be natural, perhaps blood vessel impressions, that were later intentionally modified and overmarked by humans. Echegaray (1988) stated that the natural causes of most of these marks have not yet been identified, although “production by human agency is undeniable” for some pieces, which he states “seem most likely to be intentionally decorative” (Echegaray & Freeman, 1971: Figure 74 and 1973: Plate D, here reproduced in Figure 2).

Stránska Skála. Valoch (1972, 1987) described as deliberately engraved a juvenile elephantid vertebral body found in Cave 8 of the Stránska Skála site. According to his description, the flat ventral side of this sacral vertebra bears one set of seven radial grooves and two large U-shaped grooves running obliquely from the upper to the lower edge of the bone (Figure 3). Valoch notes that none of the grooves can be considered a result of recent (i.e., excavation or post-excavation) damage:

“their hue and the rounded edges are identical with the rest of the bone surface. . . . Neither can they be explained by the activities of predators . . . since any other vestiges documenting their gnawing or otherwise affecting by animals are missing” (Valoch, 1987: p. 141).

Valoch believes that the radial grooves were made by stone tools. Since the radial grooves cannot be explained by any utilitarian function, he suggests that they might be interpreted as a “first attempt of aesthetic-symbolical manifestations”. The object was recently examined by Patou-Mathis (1995), who found visual examination insufficent to diagnose the origin of the
radial pattern and suggested scanning electron microscopy (SEM) analysis to solve the problem.

Bednarik (1992, 1995) accepts a non-utilitarian interpretation of the markings. Comparing them with other putative engravings from Bilzingsleben and Prolom, he suggests that the Stránska Skála radial grooves may be the early expression of a conceptual evolution of the graphic motif of convergence from sets of unconnected lines to a more succinct pattern of joined lines. For him, the Stránska Skála engravings, like those from Bilzingsleben and Prolom, are recognizable as phosphene motifs (i.e., representations of luminous visual sensations experienced by pressing the eye-balls), comparable with those found in Australian petroglyphs, and supporting his theory that the earliest art “consists entirely of phosphene motifs” (Bednarik, 1995: p. 614).

Holes

Humanly perforated bones, often interpreted as pendants, have been claimed for at least six Middle Paleolithic sites: Pech de l’Azé II and Bois Roche (France), Kulna (Moravia, Czech Republic), Repolusthöle (Austria), Bocksteinschmiede (Germany). Long bone shafts apparently with double or multiple perforations from Divje babe I (Slovenia) and H au a Fteah (Libya) have been interpreted as musical instruments. Numerous perforated animal phalanges, sometimes interpreted as whistles, have also been reported from a number of Middle Paleolithic sites (e.g., La Quina, Combe Grenal, Bocksteinschmiede, Prolom II; M artin, 1907–1910; W etzel & Bosinski, 1969; Stepanchuk, 1993). These have been discussed recently by Chase (1990), who used actualistic data to support the interpretation as carnivore punctures, a hypothesis previously put forward by Martin (1907–1910) for the majority of perforated phalanges at La Quina. However, according to Martin, at least one reindeer phalanx, presenting two symmetrical perforations on the posterior and anterior faces, was humanly-made.

According to Taborin (1990), who has re-examined this latter object, the edges of the perforations are sharp and angular, as in carnivore punctures, and cannot be due to drilling. Davidson (1990), also rejects the idea of human manufacture. We will discuss below the group of perforated bones interpreted as pendants, to the exclusion of perforated phalanges (already discussed by Chase) and perforated teeth (for which we do not have adequate documentation).
Pech de l’Azé II. This long bone fragment, found in level 4a, dated to isotope stage 5 (Grün et al., 1991) presents an incomplete hole (diameter 8.5 mm; Figure 4). It was considered as human-made by Bordes (1969), who stressed the regular shape of the perforation, the presence of a flared facet on the medullar side of the hole and the apparent presence of striations due to the drilling tool. According to Bordes (1969), the hole is incomplete because the piece was broken and polished by postdepositional abrasion. His diagnosis is accepted by Vincent (1993), who examined the piece and interprets the facet as a possible trace of opposite drilling. Vincent also noticed that the cortical face of the fragment is exfoliated. Thus, she says, it is impossible

Figure 4. (a) and (b): perforated bone from layer 4(a) of Pech de l’Azé II, scale bar=1 cm; (c) and (d) SEM micrographs showing detail of the hole surface and of the bone outer surface. Note the similarity between the two areas, and their parallel bone fibers revealed by etching and their resemblance to the surface of hyena-regurgitated bones of Figure 15(b).
to establish if the perforation was actually done by opposite drilling since the original medullar face is not preserved. The artefactual nature of the Pech de l’Azé perforation is accepted by Harrold (1989); Marshack (1988); Bednarik (1992) and Stringer & Gamble (1993) among others. Mellars proposes chemical erosion as an alternative natural cause, and attributes this suggestion to Chase (1990), although this latter author discusses only carnivore punctures on animal phalanges.

Kulna. This long bone fragment with a complete perforation (diameter 3·6 mm; Figure 5) was found in layer 7a containing a Micoquian stone industry and dated to about 45,000 BP (Valoch, 1988). Also studied by Vincent (1993), the hole is thought to be the result of opposite drilling on the basis of the flaring of both edges.

Bois Roche. This bone fragment with a complete perforation (diameter 6 mm; Figure 5), was discovered during excavation of this small cave¹ by B. Vandermeersch and was considered anthropic by Vincent (1987, 1988a, 1993). The site has yielded a rich faunal assemblage, a few Middle Paleolithic artefacts, and some putative “bone tools”, also studied by Vincent (1988a, 1993). According to Delpech (in Vincent, 1993), the piece is a femoral shaft fragment of a large ungulate. Vincent observed the presence of an oblique facet on the cortical side of the hole which she interpreted as a trace of opposite drilling. The absence of tool marks is attributed to

¹ Bois Roche, near Cognac, Charente, France is a small cave discovered in 1978, and under current excavation by P. Villa & L. Bartram (1996). At the time of the discovery the main chamber was filled by deposits almost to the ceiling, its floor covered with bones and hyena coprolites. The known part of the deposit, dug to a depth of 60–70 cm, contains a large faunal assemblage, about 4500 specimens with coordinates, and several thousand small bone fragments recovered through fine-mesh water-screening. A few Levallois flakes date the top part of the deposits to the Middle Paleolithic. Contextual evidence, i.e., very low ceiling height, abundance of coprolites and deciduous hyena teeth, combined with high frequency of gnaw marks, complete bone shafts and hundreds of small bone pieces bearing the distinctive features of partial digestion by hyenas (circular holes, scalloped surfaces, sharp eroded edges), show that the excavated macrofaunal assemblage represents accumulation by hyenas using the small cave as a den.
the alteration of the bone surfaces. Both Taborin (1990) and Davidson (1990) are skeptical of the anthropic origin of the perforation, but in the absence of direct examination they do not suggest alternative interpretations.

Bocksteinschmiede. Two pierced bones from the Micoquian layers of this cave (with an approximate date within isotope stage 5) were published by Wetzel & Bosinski (1969). One of the two bones is a wolf metapodial, 6 cm long, with an irregular hole, approximately 3 mm in diameter, in its distal epiphysis (Figure 6). Davidson (1990) thinks that the hole is a product of gnawing (or perhaps erosion of the bone surfaces), but Marshack (1988, 1991) considers it human-made. According to Marshack, the gouged area clearly visible on the distal edge of the hole on the posterior face of the bone is proof of the anthropic origin of the perforation. He argues that gnawing produces planar, flat surfaces on bones. By contrast, the gouged area is concave in shape. The text and the photo of rodent gnaw marks on a roe deer antler provided by him in support of his ideas indicates that Marshack (1991) does not distinguish carnivore gnaw marks (punctures, as implied by Davidson in this case) from rodent gnaw marks (parallel flat grooves).

The second bone, a wolf caudal vertebra, bears a perforation near one of the epiphyses; the object is now lost. Two more perforated bone fragments (Figure 6) were published by Marshack (1991), who interprets them as natural holes “perhaps bored by larvae” but nevertheless suggesting “the possibility of their use as bead or pendant”.

Repolushöhle. The Middle Paleolithic levels of this cave (Mott, 1951; Bednarik, 1992) have yielded two perforated objects, interpreted as anthropic: a long bone fragment with a complete perforation near the edge of the fragment and a wolf incisor with a perforation near the apex of the root.

Divje babe I. This femur of a young cave bear with two holes on the posterior face was found in layer 8 containing Mousterian artefact and dated to 45,100+1500–1800 (RIDL Laboratory 745; Turk et al., 1995). Another possible hole, aligned with the first two on the long axis of the bone, is present with only half its circumference preserved due to breakage. Turk et al. (1995) suggest that it may be a musical instrument, but caution that human manufacture of the perforations is not yet proven, and that the alternative interpretation of these features as carnivore punctures remain to be refuted.

Haua Fteah. A long bone shaft with a single perforation (about 7 mm in diameter) was found in the Middle Paleolithic levels of Haua Fteah, Libya (McBurney, 1969). One of the shaft’s broken edges is concave and has been interpreted as a remnant of a second hole, aligned with the first. According to Davidson (1991), the hole is a carnivore puncture.

**Analytical procedures**

To check the various conflicting interpretations we have used comparative data obtained from modern reference collections. Complementary information was provided by analog materials from archaeological sites. Both kinds of materials have been submitted to morphometric and/ or optical and SEM analysis. The same procedures have been followed for the putatively engraved and perforated bone objects.
Figure 6. Top: distal epiphysis of a perforated wolf metapodial from Bocksteinschmiede, Germany. Bottom: two perforated bone fragments from Bockstein. After Marshack, 1991 (no scale in the original publication; reproduced with the publisher’s permission).
**Table 2**  
**Hyena-regurgitated bones collected by Sutcliffe (collection kept in the Natural History Museum in London)**

<table>
<thead>
<tr>
<th>Den location</th>
<th>No. of bones collected in dens</th>
<th>No. of perforated bones</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ngorongoro Crater (Tanzania)</td>
<td>89</td>
<td>17</td>
</tr>
<tr>
<td>Alemaya (Ethiopia)</td>
<td>36</td>
<td>8</td>
</tr>
<tr>
<td>Hwange Natural Park (Zimbabwe)</td>
<td>24</td>
<td>4</td>
</tr>
<tr>
<td>Lake Abiata (Ethiopia)</td>
<td>18</td>
<td>0</td>
</tr>
<tr>
<td>Queen Elizabeth Park (Uganda)</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Mt Elgon (Kenya)</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>172</td>
<td>32</td>
</tr>
</tbody>
</table>

**Grooves**

We examined bones of large and medium-sized mammals in the modern osteological collection of the Quaternary Institute in Bordeaux in search of surface features mimicking anthropic engravings. Grooves of this nature have been observed on some bovid bones, such as ribs, a sacrum, and a humerus.

In search of analogous archaeological materials with natural grooves we have examined all faunal remains from two French Paleolithic sites. The large faunal assemblage of Bois Roche, an Upper Pleistocene hyena den (see above) provided four fragments of long bones (two bovid humeral shafts and two shaft fragments) with grooves. Four more bones with similar grooves have been found by us in the fauna from Pech de l’Azé II, the site which has yielded the well-known “engraved” rib studied by Bordes (1969) and Marshack (1977). Our Pech de l’Azé II sample consists of three bovid ribs from layer 9 and one bovid sacrum from layer 7. Another piece, a bovid humeral shaft fragment from Roc de Marcamps, a Magdalenian rock shelter (Gironde, France; Lenoir, 1983), was kindly given to us by Michel Lenoir.

Bones from the osteological collection of the Quaternary Institute and from the Paleolithic sites were examined with a reflected light microscope; selected areas were replicated with Provil L elastomer (Bayer, Leverkusen, Germany). Positive casts, made in RBS resin (T2L Chalabre, France), were mounted on metal supports, coated with gold-palladium and observed with a SEM 840A Jeol (Bromage, 1987; d’Errico, 1988). The “engraved” rib from Pech de l’Azé II, kept in the Prehistory Museum at Les Eyzies, France, was submitted to the same treatment; three areas of the rib internal face were replicated and observed with the SEM.

**Holes**

Our reference collection consists of 172 partially-digested bones collected by Sutcliffe (1970) from spotted hyena dens in Africa, now kept in the Natural History Museum in London (Table 2). As indicated by Sutcliffe (1970) (see also Kitching, 1963; Kruuk, 1972; Brain, 1981; Horwitz, 1990), adult hyenas frequently regurgitate indigestible materials; piles of bone, tooth and hoof fragments packed with masses of hair were found by him at den entrances. According to Sutcliffe (1970) distinctive features of regurgitated bones are: scalloped bone surfaces, knife-sharp edges between two eroded faces and small circular holes. Not all these features are present on all bones.

Complementary information is provided by materials found in Pleistocene hyena dens. The richest assemblage is provided by the site of Bois Roche where recent excavations have yielded...
more than 3500 bones and bone fragments recorded with Cartesian coordinates and about 30,000 bone splinters recovered through fine-mesh water screening. We have examined the entire assemblage and identified more than 400 fragments showing perforations and a variety of surface modifications suggestive of partial digestion and regurgitation by hyenas (for other kinds of bone modifications by hyenas see Sutcliffe, 1970; Klein, 1975; Richardson, 1980; Brain, 1981; Horwitz & Smith, 1988; Cruz-Uribe, 1991; Lyman, 1994).

The following variables were recorded for both modern and Pleistocene samples: maximum length and thickness of the bone fragments, type of bone tissue (compact or spongy), numbers of holes per fragment, and hole morphology (with complete or incomplete circumference). Hole diameters were recorded with a digital caliper to a precision of 0.01 mm. For comparison we measured diameters of nutrient foramina on Bois Roche bones of large size and no traces of digestion.

Characteristics of the Pleistocene bone surfaces were studied with optical and scanning electron microscopes, using replicas. SEM analysis of bones regurgitated by hyenas from Sutcliffe's collection was carried out at a low voltage (15 kV) on the uncoated originals. Molds of two specimens clean enough to be replicated without removing adhering hair were made using the same procedures described above and observed under SEM.

The “perforated” bone from Pech de l’Azé II (Bordes, 1969), kept in the National Museum of Prehistory at Les Eyzies, France, and the Bois Roche specimen (Vincent, 1988a), kept in the Quaternary Institute in Bordeaux, have also been submitted to microscopic analysis. Published photos and descriptions of the “perforated” piece from Kulna, the specimen diagnosed as human-made by Vincent (1993) have been used to record variables such as length, hole diameter, hole morphology, and presence of diagnostic features of hyena-regurgitated bones.

Results

Grooves

Bones from the sites of Bois Roche and Roc de Marcamps (Figure 7) show the same meandering and branching pattern described by Marshack (1977) and Freeman (1978) from Pech de l’Azé and Cueva Morin (Figures 1–2). These patterns are formed by double and triple (occasionally up to five) parallel grooves between 500 µm and 1 mm apart from the main one; the central groove is always deeper and wider. Groove segments can be rectilinear or curvilinear and join either obliquely or perpendicularly.

When observed with a SEM [Figure 8(b), (c)] these grooves show rounded edges and U-shaped sections; their walls show a number of funnel-like openings of different sizes. In some cases the grooves appear to tunnel under the surface of the bone, as also observed by Marshack (1991) on the Morin bones. Our photos indicate that the grooves merge perfectly into the bone surfaces and that they are natural features. It is clear that grooves should be interpreted as blood-vessel impressions; the funnel-like openings correspond to capillaries. This interpretation is confirmed by the findings of similar grooves on the surface of modern bones of various species from the osteological reference collection in the Quaternary Institute at Bordeaux. Figure 8(a) shows the impression of a vascular groove on the surface of a modern bovid humerus displaying the same features (rounded edges, U-shaped section, funnel-like openings) observed on the archaeological specimens. The same kind of grooves (occurring singly or in groups) have been observed on a large sample of human tibiae from Anglo-Saxon cemeteries by Wells (1963). He noted that 35% of his sample presented single channels, 40% had double channels, and the rest had three or more channels. He explains the single channels as marks
Figure 7. Meandering grooves on bovid humeral shafts from the archaeological sites of Bois Roche [(a), (c)] and Roc de Marcamps (b). Scale=1 cm.
Figure 8. SEM micrographs of blood-vessel impressions observed on the surface of bovid humeri from the osteological reference collection of the Quaternary Institute of Bordeaux (a) and from the archaeological site of Bois Roche [(b), (c)]. (a) Scale bar = 100 µm; (b) scale bar = 1 mm; (c) scale bar = 100 µm.)
caused by a single vessel, while multiple channels would be due to an artery accompanied by one or two veins.

Microscopic analysis of the internal face of the Pech de l’Azé rib reveals two different classes of marks. The first group is composed of subparallel, curvilinear grooves [Figures 9(a) and 10(a)] forming an interconnected pattern. In close-up view, these grooves possess rounded edges, a U-shaped section and several small openings [Figure 9(b)], quite similar to the natural features in Figure 8 described as vascular grooves.

The second group comprises straight or slightly curved sharp striations, of different widths, lengths and orientation, isolated or organized in parallel sets [Figure 10(b)]. These striations, which cover the entire surface of the bone, are traces of heavy mechanical abrasion which has obliterated most microscopic anatomical features of the bone surface. In Figure 9(c) a sharp double horizontal striation crosses parallel smooth grooves; the intersection of the two markings clearly indicates that the thin slicing or trampling mark overlays the vascular groove, partially obliterating its walls.

Note also that none of the grooves of Pech de l’Azé show the characteristics of experimental engravings produced by a flint point, such as internal striations, sharp edges and angular sections (Shipman, 1981; d’Errico & Cacho, 1994). Three other bovid ribs from layer 9 of the site show, on their internal face, vascular grooves identical to those on the “engraved” rib. These bones were not noticed by Bordes (1969).

In the faunal collection from Pech de l’Azé we have found a bovid sacrum showing three sets of grooves on the ventral face of the first and second sacral vertebrae (Figure 11). Two of the sets have grooves arranged in a radial pattern, converging toward the fusion line between the first and second sacral vertebrae. This pattern is clearly analogous to the one described on the Stránska Skála sacral vertebra, in terms of radial disposition of the grooves, their length relative to bone size, and anatomical position on the ventral face of the bone. SEM inspection of the Pech de l’Azé sacrum reveals the same feature described on the Bois Roche and modern bone sample: grooves with rounded, U-shaped sections, smooth edges, branching and capillary openings (Figure 12).

In conclusion, it is clear that the engravings on the Pech de l’Azé II rib, and probably those of Morin and Stránska Skála, are vascular grooves. They are not the result of taphonomic processes, as recently suggested by Marshack (1991), since they are present both in modern and in well-preserved prehistoric materials.

Holes
Among the hyena-regurgitated bones collected by Sutcliffe (1970), 32 of 172 (18.6%) show either single or multiple holes with regular edges and circular or elliptical shapes; some of the holes have incomplete circumferences (Figure 13). On thinner specimens borders are transparent, due to the action of the gastric hydrochloric acid which results in loss of mineral matter [Figure 14(c)]. Recent experiments carried out on rodent bones, simulating digestion by predators, suggest that hole formation is due to the combined action of acids and enzymes present in the stomach (Denys et al., 1995).

The bone fragment surfaces are generally corroded and pitted. At microscopic scale the surfaces show patches of bowl-shaped microconcavities [Figure 15(a)]; their diameters can be as much as 2 mm. Etching caused by the hyena’s gastric acids reveals the fibrous bone structure; microscopic fissure lines can be seen parallel to the bone fibers [Figure 15(b)].

At Bois Roche, 431 small bone fragments show single and multiple perforations, either complete or incomplete; hole shapes and edge morphology are almost identical to those in
Figure 9. Pech de l’Azé II rib. (a) detail showing an interconnected pattern of curvilinear grooves; (b) macrophoto of a groove with U-shaped section and openings of capillaries indicated by arrows; (c) heavily abraded vascular grooves (vertical) overlain by a double striation (horizontal) probably produced by trampling. (a) Scale=1 cm; (b) scale=500 µm; (c) scale=1 mm.
Sutcliffe's sample [Figure 14(a), (b)]. Most of these pieces show the same corroded and pitted surfaces (Figure 16); in several specimens these surfaces appear smoothed, perhaps by depositional or postdepositional abrasion [Figure 15(c)]. In the Bois Roche sample, as in Sutcliffe's hyena den material, pieces have thin, sharp edges, meeting at acute angles.

Many of the larger holes appear to be enlargements of pre-existing foramina attacked by gastric acids. In fact, in a few pieces, identifiable to anatomical region, the hole is located where a foramen is expected. Furthermore, in several cases the perforation is oblique with respect to the long-axis of the bone, a common feature of long bone nutrient foramina (Brookes, 1971).

Quantitative analysis of the Bois Roche and modern regurgitated bones confirms the strong similarity of the two samples. Perforated fragments with single holes are most common; the two samples show the same frequency distributions [Figure 17(a), (b)]. Hole diameters

Figure 10. SEM micrographs of the Pech de l'Azé rib, showing (a) two "engraved" curved lines; in (b) the "engraved" lines are crossed by sets of short and sharp striations indicating mechanical abrasion.
vary between 0.3 and 9.5 mm in Sutcliffe’s sample, and between 0.4 and 9.1 mm at Bois Roche [Figure 17(c), (d)]. In both samples the large majority of the values range between 0.5 and 4 mm. Figure 17(e), (f) shows that complete holes generally have smaller diameters than incomplete holes. This seems to be due to the fact that incomplete holes are formed near the edge of the piece where the border is thinner and less resistant to the attack of acid. Note that the great majority of the holes in the Bois Roche sample have diameters smaller than those of nutrient foramina measured on bones of the same assemblage (Figure 18). This suggests that, with the exception of those of larger size, most holes are not altered nutrient foramina.

All fragments are small and lengths generally between 10 and 60 mm [Figure 17(g), (h)]; in this diagram Sutcliffe’s sample includes all regurgitated bones, whether perforated or not. The largest specimen collected by Sutcliffe is 11.8 mm; this piece is not included in our diagram to facilitate visual comparison with the Bois Roche length diagram. Thickness is generally less than 2 cm in both samples, with most examples falling in the 0.5–10 mm class [Figure 19(a), (b)].

At Bois Roche most holes occur in compact bone [Figure 19(d)]. The same predominance of compact bone can be observed among modern regurgitated bones, whether perforated or not [Figure 19(c)]. Compact bone fragments are generally thinner than those whose spongy bone is present [Figure 19(e), (f)]. The lower proportions of spongy bone fragments and their relatively greater thickness appear to be due to differential preservation because thin spongy fragments have a lower probability of survival. In both samples single holes occur most frequently in compact bone, which must be a consequence of greater resistance of compact bone to chemical action [Figure 19(g), (h)].

On the basis of comparisons with Sutcliffe’s hyena-regurgitated samples we conclude that the Bois Roche perforated bones are also hyena-regurgitated fragments. That these bones have been regurgitated by Pleistocene hyenas, that they have been submitted to postdepositional and other long-term processes (such as sediment compaction and collagen loss), and that they
were deposited in a limestone cave makes the Bois Roche sample particularly useful for comparisons with archaeological materials from limestone caves frequented by Pleistocene hyenas.

It is now possible to say that features, typical of hyena-regurgitated bones are present on archeological specimens previously interpreted as humanly perforated. Corroded surfaces can be seen on the ulna, Bois Roche (Vincent, 1988a) (Figure 5), Pech de l’Azé II (Figure 4(c), (d)) and Bocksteinschmiede (Figure 6 top); pits and/or bowl-shaped microconcavities are also visible on the Bois Roche and Pech de l’Azé specimens. Thin, sharp edges are present on all the specimens. Holes on the Bois Roche and Pech de l’Azé bones have cylindrical sections with straight edges, like bones digested by hyenas, and unlike Upper Paleolithic and experimental perforations produced by rotation of a flint point. The latter pieces have conical or biconical sections. None of the putatively perforated pieces show the striations and scraping marks

Figure 12. SEM micrographs of a bovid sacrum from layer 7 of Pech de l’Azé II. Notice the branching pattern in (a); the arrow points to the area enlarged in (b).
associated with the use of stone tools, as documented experimentally and by Upper Paleolithic perforated objects (Stordeur, 1979; d'Errico et al., 1983). The parallel striations purportedly produced by a drilling tool ("stries parallèles creusées par le silex tournant") noted by Bordes on the Pech de l’Azé specimen are the result of chemical alteration of the bone fibers, as demonstrated by the fact that the bone outer surface and the hole inner surface have identical morphology [Figure 4(c), (d)]. The same morphology can be observed on modern and fossil hyena-regurgitated bones (Figure 15).

The oblique flared facet on the external face of the Bois Roche specimen is clearly indicative of a nutrient foramen entrance point. The incomplete hole of Pech de l’Azé was described by Bordes as broken after manufacture and utilization. However, the bone edges adjacent to the hole meet at an acute angle, with no evidence of fracture, bearing instead a very

Figure 13. (a) Bones of juvenile wildebeest from Ngorongoro Crater (Tanzania), partly digested and regurgitated by spotted hyenas (courtesy of A. Sutcliffe), scale=1 cm. Notice the hair inside the larger specimen. The specimen at the top has two adjacent incomplete holes. (b) Bone fragments regurgitated by hyenas from Queen Elizabeth Park (Uganda), with single, multiple complete and incomplete (at left) holes; scale bar in cm.
close resemblance to the sharp edges of incomplete holes on hyena-regurgitated fragments [Figure 16(b)].

The length and hole diameters of all these specimens fall in the size range of hyena-regurgitated bones [Figure 17(d), (h)]. The single large perforations observed in these specimens is not proof of their human manufacture, since single holes are very common among hyena-regurgitated bones [Figure 17(a), (b)]. The position of the hole at one end of the bone, the regular morphology of the hole, and the symmetrical shape of the piece, are all characters that can be found together in some of the hyena-regurgitated specimens, such as the piece depicted in Figure 20 and several in Figure 16(a).

The Bocksteinschmiede perforated wolf metapodial requires a separate discussion. The hole morphology is irregular and does not resemble our reference material. The opposing perforations on the posterior and anterior face of the bone and their position at the articular end of the bone are clearly suggestive of carnivore punctures (as noted by Davidson, 1990). In contrast to Davidson, we believe that the erosion of the bone’s distal end, described by him as postdepositional, is, at least in part, the effect of partial digestion of a previously punctured bone. Chase (1990: Figure 5) illustrates a cervid phalanx punctured near the distal end and subsequently digested by a canid. The action of the gastric acid has resulted in marked alteration of the compact bone around the hole exposing the spongy tissue below. The hole and erosion observed on the Bocksteinschmiede piece closely resemble those on the object illustrated by Chase. The gouged area near the hole edge, proof of anthropic origin for

Figure 14. (a) SEM micrograph of a marginal hole on a bone fragment regurgitated by a spotted hyena, Sutcliffe’s sample. (b) Marginal hole on a regurgitated bone fragment from Bois Roche, (c) edge of a thin bone fragment regurgitated by spotted hyena showing a transparent border, due to the action of the hydrochloric acid, Sutcliffe’s sample [(a)-(b), scale=1 mm, (c) scale=200 µm].

20...
Figure 15. (a) Corroded surface on a regurgitated bone fragment from a hyena den near Alemaya (Ethiopia); macrophoto of a resin replica seen in transmitted light. (b) Corroded surface on a hyena-regurgitated bone fragment from Sutcliffe's collection, seen with a SEM; scale=500 µm. (c) SEM view of the corroded surface of a bone fragment with multiple holes from Bois Roche.
Figure 16. Bone fragments from Bois Roche with single complete (a), single incomplete (b) and multiple (c) holes. Scale=1 cm.
Figure 17. Frequency distributions of selected variables in the Bois Roche and Sutcliffe's samples. (e) and (f) Complete holes; (□) incomplete holes.
Marshack (1991), is also present on Chase’s object. Thus, the Bocksteinschmiede morphology is better interpreted as a consequence of the combined effects of gnawing, partial digestion and postdepositional erosion (which has played no role in modifying Chase’s specimen). It is important to note that carnivore activity is documented at the German site by two other perforated bone fragments, described by Marshack as “perhaps bored by larvae”, and possibly used as pendants. These two fragments actually display all of the features of regurgitated bones: small size, corroded surfaces, pits, and thin sharp edges (Figure 6 bottom).

The Repolulstöhle perforated long bone fragment is known to us only through the drawing published by Bednarik (1992) and a short description, with no details on possible manufacture traces. We are, therefore, not really in a position to suggest an alternative interpretation of this object.

The DivjebabeI perforated bear femur cannot easily be interpreted as a hyena-regurgitated bone due to its large size (11 cm), and to the hole diameters (about 8 mm), which put this specimen at the upper limit of known distributions for hyena-regurgitated bones. The hypothesis of carnivore punctures was not excluded by the authors (Turq et al., 1995). Although they did not recognize gnaw marks on this piece, the crenulated morphology of one broken edge of the bone suggests to us carnivore gnawing. The Haua Fteah bone has been illustrated with a photo by Davidson (1991: Figure 1). No traces of stone tool marks can be detected in this photo. The bone surface, however, is heavily exfoliated. Davidson’s interpretation that this is a carnivore puncture is supported by the morphology of the internal walls of the hole, which exhibits splintered and depressed bone lamellae. This suggests to him the action of a carnivore tooth. Although this morphology could also be the result of postdepositional exfoliation of a pre-existing hole, we agree with Davidson that there is no evidence of human intervention.

In summary, the size of the bone fragments, the presence of corroded surfaces associated with pits and bowl-shaped microconcavities, the occurrence of thin edges meeting at acute angles, and the diameters and general morphology of the holes, demonstrate that pieces like

![Graph](image-url)

Figure 18. Range of diameters in anatomical holes in the Bois Roche faunal assemblage.
Figure 19. Frequency distributions of selected variables in the Bois Roche and Sutcliffe’s samples. (e)-(f) (□) Compact; (▼) compact and spongy; (▲) spongy.
Kulna, Pech de l’Azé and Bois Roche are not intentionally perforated, but are bone fragments partially digested by hyenas.

**Discussion**

Natural causes have already been suggested for grooves in bones such as those from Pech de l’Azé II and Morin. As noted above, Binford (1981) thought that they could have been caused...
by plant roots etching the bone surfaces. Chaix (in Baud, 1986: p. 143) and Morel (1986) report grooves with rounded sections produced by the action of carnivorous mollusks on bone surfaces. None of the grooves on the specimens discussed here can be attributed to these causes. Figure 9(b) shows capillary openings in the groove which are not consistent with root marks or marks produced by gastropods. SEM photos published by Andrews (1990) of root marks on a cow’s rib clearly show smooth, uniform walls with no openings inside the channel. In the Natural History Museum in London we have observed modern bone pieces collected by Sutcliffe with roots still adhering to the bone surface. These grooves also have smooth walls without openings.

Shipman & Rose (1984) have shown that vascular grooves on bovid distal humeri can mimic cut marks. On human tibiae these grooves have sometimes been interpreted as a pathological phenomenon or as traces of surgical operation done with stone tools (Møller-Christensen, 1955 and Wakefield & Dellinger, 1937 in Wells, 1963). Our work shows that vascular grooves, that can be found in other anatomical regions of humeri, on other kinds of bone (i.e., ribs, vertebrae), and with much more complex patterns, have been confused with deliberate engravings.

Freeman (1978) has suggested that the Cueva Morin grooves might, in fact, be vascular grooves intentionally modified and overmarked by humans. This statement can be accepted only when a microscopic analysis documenting the occurrence of tool marks overmarking the grooves is undertaken.

In addition to those already discussed above, a number of natural processes may produce holes on bones. Perforations by mushrooms and bacteria, experimentally reproduced by several authors, and identified on fossil bone (Baud, 1986), are too small (between 1 and 10 µm) to be of relevance for this paper. Beetles of the genus Dermestes, in their larval state, bore into a variety of organic materials (Hinton, 1945; Jodry & Stanford, 1992) producing holes 6 mm in diameter. Even larger holes (8–10 mm) are reported by Kitching (1980) and attributed to carrion beetles. These kinds of hole are produced in long bones in order to use the inner cavity as a pupation chamber. Only bones thus perforated and postdepositionally broken into flat fragments could mimic pieces studied in this paper. More importantly, the archaeological pieces show features such as corroded and pitted surfaces and thin edges which clearly point to the action of hyenas.

Final remarks

Although we have not been able to examine all putative engraved and perforated bones of Lower and Middle Paleolithic age, our survey seems to indicate a difference between these two categories of objects. Some of the bones with either notches or single stroke lines illustrated by photos appear to be strong candidates for being true human-made artefacts, while none of the published so-called perforated bones appear to possess convincing attributes of human manufacture. We are not denying the possibility of non-utilitarian or symbolic behavior in the Lower and Middle Paleolithic. However, we have shown that some of these pieces have been misinterpreted, and cannot be used as evidence in favor of the emergence of symbolic behavior in early times.

We should underline the fact that our survey is limited to only one category of possible non-utilitarian behavior. Several stone objects, reported from Lower and Middle Paleolithic sites (e.g., from Bacho Kiro, Temnata, Quneitra: Marshall, 1976, 1995; Cremades et al., 1995) appear, on the basis of published photos, to bear deliberate engravings. Criteria we have
developed for the interpretation of marked bones cannot be effectively employed to verify engravings on stone. However, the general procedures followed here using actualistic and experimental data, can provide firmer foundations for arguments concerning: (1) the human origins of the marks, (2) the technical behavior documented (e.g., tool type, stroke directions, chronological order of markings), and (3) the significance of the behavior with respect to the problem of the origin of symboling.

We have gained important insights by systematic examination of the assemblages from Pech de l’Azé II and Bois Roche, two sites that have provided some of the objects discussed here. Visual inspection of the bone pieces in search of similar features, and knowledge of the assemblage depositional context are essential elements to consider in understanding the nature and the significance of apparently exceptional pieces. In contrast, the usual procedures followed by scholars in describing “art” objects has been to concentrate attention on these unique findings, without systematic analysis of the rest of the assemblage. A comprehensive overview of the assemblage is necessary to eliminate the possibility that the piece, far from being an idiosyncratic example of a rare behavior, is only an individual within a population of similar but less striking phenomena.

A clear understanding of the problem of art origins has been made difficult by the idea that proof will come from the accumulation of individual cases. Since most of the cases consist of objects of unverified human manufacture or of unverified behavioral significance, their quantity should not be considered as an element of proof (Bednarik, 1992, 1995).

An aspect we have not treated, but one that should always be carefully considered prior to acceptance of a piece as documenting early non-utilitarian behavior, is the stratigraphic provenience and cultural attribution of the object. The small size of many of these objects and the fact that sites often contain overlying Upper Paleolithic levels, are factors not to be overlooked. Trampling experiments (Villa & Courtin, 1983; Giitord-Gonzalez et al., 1985) suggests that vertical displacement of small objects is a likely occurrence in sediments unconsolidated at the time of occupation, causing mixing of materials belonging to two separate levels. At several stratified sites refitting has demonstrated vertical displacement of materials up to 1 m, and across distinct excavation levels (e.g., Terra Amata, Lazaret, Hortus, Grotte Vaufrey, Lunel Viel; Villa, 1982, 1983; Patou, 1984; Geneste, 1988; Le Grand, 1994).

In sum, we believe that a detailed, validating analysis of each object interpreted as an early manifestation of non-utilitarian behavior is a necessary prerequisite to any discussion of their significance for the evolution of human cognitive abilities.

Acknowledgements

This research was made possible in part by grants from the L. S. B. Leakey Foundation and the French Ministry of Culture to Paola Villa for the excavation and analysis of the Bois Roche materials. We owe a special debt of gratitude to Anthony Sutcliffe for his permission to study his collection of hyena-regurgitated bones, and for very helpful discussions during the preparation of this work. Our thanks also go to Jerry Hooker, Curator of Vertebrate Paleontology in the Natural History Museum of London. We thank Jean-Jacques Cleyet-Merle, Chief Curator of the Les Eyzies Museum, for facilitating the study of the Pech de l’Azé II rib and perforated bone. The Pech de l’Azé II faunal assemblage was studied thanks to the kindness of Françoise Delpech. The Roc de Marcamps and Camiac material was generously given to us by Michel Lenoir. We thank three JHE referees and Terry Harrison for very useful, critical comments.


