Solutrean laurel leaf production at Maîtresaux: an experimental approach guided by techno-economic analysis

Thierry Aubry, Bruce Bradley, Miguel Almeida, Bertrand Walter, Maria João Neves, Jacques Pelegrin, Michel Lenoir and Marc Tiffagom

Abstract

Large-sized Solutrean laurel leaf typology has been defined on the basis of the exceptional pieces found at Volgu, France, in 1874. The geographical distribution of this rare type of large bifacial piece is limited to the border of the French Massif Central. Located at the northern limit of this distribution area, the Maîtresaux site provides new data on the reduction schemes of these pieces. Refitted sequences indicate that the Solutrean presence was motivated by the exploitation of local flint resources to produce reserves of lithic tools and/or blanks, elements for composite projectiles and preforms for exportation and later finishing and use/retouch elsewhere. Results of techno-economic and spatial analyses are compared with those of an experimental project, mostly centred on laurel leaf techno-economy. This integrated experimental approach strongly contributes to the on-going social interpretation of the Maîtresaux group, allowing us better to characterize and quantify the remains of laurel leaf reduction processes. Also produced were in situ ‘undisturbed’ knapping features for taphonomic reference and interpretation.

At the site scale, experimental work coupled with spatial and techno-economic analysis is relevant for the interpretation of different geoarchaeological, technical and social aspects of the archaeological record. At a regional scale, experimental work on the available raw materials in each geographic zone is required to clarify issues related to raw-material procurement, exploitation and circulation, such as regional lithic resource exploitation strategies and inter-site discontinuities of production.

Keywords

Solutrean; Maîtresaux; experimental; laurel leaf; palaeo-ethnological.
The Maitreaux record, in the context of Solutrean large laurel leaf production

In Philip Smith’s typology of Solutrean laurel leaves a ‘type J’ (1966: 53) was defined on the basis of (at least) fifteen pieces, ranging, when complete, between 25 and 33cm (Plate 1), found at Volgu (Saône-et-Loire, France) in 1874 (Chabas 1874; Cabrol 1940; Masson 1984; Aubry et al. 2003a: 245). The geographical distribution of this peculiar and rare type of large bifacial piece is limited to the border of the French Massif Central, where raw material of the needed quality and morphology is available (Aubry et al. 2003b, in press a). However, additional criteria besides raw material availability must be relevant to this geographic distribution, since some sources of large-sized flint nodules in the Iberian Peninsula known by the Solutrean knappers were never exploited to produce these tools. This was the case even though their size allowed it and they were in fact used for the production of large foliated pieces during the Chalcolithic (Forenbaher 1999).

Located at the northern limit of this area around the Massif Central, the Solutrean site at Maitreaux lies along a small tributary of the Claise River that cuts through Upper Turonien limestone degradation formations bearing large nodules of an excellent flint (Plate 1). The excavation of the site, between 1994 and 2005, provided new data on the association of this type of laurel leaf (generally attributed to a Middle Solutrean phase) with shouldered points, which in French stratigraphic sequences are limited to the late Solutrean (Peyrony and Peyrony 1938; Smith 1966). Spatial and statistical analyses

Plate 1 The Maitreaux site and the drainage basins of the northern area of the Massif Central and (right) foliated piece from the archaeological cache of Volgu (photo: Laurent Klaric/Jean-Baptiste Peyrouse; courtesy of the Musée d’Archéologie).
of the circa 60,000 flaked stone items recovered during the excavation show no evidence of significant post-depositional alterations. This was confirmed by micro-morphological analyses that detected a dual aeolian and low energy alluvial deposition process of the silty sediment covering the lithic remains (Liard 2004: 220–1; Aubry et al. in press b). Furthermore, technological analysis of the recovered lithic remains permitted the direct reconstruction of (most of) the production scheme and inter-site organization of the production sequence of ‘type J’ laurel leaves manufactured at Maîtreaux. This is where most of the reduction sequence was carried out and preforms were exported from the site for finishing elsewhere. From this we have also inferred the phases of production conducted at other sites (Aubry et al. 1998: 181; Almeida 2005: 42).

A problem-oriented experimental project, integrated with spatial and techno-economic analysis

The micro-stratigraphic and palaeo-ethnological reconstruction of the Maîtreaux Solutrean group

The abundance of technological data and the excellent preservation of spatial information, exceptional for a Late Glacial Maximum site, permit a micro-stratigraphic reconstruction of the Solutrean occupations of Maîtreaux, although restricted to activities represented in the mineral record, since no organic remains were preserved (Almeida 2005; Almeida et al. 2007: 42–4).

Based on this micro-stratigraphic reconstruction and on the resulting information about the related technical activities occurring in complementary knapping pauses, a preliminary palaeo-ethnological interpretation of the Maîtreaux Solutrean group(s) has been proposed, focusing on economic strategies and social organization at a regional scale (Aubry et al. in press a). The results of the techno-economic and spatial analyses of refitted sequences indicate that the Solutrean presence at Maîtreaux was motivated by the exploitation of local flint resources to produce reserves of lithic tools and/or blanks, elements for composite projectiles (shouldered points and backed bladelets) and preforms (laurel leaves) for export from the site and later use/retouch, as exhibited by (1) the clear excess blade production in view of the relatively rare blade tools recovered on the site, (2) the scarcity of final shaping flakes, (3) the unfinished character of the pieces found at the site and (4) the recurrent manufacturing fractures on these pieces (Aubry et al. 2003b).

This attempt to recover palaeo-ethnological information from lithic technological data is based on a systematic refitting programme, technological analysis of the refitted sequences and raw material economy. Naturally, such an archaeological record and research objectives constitute the ideal situation to develop an experimental programme, because: (1) technological observations made on the archaeological material will call for external testing, and thus feed the experimental programme with specific questions; and, on the other hand, (2) the abundance of technological data in the archaeological record acts as a close control of the relevance of the experimental results.
Many hands, many heads on experimental work: choosing diversity and exchange rather than stability

Thus, the on-going multidisciplinary research project of Maîtreaux includes an experimental programme for which a ‘Solutrean knapping group’ has been formed, integrating knappers of distinct backgrounds and diverse knapping experience, including Thierry Aubry, Miguel Biard, Jean-Guillaume Bordes, Bruce Bradley, Michel Lenoir, Serge Maury, Michael Miller, Jacques Pelegrin, Marc Tiffagom and Bertrand Walter. This group was not intended to represent the variability that could be expected in a Solutrean knapping situation. Rather, the aim was to provide us with diversified answers to the problems presented to the knappers, rather than restricting the possible solutions to the technical repertoire of just one or two knappers. The (accepted) consequences derive from the fact that we constitute a culturally (in terms of technical background) much more heterogeneous group than we would expect to see in any archaeological record. This came, in fact, to be reflected in the significant variability of technical solutions and even of production concepts among the group’s products (Plate 2 and Fig. 1).

Nevertheless, this was not considered a troubling problem because we never intended to use the whole group’s experimental products as any kind of reference for a pre-historic group. On the other hand, if the experimental sessions were to be continued, we expected to observe some reduction of the group’s internal ‘cultural’ diversity, as technical knowledge would be exchanged during these sessions and all would progressively benefit from the accumulated experience of the more skilled knappers.

Plate 2 A sample of the diversity of morphology, technology and skill level within the products of the experimental group.
The Maîtreaux experimental protocol principles and direct reference to archaeological data

Although designed to reduce to a minimum interference with the knappers during knapping, the experimental protocol adopted included setting standards for the variables tested in order to produce a useful analogue. As a fundamental premise, considered an indispensable condition for the applicability of the experimental work to the specific archaeological problems, the protocol requires the exclusive use of archaeologically compatible raw materials, knapping tools and techniques (Pelegrin 1984, 1991). The use of recovery techniques and recording methods similar to those used in archaeological excavation allows us to make direct comparisons with the Maîtreaux record.

Our experiments are focused on the archaeological problems specific to Maîtreaux and guided by close reference to the archaeological materials from the site. The specific issues addressed include:

- **Large-sized (‘Type J’) laurel leaf technology and economy**  Technological analysis of the Maîtreaux broken large-sized performs further confirmed by archaeological refits shows two different manufacture strategies: (1) a classically identified symmetrical (bifacial) reduction scheme, with the resulting piece being produced from the central portion of the nodule; and (2) a previously unknown asymmetrical scheme, identified at Maîtreaux by technological analysis of broken performs (Aubry et al. 1998: 175) and further confirmed by refitted reduction sequences (Almeida 2005). This is where nodules were carefully selected with one very flat cortical face and reduction proceeded unifacially toward this face, removing the central region of the nodule, which frequently is coarser grained, and leaving the

![Figure 1 Ratio between initial nodule length and finished/broken preform lengths of the experimental material.](image)
subcortical higher-quality material for the finishing of the piece (Plate 3). Experimental work was designed to help determine the phasing of these reduction schemes, to clarify the specific characteristics and advantages of each one.

- **Small-sized laurel leaf technology and economy** Solutrean laurel leaf dimensions reveal a clear cluster of finished objects less than 15cm long. These pieces are frequently recovered from Solutrean sites as basal or medial fragments with hinge fracture and impact breaks interpreted as typical of projectile point breakage (Geneste and Plisson 1990: 306–7). Although direct evidence of the production of these small-sized laurel leaves is less represented at Maitreaux and relatively scarce in the Solutrean archaeological record, existing data seem to indicate a certain variability of possible options of blank selection. These include unmodified natural forms such as nodules or angular pieces, flake or laminar blanks and even broken fragments of ‘type J’ laurel leaves (Plate 4). Each of these should produce distinguishable differences in the resulting remains, with early removals from flake/laminar blanks retaining remnants of the dorsal ridges and of the bulbar surface (Plate 5). Based on experimental results a technological analysis of Maitreaux and other Upper Solutrean assemblages is currently being carried out to determine the production scheme(s) of these tools. The experimental aspect of this research aims to illuminate the advantages and constraints of different blank morphology choices and technologically characterize and quantify the residues of these approaches in order to address this question.

- **Interpretation of lithic concentrations and spatial features** Finally, the recovery of remains and spatial information of the experimental sessions is being directly compared to spatial analysis and interpretation of the techno-economic and micro-stratigraphic reconstructions of the Maitreaux occupations.
Archaeological data for the reconstruction of large-sized laurel leaf reduction sequences

The unprecedented volume of quality information about the production of large-sized laurel leaves resulting from the excavation of Maîtreaux justified a focus on the study of these tools, which bear a large interpretative potential, with social implications deriving from the group investment needed for their production. Laurel leaf production is relatively expensive, involving investments in technical learning, raw material procurement, time-consuming production, etc. In order to understand the production sequences and possible intentions, a morphometric analysis on the width to thickness ratio

Plate 4 Archaeological example of initial blank used for small-sized laurel leaf production.

Plate 5 Experimental laminar blank and examples of characteristic by-products resulting from its shaping into a small-sized laurel leaf (experiment 2006, Jacques Pelegrin).

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of laurel leaves from a range of Solutrean sites (Solutré, Pech-de-la-Boissière, Fourneau-du-Diable and Jean-Blancs), conducted by Bruce Bradley, suggested that the division of the reduction sequence into five arbitrary phases: testing, early, middle, late and finished could be a useful measure of sequential production intent. These arbitrary phases were monitored during the experimental production of laurel leaves (Fig. 2a).

Study of the Maitreaux materials indicates two clear segmentations of the production scheme (into three stages) (Fig. 2b): (1) the testing and eventual summary preforming of the nodule, mostly accomplished by mineral hammer percussion; (2) most of the reduction sequence, predominantly carried out by organic percussion, producing more or less simultaneously the thinning and the shaping of the piece, until obtaining a balanced and thin enough preform for finishing; and (3) the finishing stage, which (according to the observations made of other site assemblages) can include some pressure flaking technique towards the end of the shaping sequence.

Significantly, this segmentation of the production scheme indicated by the technological analysis of the Maitreaux refits is confirmed by spatial analysis showing that preforms were usually introduced into the site (or rather in the excavated area of the site) after

Figure 2 Archaeological data on the phasing of the large-sized laurel leaf reduction sequences. A: morphometric analysis of Solutré, Pech-de-la-Boissière, Fourneau-du-Diable and Jean-Blancs preforms and finished pieces; B: technological and spatial analysis of Maitreaux refits.
testing and eventual early preforming, and were systematically exported before the finishing phase.

On the other hand, rather than a discontinuous succession between the proposed ‘early’, ‘middle’ and ‘late’ phases, all the criteria studied indicate a continuum through the production sequences carried out at the site, even if some progression is observed along these sequences (from more expeditious to more careful platform preparation; from an emphasis on thinning to an emphasis on shaping; and so on).

** Tradition and adaptation in large-sized laurel leaf technology **

*Quantifying remains and characterizing volumetric advantages of the asymmetrical reduction sequence*

The refitting of archaeological remains indicates the use of an asymmetrical reduction sequence for some of the large laurel leaves produced at Maîtreaux (see Plate 3). The experimental reproduction of the asymmetrical scheme, followed by refitting and technological analysis of the experimental sequences, as conducted on archaeological material, have allowed us to typify and quantify the characteristic remains of this scheme (Plate 6):

- the superior face produces multiple thinning flakes with characteristic platforms and relatively flat sections, resulting from unifacial thinning of the preform. Some of the

*Plate 6* Refitted experimental sequence showing the asymmetrical reduction scheme (experiment Ws’05, Bruce Bradley).
flakes from the superior face, specifically the first removal sequence, do exhibit cortex, but the majority do not;

- the inferior face produces small flakes, with distal cortex, curved profiles and an obtuse debitage angle, resulting mainly from the preparation of the striking platforms; but
- the inferior face also produces a second type of characteristic remains: when the thinning of the superior face has been concluded the inferior face is then shaped; the first series of these thin, almost final flakes on the inferior face also retain some cortex.

Used as a hypothesis-testing tool, experimental work allowed us to clarify the technical advantages of this asymmetrical scheme over the standard symmetrical approach where the biface plane is in the centre of the nodule. As predicted by technological analysis of the archaeological material, the asymmetrical scheme allows the possibility of rapid thinning, better flaking angles, larger margins for eventual error correction, easier elimination of internal badly silicified zones and less need for continuous biface plane adjustment (Fig. 3) (Almeida 2005: 41–2).

Although this asymmetrical approach may be applied to any raw material that has one flat face, it is particularly advantageous when the material has a coarse internal zone and a high-quality sub-cortical zone, as is the case at Mâtreaux. Hence, the particular characteristics of the raw material available at the site may have decisively encouraged the development of this asymmetrical approach as a means to guarantee the best raw material available for the critical finishing phase of the reduction sequence.

The overshot technique, between errors, tactics, strategy and culture

Although in previous Solutrean studies the occurrence of overshot flaking had been interpreted exclusively as a knapping error, its recognition at Mâtreaux as a particular technique controlled by the knapper was preceded by the previous identification of this knapping resource as intentional in Neolithic bifaces from Qatar (Inizan and Tixier 1978) and in the New World Palaeoindian context (Bradley 1982). Later, this procedure was also

![Figure 3](image-url)
identified in archaeological assemblages of other laurel leaf sites in France (Bradley and Stanford 2004: 465). At Maîtreaux, it was at first identified in the context of error correction procedures (Almeida 2005: 59–60), along with other correction and specific shaping procedures (Fig. 4).

The experimental programme thus focused on characterizing the conditions and effects of this particularly skill-demanding technical procedure. Meanwhile, we should stress that at Maîtreaux the use of this technique occurs at a low frequency, as it does not constitute (at the Maîtreaux site) a systematic thinning technique, but rather an alternative technical option. Even if technological analysis of archaeological refits shows a strategic use of the overshot technique by the Solutrean knappers of Maîtreaux, this is in addition to its described tactical use as an error correction procedure, for example as a means of removing a ‘square’ edge on the opposite edge of the blank. In fact, experimentation has shown that, once the overshot technique has been added to a knapper’s repertoire, it may be used to serve different tactical or strategic objectives and even be included in the knapper’s plan from the first evaluation of the nodule, in order to solve a volumetric deficiency in an otherwise suitable piece of raw material. This situation has been recognized in the archaeological material (Plate 7).

So, the particular advantages of using this technique include its being a means of dealing with otherwise unrecoverable mistakes (such as stacking), an efficient means of removing square edges and a method of rapid reduction (‘rapid’, in terms of efficiency of knapping motions). On the other hand, the main disadvantage of the overshot technique is that it is

Figure 4 Archaeological examples of error correction procedures from Maîtreaux. A: burinant flaking; B: overshot flaking.
difficult to control and can be mastered only through long experience and knapping skill, since, to remove controlled overshot flakes, platforms have to be carefully prepared and any mistake in preparation or striking may result in failure.

Hence, the value of such techniques (like overshot and apical burinant flaking) as relevant cultural markers could be discussed on the basis of their complexity, skill exigency and the risk assumed by the knappers. However, any argument on this issue demands a detailed revision of other bifacial industries from within and from outside the Solutrean
geographic and chronological frames. Such revision clearly exceeds the specific objectives of the Maitreaux experimental programme and of this paper.

Spatial analysis and palaeo-ethnological interpretation at site and regional scales

Producing in situ ‘undisturbed’ knapping features for taphonomic reference

As the focus of the Maitreaux research project is placed in a palaeo-ethnological perspective aiming for a reconstruction of the Maitreaux Solutrean group’s techno-economy, subsistence strategy and circulation patterns, a strong emphasis on internal taphonomic critique of the stratigraphic record is essential, in order to determine the anthropogenic processes of the constituents and the post-depositional degradation of the archaeological levels (Aubry et al. in press b).

The experimental programme was also designed to address this question, since the recovery of the spatial data of knapping features resulting from the experiments could produce an analogue for spatial distribution analysis of the Maitreaux archaeological remains, mainly in concentrations of lithic objects interpreted as knapping features. From a geoarchaeological perspective, this analogue was crucial in the discussion of the degree of preservation of the archaeological levels integrating these spatial features, because in some cases these archaeological features seemed to present spatial distributions frequently considered as characteristic of post-depositional disturbances of the original features.

For this analogue to be applicable two conditions were required:

- that the anthropogenic factors affecting the original constituents of these knapping concentrations had to be controlled: these included the knapper’s work position, activity tools (such as seats), production objectives, spatial distribution of knapping activities and the knapper’s interventions on the feature during knapping; and
- that the structure of the spatial features resulting from the experimental knapping should be completely independent of all the environmental factors (such as slope percentage, slope direction, vegetation cover, erosion agents and time) from which we intended to differentiate the anthropogenic factors.

The aim of the test was to determine if a knapping concentration completely unmodified by any secondary post-depositional process can mimic those spatial features otherwise interpreted as evidence of taphonomic disturbance. Hence, a third condition of the test was that the knappers whose spatial distribution features were being used for this purpose should not be aware of the objectives of this test.

The results obtained clearly showed that, considering some (limited) reworking by cryoturbation, the spatial features identified at the Maitreaux archaeological site fell within the variability of those resulting from completely controlled and undisturbed experimental knapping features, hence confirming the excellent degree of preservation of these archaeological levels.

Generally, except for some isolated individual pieces that land on an external semi-circle of around 3 meters (or occasionally more) from the knapper’s position, the undisturbed
spatial features resulting from a continued and long enough knapping activity are structured around a central concentration of lithic remains in front of the knapper (up to 80–100 cms in diameter for the preformed laurel leaf experiments) where most of the flakes and debris accumulated (Plate 8). Closer to the knapper a smaller cluster concentrates most of the smallest flakes, debris and flint dust (mainly resulting from edge preparation procedures) (Boëda and Pelegrin 1985; Boëda et al. 1985). These feature characteristics, however, may significantly vary according to each knapper’s specific routines: for instance, the main concentration may be divided in two asymmetrical clusters if the knapper uses one of his legs as a support.

In addition, some of the knapping features resulting from these experiments, independent from environmental and taphonomic factors, clearly mimic spatial

Plate 8 Examples of spatial characteristics of knapping features. A: archaeological; B: experimental.
distributions that are systematically interpreted as evidence of post-depositional disturbances such as bimodal distributions, preferential orientations of some of the artefacts, imbrications and wall effects and grain size segregation, thus recommending additional caution in these interpretations.

The first step to prediction and testing in palaeo-ethnological reconstruction at Maîtreaux

At the site scale, experimental work coupled with spatial and techno-economic analysis of archaeological material is relevant for the interpretation of different geoarchaeological, technical and social aspects of the archaeological record. Thus, it was crucial to understand various geoarchaeological aspects of the site formation processes and taphonomic degradation of the Maîtreaux archaeological levels. As stated above, this spatial facet of the experimental programme aimed at producing an objective analogue of undisturbed spatial concentrations resulting directly from knapping activities. Further development of this line of research should benefit from a direct comparison with the results of third party experimental programmes looking at the post-depositional degradation of this kind of archaeological feature.

As for the technological aspects, the experimental approach produced an essential reference to access the technical potential and particular constraints imposed by the Maîtreaux raw material and to understand each knapper’s technical and economical options and the characteristics of the specifically used reduction schemes (e. g. the asymmetrical shaping scheme).

Finally, although these issues were approached experimentally via the Maîtreaux assemblage, the results may also contribute valuable comparative information for the study of a certain number of social aspects of the archaeological record, such as intra-site spatial and functional organization, social relationships and norms and group composition (addressing the question of the knappers’ different skills and experiences).

At a regional scale, on the other hand, experimental work on the available raw materials in each geographic zone is required to clarify issues related to raw material procurement, exploitation and circulation. These include interpreting regional lithic resource exploitation strategies, inter-site discontinuities of production and, if used in a prospective way, the integration of lithic tool production with other technical and economic activities.

Concluding remarks

The integrated experimental approach represents an important initiative in the on-going micro-stratigraphic reconstitution of the site and palaeo-ethnological interpretation of the Maîtreaux group, as it addresses specific archaeological questions, developed during the previous study of archaeological material and data.

However, it should be stressed that a strict understanding of prehistoric conditions such as raw material availability, knapping toolkit and technical knowledge is necessary for this problem-oriented experimental programme to produce a significant and objective analogue for spatial organization and techno-economic options of the Maîtreaux knappers. Likewise, the material and information resulting from experimental work must
be submitted to analytical procedures similar to those used for the archaeological material. At the Maitreaux project these include time-consuming systematic refitting and technological analysis of the refitted experimental sequences, before their comparison with archaeological data.

Experimentation presents great scientific potential in archaeology, as both an exploratory and a hypothesis-testing tool. However, for the experimental work to be scientifically exploitable, its methodological difficulties and interpretative limits must be acknowledged and respected. Among the difficulties in this case are the danger of confusion introduced by variability among the knappers, which results from the lack of a common ‘cultural’ concept of technical aspects, differences in skill and technical backgrounds, and the possibility that their techniques are ‘polluted’ by knowledge of different technologies inappropriate to the Solutrean. We have tried to deal with all of these problems by including and comparing several knappers with different technical backgrounds, by communication among the knappers and especially by close control of the experiments by systematic comparison with the archaeological data.

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