# Artefact Analysis

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*Abstract*

*Historically, artefact analysis has focused on classifications and typologies. In fact, the typological approach may be considered as a particular cognitive step in the evolution of Archaeology. In this text more ambitious actual approaches of artefact analysis are described, relying on obtaining more cognitive information from artefacts. The applicable quantitative methods, which have been developed and tested to solve classical and modern archaeological problems, are detailed. Finally, a general methodology, founded on recent results in semiology, mathematical modelling and neuroscience, may be considered as a contribution to a renewed role of artefact analysis in archaeological reasoning.*

## 1. Introduction

Artefact analysis is the beginning of archaeology. In order to find an answer to the question: "what is this thing?" a question posed when curious remains or ruins were found, scientists created a new science: archaeology. Artefact analysis is a fundamental platform to nearly all formalised archaeological questions. Thus, theoretical and methodological questions concerning artefact analysis are extremely important for our discipline.

## 2. Artefact: A definition

"Artefact" is perhaps the most popular word in Archaeology. It means a "thing" manufactured by persons and discovered by archaeologists. Of course the word "artefact" is a concept. From a semiotic point of view, it means a "thing" which is not easy to identify and recognise, archaeologically speaking, a "thing" manufactured by persons in the past. Any experienced archaeologist will of course agree with such a proposition.

Firstly, an "artefact" is a physical find, manufactured by persons. More precisely, I would define an "artefact" as the result of a more or less explicit design and of a more or less controlled manufacturing process: a standard to be identified by archaeologists and a variability to be explained (hazards of manufacturing, quality, reproducibility, personal style, etc).

A surprising issue in such a definition, is that an artefact exists by itself (as a standard), but also through the success of the identification process resulting in the interaction between the archaeologists and the artefacts.

But because an "artefact" is a concept, it would be unfortunate to restrict its definition merely to physical finds. The same definition of an "artefact" may also be applied to "logical" artefacts, i.e. any set of physical finds: for example, spatial associations of artefacts, burning structures, taphonomic assemblages, working areas, burials, settlements, buildings, sites, etc.

Therefore, it is interesting to point out the similarities in the formal definition of "physical" and "logical" artefacts, but it is also interesting to emphasise the re-entering feature of the definition, hierarchically from a physical object to the totally reconstructed civilisation.

Perhaps our proposition is just a formalisation of evidence or common sense which archaeologists know well. But unfortunately, the history of archaeology provides us with thousands of examples of deceptive appearance of artefacts such as natural origin, geological alteration, manufacturing waste, random association with other artefacts, misinterpreted spatial structure, etc. History of artefacts in archaeology is also the history of diagnostic errors.

With a methodological perspective, artefact analysis is a fundamental method in archaeology, with special needs to refer to semiology, taxonomy, systemic analysis, and finally cognitive science. At any level of archaeological reconstitution, artefact analysis is directly connected with the question of artefact knowledge.

## 3. A brief history of the concept of the artefact

The history of the concept of the artefact in archaeology is strongly associated with the history of theoretical approaches in archaeology since the very beginning of this science.

At first artefacts were merely "unknown things" and for that reason, they were collected and stored world-wide in "curiosity cabinets" of the upper classes.

With the progressive discovery of the remains of great civilisations, artefacts became selected beautiful pieces from burial excavations or famous archaeological sites. In the eighteenth century these pieces were kept in large private collections, and in the beginning of nineteenth century the first museums appeared.

The influence of Natural Science during the second part of the 19$^{th}$ century and the first part of the 20$^{th}$ century has led to a concern for the European prehistory field, a concern accompanied by systematisation and classification of artefacts. Particularly important was the establishment of chronology. The concept of "fossile directeur" has been used and re-used as an apparent projection of the Darwinian theory on human systems, materialising the strong influence of the positivist approach.

The concept of "style" in Art History, whether applied to an individual or to a school, varies with time and region, and is characterised by changes in technological, social or ideological context.

In the 1960s, growing out of Linguistics and Semiology, artificial intelligence has included research on exhaustive representation of artefacts, using standardised vocabularies, indices and thesauri.

At the same time, the quantitative movement in social and human sciences based on applied mathematics, information theory and computers, found itself at the beginning of the development of artefact measuring which involved the use of numerical taxonomy and exploratory data analysis.

Archaeology was also influenced by physics, via Archaeometry and physical/chemical characterisation, used to solve problems concerning the origins of raw material, localisation of manufacturing centres and distribution of artefacts.

In archaeology (viewed as cultural anthropology, revisited in the following general movement of neopositivism and structuralism of New Archaeology after the Second World War), artefacts may be analysed as an individual, functional, social and ecological signature.

In the 1980s, experimental archaeology was concerned with an important development focused on artefact technology, use-wear analysis, paleometallurgy, dwelling reconstitution, etc.

In the 1990s, as a reaction against caricature modelisation of the new archaeology, models are seen more as a projection of the archaeologist himself onto the artefact than as a normal top-down formalisation. The post-modern archaeology, more concerned with the modelling of the modeller, is focusing on the archaeologists' views of the artefact and no more on the artefact itself.

During the same time, under the influence of Neuroscience, cognitive approaches are focusing on the interaction between the archaeologist and artefacts as a learning dynamic process, in a attempt to include both the modelling process and the empirical-inductive approaches.

As a consequence, it is impossible to debate artefact analysis without knowing in each case the exact underlying theoretical context involved. It is nevertheless possible to try to conceptualise on a higher level the formalisation of the artefact analysis in order to replace all those theoretical models as particular cases of a more general approach. This is the aim of the present paper.

## 4. Theoretical background of the artefact

Certainly some archaeologist would wonder if we are not perversely over complicating a non-complex question: a statue is a statue, a hammer is a hammer, a wall is a wall, and so on. This is generally right in all cases where identifying an artefact is trivial. But, in the more general case, identification is the first question, and that is why it is necessary to consider such a theoretical background.

This is not the place to write a new digest concerning an endless philosophical debate carrying on since Aristotle, Kant or more recently Pierce, amongst others, as regards the reality of the concept of things: Nominalism versus Realism. Do things exist because we name them or is true that we can give them a name because they exist, independently from us?

To avoid such a debate where archaeologists have no better evidence than semiologists, I would dare to put forth a personal proposition, influenced by cognitive approaches, which is a process rather than a definition:

> "Artefact existence and identification is a part of the artefact knowledge which in turn is the result of an uninterrupted interaction between the artefact and archaeologists".

The cognitive process may be formalised by a protocol, with the following steps:

- prior perception,
- identification,
- characterisation,
- naming,
- encyclopaedic knowledge,
- determination (keys to recognition).

I would like to emphasise the fact that my proposition is not only a classical one but also may be seen just as renaming various equivalent approaches, in particular two of them, the semiotic approach and the taxonomic approach.

Following Eco (1999), a semiotic approach to the question of artefact identification may be summarised by the following protocol:

- a perceptive semiosis (phenomenology),
- a cognitive type, obtained via:

  personal and informal perception,

  occurrence accumulation (implicit prototyping),

  naming
- a core content (explicit characterisation),
- a molar content (extended knowledge).

The taxonomic approach may be defined by the following protocol:

- a prior analogical perception,
- a quantitative procedure, involving:

  similarities and dissimilarities,

  description and measures,

  partition searching,

  naming
- characterisation,
- encyclopaedic knowledge.

As it is often the case in numerous sciences, apparently different approaches are very similar.

## 5. The role of artefact analysis in archaeology

Artefact analysis plays a major role in a number of archaeological constructs. The following list is not exhaustive, but representative of certainly 95 % or more of archaeological studies.

- artefact identification and classification,
- "culture" identification or assemblage of variability studies (time and space systems obtained from artefacts),
- seriation (chronology from artefacts),

- intrasite spatial analysis (artefact spatial distribution studies),
- identifying raw material sources and manufacturing centres (artefact production subsystem studies),
- anthropological studies (artefact as a functional, social, individual, hierarchical, tribal, environmental, symbolic signature),
- identifying distribution networks (artefact exchange and trading subsystem studies),
- intersite spatial analysis (artefact for territory identification, peopling, carrying capacity, demography as well as time and space changes).

It is of course obvious to say that the artefacts are of concern in all archaeological studies, but it is also important to point out that the same artefact may serve many different studies, as if an artefact was a limitless source of intrinsic information.

# 6. Artefact identification

## 6.1. The concept of type

Unfortunately the concept of types in archaeology has been neglected over the last twenty years as if the theoretical debate concerning typologies was already definitively closed. The reason for such an attitude is probably due to some Natural Sciences sterile heritage considering that artefacts remain widely defined as an existing type in an existing and definitive typology.

Semiology and cognitive sciences have fortunately enhanced the debate concerning the types and classification, allowing us to introduce some new definitions:

1. A *real type* is a type resulting from a manufacturing design, which must be statistically demonstrated on a representative collection of artefacts. Such a type exists independently of the archaeologist, who nevertheless has discovered it.
2. A *virtual type* is a type resulting from a formalisation realised by the archaeologist for a given archaeological construct. The formalisation is validated by the success of the construct.
3. A classification (or typology) is a virtual organisation of real or virtual types.

## 6.2. Intrinsic and extrinsic information

By definition, *intrinsic information* is information perceived by an archaeologist about an artefact, formalising a (and not the) representation of this artefact. The richness of intrinsic information is the result of the efficiency of a cognitive interaction between the artefact and the archaeologist. In fact, intrinsic information is not information but knowledge.

On the other hand, *extrinsic information* is information recorded from the context of the artefact: stratigraphy, spatial localisation, environment, etc. The richness of the extrinsic information is the result of the quality and the precision of the survey or excavation. Extrinsic information is archaeological information.

Artefacts, intrinsic and extrinsic information define a system. The correlations between intrinsic and extrinsic information initiate a cognitive process increasing the knowledge of the artefacts system (Djindjian 1980). This may concern both the level of the system structuration, the meaning of the intrinsic information and the explaining role of the extrinsic information.

## 6.3. The multiple representations of an artefact

Multiple representations of an artefact result from different pieces of intrinsic information the archaeologist is able to perceive as regards the artefact. While such information is knowledge, the richness of this information is the result of an uninterrupted cognitive process, having started at the beginning of the archaeological study and with no end in sight.

A non-exhaustive list is given below:

- size,
- morphology,
- physical and chemical characteristics of the raw material,
- manufacturing technology,
- manufacturing quality,
- decoration,
- function,
- use,
- value,
- social meaning,
- individual signature,
- symbolism,
- etc....

There are as many classifications as there are different sets of intrinsic information selected to describe an artefact.

Until the 1960s, lithic and ceramic typologies in European prehistory were generally built from a non-formalised description implicitly involving morphology (supposed to indicate function) and technology. Such a combination of uncontrolled intrinsic information has often produced a mixture of structurations impossible to interpret (see infra chapter 7).

Among other intrinsic information new archaeology has put the highest emphasis on function, individual signature (named style), and social meanings.

Through various separate studies recent experimental approaches have generally focused on technology and use-wear (supposed to be function), and no longer consider morphology.

But in fact, all sets of intrinsic information are potentially, independently but also correlatively, cognitive.

## 6.4. Searching for a partition

Artefact identification is achieved through the search for a real partition in a multidimensional representation of space artefacts.

The process of artefact identification was first formalised by Spaulding (1953) through his attribute analysis and by Clarke (1962) with his matrix analysis, using quantitative methods available at that time (respectively Chi-square test of statistical independence, and matrix permutation).

The revolution in multidimensional data analysis between 1965 and 1980 has finally provided algorithmic solutions to numerical taxonomy in general as well as to artefact identification. In archaeology, early methodological references are:

- Cluster analysis (Hodson, Sneath and Doran 1966),
- K-means cluster analysis (Hodson 1971),
- Multidimensional scaling (Hodson 1971, Doran and Hodson 1975),
- Correspondence Analysis with cluster analysis (Djindjian 1976),
- Principal Components Analysis with cluster analysis (Christenson and Read 1977, Whallon 1982).

Correspondence analysis is now used successfully in many countries: Boelicke et al. (1981), Bolviken et al. (1982), Moscati (1986), Slachmuylder (1985), Greenacre (1984), Scollar (1985), Ringrose (1988), Madsen (1988), Baxter (1994).

But several improvements are necessary in order to utilise the efficient algorithms and software and to realise a practical method for artefact identification (Djindjian 1991):

- selection of a single set of intrinsic information for classification,
- unambiguous definition of attributes and variables, vocabulary and measure,
- transformation of a description model in a variable list,
- adapted coding and metrics to handle simultaneous analysis of metric and qualitative variables,
- guided description (by defining an explicit protocol for choosing variables),
- searching for resonance (i.e. the minimal description for the best discrimination of clusters),
- computing the precision of the clustering, in terms of probability.
- comparison of classifications obtained for different sets of intrinsic information, recorded on the same artefacts.

## 6.5. Ceramic classification

A good example of artefact identification and classification is ceramic classification. The question is as old as archaeology itself, i.e. it has been going on since the 19th century (Montelius, Petrie, Dechelette, etc.) when ceramic classification took a major place in the archaeological corpus. Ceramic morphology, being the direct result of the design of a ceramist, is important intrinsic information with respect to a better understanding of manufacturing standards.

Historically, the quantitative methods for morphological classification of ceramics have used two different types of description: numerous measures between various selected points (for example, Mohen, Whallon) inspired by physical anthropology and profile digitalisation inspired by pattern recognition techniques.

Profile digitalisation, which can be entirely automated by a camera, has been increasingly used, and many authors have contributed to the optimisation of algorithms for a better differentiation of ceramic shapes:

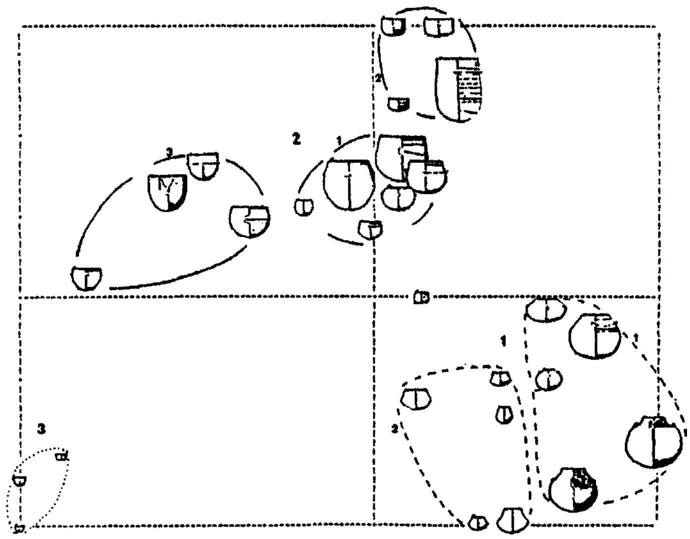

*Figure 1: Real Ceramic types obtained by P.C.A. and cluster analysis from the chalcolithic dwelling of Boussargues (Herault, France). (Giligny 1990).*

- Sliced method (Wilcock and Shennan 1975),
- Tangent-profile technique (Main, 1986),
- Extended sliced method (Djindjian et al. 1985),
- B-spline curve (Hall and Laflin 1984),
- Fourier series (Gero and Mazzula 1984),
- Centroid and cyclical curve (Tyldesley et al. 1985),
- Two-curves system (Hagstrum and Hildebrand 1990).

For example, the extended sliced method is a coding system specially adapted to separate size from shape and then to decide whether to keep or to eliminate size from the classification.

In the study of an exceptional broken (in situ) ceramic set from the chalcolithic dwelling of Boussargues (Herault, France), Giligny (1990) used a PCA with $L_i/L_{max}$ on eight profile measures. He obtained three real types interpreted as ceramics for storing, cooking and consuming food (figure 1).

In another study on 87 pieces of ceramics from the final Neolithic period at Clairvaux (Ain, France), the same author (Giligny 1990), he classified the shape and size using PCA and profile measures, and extended his classification to other intrinsic pieces of information (technology, decor), furnishing virtual types. Then he obtained by a correspondence analysis a seriation of Neolithic lacustrine sites in Eastern France between 2900 BC and 2200 BC (figure 2).

# 7. From assemblage variability studies to "Culture" identification

With the question of "Culture" identification, we penetrate the most controversial debate in archaeology, often considered as the greatest gap between European prehistory and cultural anthropology.

In the second half of the 19th century, the discovery of the stratigraphic method provided the only scientific way to establish

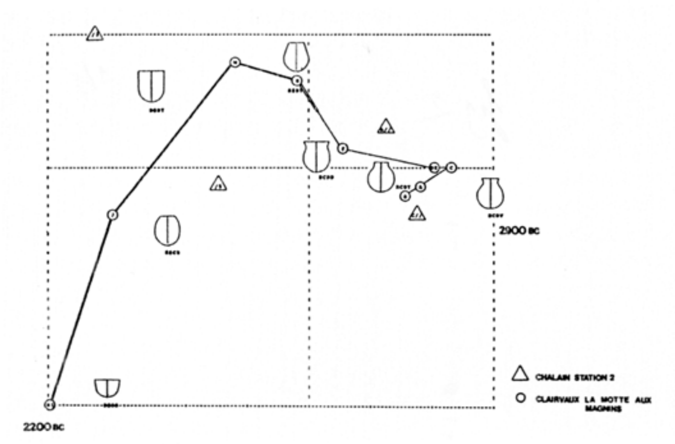


*Figure 2: Seriation by C.A. of neolithic lacustrine sites (Eastern France) from virtual ceramic types obtained by separated data analysis (P.C.A., C.A. and cluster analysis) applied on shape and size, technology and decor. (Giligny 1990).*

a (relative) chronology. The association of "fossile directeur" chronology and space permitted the definitions of a methodological approach still used today, to structure prehistoric data. But these structures, by some irrepressive semantic drift, have been rapidly interpreted in terms of an in fact never defined word: "culture" (But is it really possible to define it?):

- points like points found in Aurignac,
- Aurignacian points,
- Assemblage "du type d'Aurignac",
- Aurignacian "culture",
- the Aurignacians.

During the first half of the 20th century, the necessity to improve the use of "fossiles directeurs" with a type list, systematising the classification of prehistoric artefacts appeared: Bordes and Bourgon, Sonneville-Bordes and Perrot, Laplace, Tixier, etc.

It would take pages and pages to briefly summarise all the literature written about the complexity of the association between a typology of physical finds (lithics; bone, antler and ivory; ceramics, bronze axes, etc.) and a culture. The controversy between Bordes, Binford and Mellars concerning the Mousterian is famous. Starting from a type list, which is a mix of morphology (supposed to be functional) and technology, the first author concluded there were different subcultures, the second found different functionally specialised sites of the same population, and the third was of the opinion that a chronological evolution existed. Nobody paid adequate attention to an excellent data analysis performed by Callow and Webb (1981) which was applied to the same data used by Bordes and Binford. The study revealed the main variability of data: the first axis is an opposition between side scrapers (Quina retouch) and notches/denticulates; the second axis is an opposition between Levallois tools and others; the third axis is the frequency of bifacial points and upper Palaeolithic tools. The interpretation of this variability is rather easy: the first axis is associated with the distance for supplying good quality of flint raw material to obtain Quina side scrapers. The second axis is a technological variability in chipping flint. The third axis has a chronological significance. All three original authors failed because their methodology was faulty: Bordes because no extrinsic information was able to explain any variability in the data (stratigraphy, space, paleoclimate, etc.); Binford because the typology used was not functional, and the factor analysis sufficiently "manipulated" to obtain the expected result; and Mellars because the structure is only partially chronological.

Nevertheless it is important to point out that the key to understanding the variability in the Mousterian assemblages is the use of exploratory data analysis with repetitive attempts to associate the variability with other intrinsic and extrinsic information.

Methods for studying assemblage variability started with the development of typologies and assemblage quantification in the fifties: Bordes and Bourgon introduced well known cumulative percentage frequency graphs from sedimentology, and Laplace used histograms and the Chi-square test. However, multidimensional data analysis is the only solution.

Doran and Hodson (1966) used multidimensional scaling (as a Q-mode analysis of types), Binford (1968) used a controversial factor analysis (as a R mode analysis of types), Hodson (1969) used a Principal Components Analysis (as a Q-mode analysis of types), Graham and Roe (1970) used a canonical analysis (as a Q mode analysis of attributes), Hodson (1970) used a cluster analysis (as a Q mode analysis of types), Gower (1971) used a constellation analysis (as a Q mode method on types), Djindjian (1976) used a correspondence analysis on the abundance table and cluster analysis on factors (as a R + Q mode on types), Djindjian (1980) used a correspondence analysis on a burt matrix (as a R + Q mode on attributes). In the 1980s, virtually all major assemblages of prehistoric European Palaeolithic data were processed or revised by multidimensional data analysis, allowing major results in the structuration of the early and late prehistoric cultures (for example Djindjian, Kozlowski and Otte 1999).

The failure in understanding the Mousterian nevertheless resulted in a general movement against analytical descriptive typology, with a progressive replacement by experimental technology improving the knowledge of flint chipping process. Therefore, experimental lithic technological studies have confirmed that core reduction technology is more structuring than shaping technology in middle Palaeolithic studies; on the other hand shaping technology is much more structuring than core reduction technology in upper Palaeolithic studies. Nevertheless, some dogmatic attitudes suggest that only core reduction technology is structuring, representing a will to change a paradigm and not to improve Palaeolithic structurations and their explanations. Such a movement is also accompanied by a methodological approach voluntarily limited to only refitting core reduction and opposed to any formalisation of any description or quantification for comparison and statistics.

Such a regression is certainly temporary, when appropriate methodology has already been proposed (Djindjian 1980, 1986). A good example is given by the studies on Aurignacian structuration in La Ferrassie rockshelter (Dordogne, France) by a technological tool description without any reference to typology (3). The technological description is based on different types of blank retouch (lateral retouch, truncation, denticulation, endscraping retouch, endscraping bladelet retouch, etc.) and different types of burin reduction sequences (for a detailed study of burin reduction technology, see Djindjian 1996). The result is a structuration of Aurignacian in Perigord, in five technological (intrinsic) facies revealing a chronological (extrinsic) evolution and strongly correlated with (extrinsic) paleoclimatic variations (I: cold; II = Arcy;

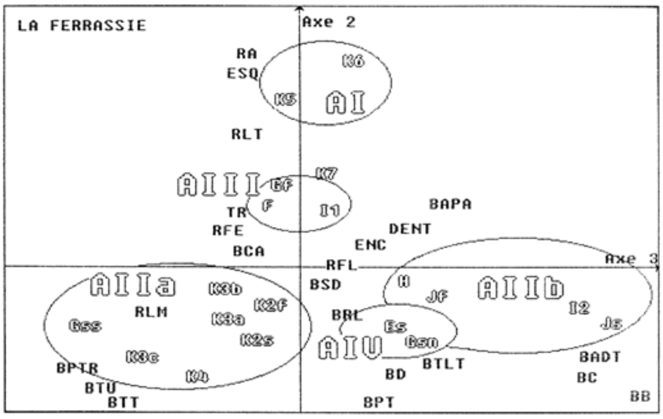


*Figure 3: Aurignacian structuration in La Ferrassie rockshelter (Dordogne, France): C.A. and cluster analysis applied on a technological description, in a two-step approach (first step: attribute analysis by C.A. separately on retouched tools and burins produced virtual technological types; second step: analysis of a technological types x layers abundance table by C.A. produced the chronological structuration). (Djindjian 1986, 1996).*

III = cold, IV = Maisieres). The result has been validated with seven other Aurignacian rock shelter sequences in Perigord.

In conclusion, the actual trend is oriented to the construction of intrinsic knowledge-based artefact descriptions structuring a real cultural system certified by other intrinsic and extrinsic explanations. Such cognitive approaches could certainly contribute to a convergence between cultural anthropology and European prehistory.

## 8. Seriation

Seriation is a methodological approach which has played a major role in establishing chronological sequences and period schemes from burials, particularly in late prehistory.

The concept of seriation is easy to understand: artefacts have a limited time of use, and their life curves are supposed to have some Gaussian profile. A burial (or any closed system) is supposed to be an instantaneous sample of artefacts at different steps of their life, and thus provides an indicator of time in a relative chronology.

The formalisation of the concept was more or less finalised in the $19^{th}$ century (for a well-known example, Petrie for the chronology of pre-dynastic Egypt, 1889). The seriation model is generally represented by the "Petrie" diagonal matrix. A matrix of types x burials may be reorganised by permutation of rows and columns under a diagonal form, if a seriation structure is present.

Rapidly, the question was to reorganise large matrices of any kind of data, using mathematics and computers. The main algorithms are now well known:

- graphs (Ford 1962),
- similarity matrix ordering (Brainerd and Robinson 1951),
- incidence matrix direct ordering (Kendall 1963),
- computerised similarity matrix ordering (various 1963-1968),

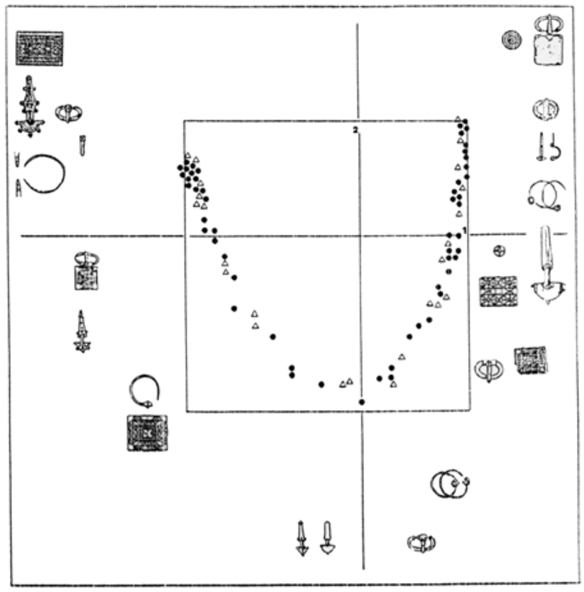

*Figure 4: Seriation of the burials of the visigoth cemetery of Duraton (Segovie, Spain). Parabolic effect revealed by a C.A. applied to a 291 burials x 60 types table. (Ciezar 1990).*

- rapid methods on similarity matrix (various 1966-71),
- multidimensional scaling (Kendall 1971),
- travelling salesman problem (Wilkinson 1971),
- reciprocal averaging method (various 1972-80),
- correspondence analysis (Djindjian 1976),
- PCA (Marquardt 1976),
- rapid method on incidence data matrix (Ester 1981),
- Toposeriation (Djindjian 1984),
- and so on (Laxton and Restorick 1989, Baxter 1994, etc).

After having succeeded in reorganising a "Petriefiable" matrix, the next question that appeared was how to process a noisy matrix with a supposed serial effect badly described by a maladapted typology and possibly disturbed excavations. This practical constraint is the explanation of the success of the correspondence analysis which reveals a superposed parabolic effect, both on burials and artefact types, furnishing a double chronological order on the first factorial axis, which can be improved by iteration on variables (typology) and units (burials) (Djindjian 1985).

Once the noisy data matrix problem was solved, it appeared obvious that the seriation model was also purely theoretical, and that archaeologists had to process more complex serial structures (Djindjian 1991):

- parasite effects (for example, male-female structure in burials),
- mix of partition and seriation structures,
- existence of non-linear seriation models,
- existence of non chronological seriation models,
- etc.

Finally, multidimensional data analysis (and especially Correspondence Analysis) is certainly able to offer the methodological

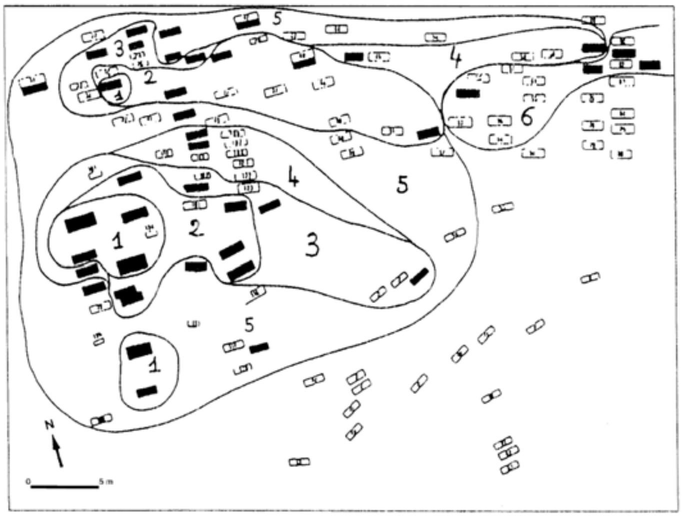

*Figure 5: The toposeriation method applied on the Merovingian cemetery of Mezieres (Ardennes, France), revealing the expansion of the cemetery in time and space from three original set of burials. (Djindjian 1985).*

tools necessary to manage the interaction between the archaeologist and the artefacts during the process of seriation. Nevertheless, if the seriation structure is exact, and if it is possible to build a periodisation from it, it is (from many archaeological and mathematical reasons) an illusion to believe that the chronological rank of each point (unit and variable) is exact.

Now, the success and the difficulty of a seriation primarily depends on the choice of a description of the artefacts having a strong chronological dependence, in other words a typology a priori correlated with the extrinsic information “chronology”.

A good example of seriation by a correspondence analysis is given by the study of the Visigoth cemetery at Duraton (Segovie, Spain) performed by Ciezar (1990). Starting with 291 published burials and a typology of 60 types, the analysed matrix was finally 56 burials x 26 types (figure 4), revealing a good parabolic effect and a periodisation into three phases.

Another example is given by the toposeriation analysis (Djindjian 1985) of the Merovingian cemetery at Mezieres (Ardennes, France). Toposeriation is a method based on an association of seriation by correspondence analysis on a burial x type matrix and of k-means-like classification on a topographic matrix with chronological constraints. The result of the program is both chronological and topographical clusters, which can be figured on the cemetery map (figure 5).

## 9. Intrasite spatial analysis

Intrasite spatial analysis deals with the study of artefact spatial distributions within an archaeological site. Compared to stratigraphy and typology, intrasite spatial analysis is a relatively new method in excavations, however it certainly plays the same fundamental role in archaeology.

Under the influence of Ecology quantitative methods with single spatial distribution analysis, appeared: Hesse (1971), Dacey (1973), Whallon (1973,1974); later on extended to two spatial distribution association tests: Hodder and Orton (1976), Hietala and Stevens (1977), Clarke (1977), Berry et al. (1980); and finally multidimensional spatial data analysis was actually used: Johnson (1984), Graham (1980), Kintigh and Ammermann (1982), Whallon (1984), Hietala (1984), Djindjian (1988), Djindjian (1999).

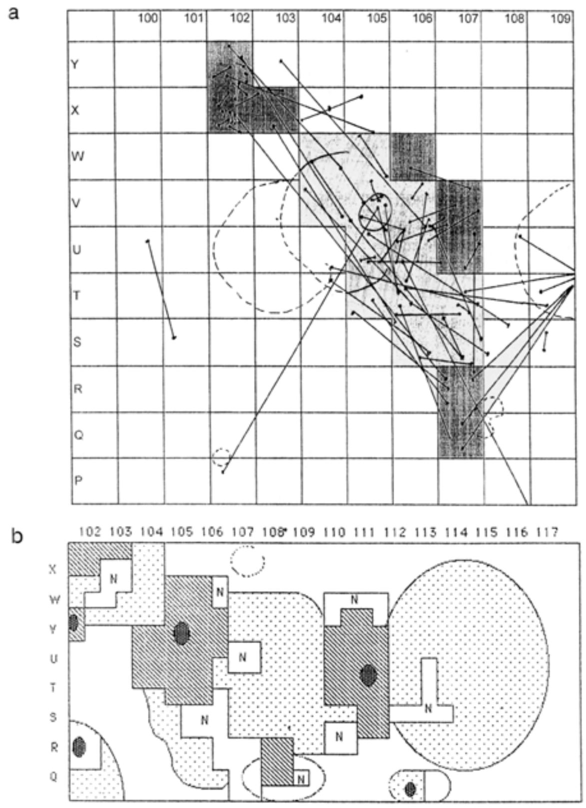


*Figure 6: Application of the spatial structuration method and of the spatial structuration method on refitted artefacts to the data of the Magdalenian camp-site of Pincevent (Seine et Marne, France). (Djindjian 1988, 1999).*

These multidimensional methods reveal spatial structures that are interpreted in terms of post-depositional effects, garbage areas, working areas or social spatial organisations.

If the quantitative methods can be considered as effective, improvements are now expected in the selection of archaeological data used in spatial distributions. It is evident that an exhaustive choice of artefact types used in other methods (typology, seriation, “culture” identification) is not an efficient strategy to use in order to discover activity areas or social organisations.

Intrasite spatial analysis can certainly be the field where functional data as obtained by use-wear analysis, subsistence data furnished by plant and animal remains, refitted data flints, burnt stones, and bones or social data estimated from ethnographic contemporary models must be used to obtain interpretable spatial structures.

For example, I offer the application of two methods, spatial structuration method (Djindjian 1988) and a complementary method: spatial structuration on refitted artefacts very useful in identifying garbage areas (Djindjian 1999). These methods have beeen applied to the data of the Magdalenian camp-site of Pincevent (Seine-et-Marne, France) published by Leroi-Gourhan and Brezillon (1972). In figure 6, a new interpretation of the spatial structure of the camp-site is given (Djindjian 1999).

## 10. Identification of raw material sources and manufacturing centres

The question as regards the sources of raw materials and the discovery of manufacturing centres is the most fully formalised question in archaeology, because it mainly involves the use of methods from physics and mathematics. The procedure may be summarised in three steps:

- data acquisition by physical and chemical characterisation of flint, ceramic, metal, stone samples,
- structuration by discriminant data analysis, which results in distinguishing and characterising samples from known raw material sources or manufacturing centres,
- decision by determination of the origin of samples coming from various archaeological sites.

Nevertheless, the method, apparently rigorous, has strong constraints:

- the localisation of sources or centres (all of them),
- a strongly discriminant characterisation,
- the control of post extraction raw material modifications by transformation, mix or pollution.

Barrandon and Irrigoin (1979) have published a beautiful study on paper manufacturing in Europe during 17th and 18th centuries. After analysing (by neutronic activation) a collection of papers, they found two clusters, discriminated by As and Co (intrinsic structuration). They discovered the difference is due to the fact that the paper was manufactured in Angouleme (France) and the Netherlands (extrinsic regional explanation). The difference is explained by the know-how of Dutch manufacturers who add smaltite (CO, Ni) $AS_3$ in the process in order to obtain a paper whiter than that of their competitors. The presence of smaltite is proven by traces of Ni in the data (discovery of more cognitive intrinsic information). Finally, they discovered that such a technical tradition has only been used after 1748, as shown by the analysis of Dutch papers from 1650 to 1810 (extrinsic chronological information).

## 11. Artefacts and anthropological models

The use of anthropological models is the only way to exploit intrinsic information, particularly difficult to estimate, such as functional, individual, hierarchical, social, symbolic, etc. information.

The anthropological models are based on intrinsic analogical knowledge deriving from only three sources:

- modern world (considered as the evolution of ancient worlds),
- experimentation,
- contemporaneous ethnographic models.

Unfortunately, such knowledge only has a local and modern value, obtained by analogy and cannot be used without being cautious as regards its scope of application.

Simulation methods are particularly well adapted to this kind of hypothetical data, and a large number of simulation methods approaching these particularly difficult questions have been tested:

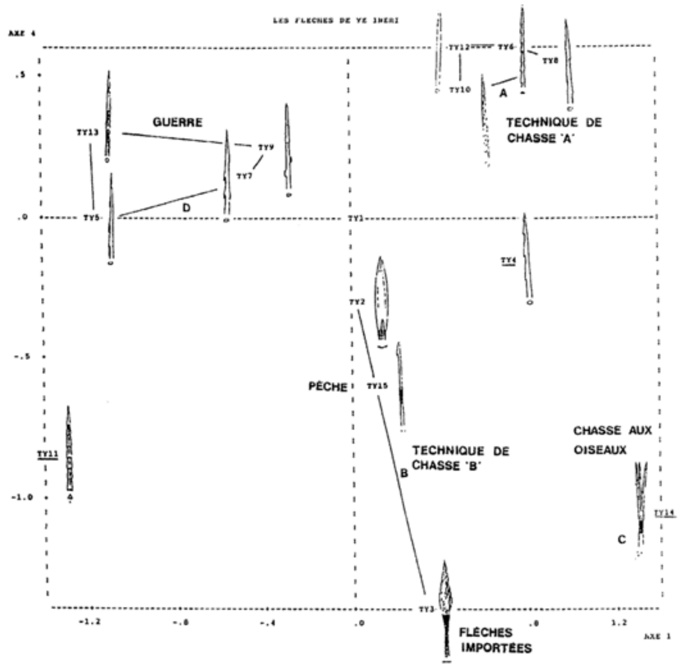


*Figure 7: Correspondence between morphological types obtained by artefact analysis and functional types known by ethnographic studies of the same arrow set from contemporary Dani tribes (Irian Jaya, Indonesia). Factorial axis 1-4 of a C.A. (Giligny and Sidi-Maamar 1990).*

- Regression by data analysis,
- Operational research models,
- Monte-Carlo simulations,
- Expert systems,
- System Dynamics,
- Decision making.

Examples of simulation methods in archaeology are unfortunately limited but are of great interest: Doran (1970), Thomas (1972), Ammermann and Cavalli-Sforza (1973), Wobst (1974), Zubrow (1975), Hassan (1977), Jochim (1976), Hodder ed. (1978), Renfrew and Cooke (1979), Sabloff (1981), Keene (1979), Belovsky (1987), Doran (1990), etc.

An elementary example of the difficulties that arise due to the differences between available and necessary data for a simulation is given by a study realised by Giligny and Sidi-Maamar (1990) on neolithic arrows from contemporary Dani tribes (Irian Jaya, Indonesia), with data collected by Petrequin and Petrequin (1990). Arrows are found in quivers found in the huts of a single village. Arrows are first analysed by an artefact analysis. Owners of quivers have offered explanations concerning the variability of the arrows. The results of the two approaches are compared. Explanations are numerous, socially complex and often individual. Factor analysis axis 1 and 4 show some correspondence between the morphological typology and the functions of the arrows (figure 7).

## 12. Identification of artefact distribution networks (exchange and trading systems)

After having identified raw material sources and manufacturing centres (cf. chapter 9), it is possible to identify the distribution network for any artefact.

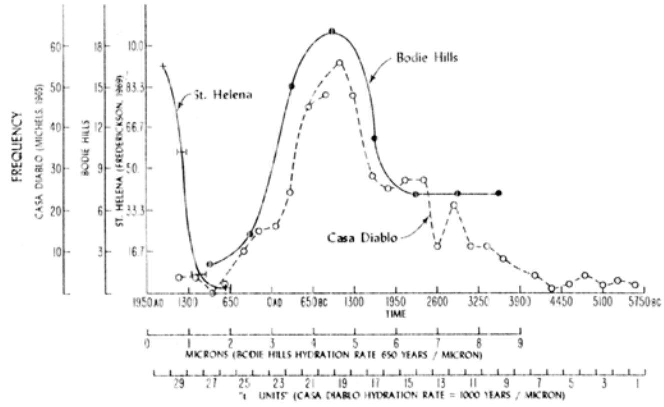


*Figure 8: Evolution of the operation of obsidian quarries on the California peninsula over a period of 7000 years (Ericson 1981).*

The procedure may be defined in three steps:

- data acquisition by sampling artefacts in archaeological sites and physical or chemical characterisation,
- network structuration by various quantitative methods like:

  distance decay diagrams,

  isodensity decay diagrams,

  gravity models,

  distance decay diagrams through time,
- exchange and trading system reconstitution by simulation methods.

A good example for the evolution of the operation of obsidian quarries in the California peninsula over a period of 7000 years is given by Ericson (1981). After the characterisation of obsidian sources and obsidian dating, Ericson can reconstitute curves of obsidian quarry activity (figure 8).

## 13. Intersite spatial analysis

Intersite spatial analysis is concerned with the studies of landscape, territory, boundaries, settlement spatial organisation and peopling dynamic models.

In contrast to previous studies, in this analysis, artefacts are archaeological sites themselves.

The procedure may be organised in the following three steps:

- data acquisition by a GIS implementation,
- identification and structuration of the territory by various quantitative methods:

  boundaries:

    artefact assemblages,

    territorial artefacts such as coins, defence sites, etc.

    geographical boundary models,

  spatial organisation:

    central place model,

    rank size model,

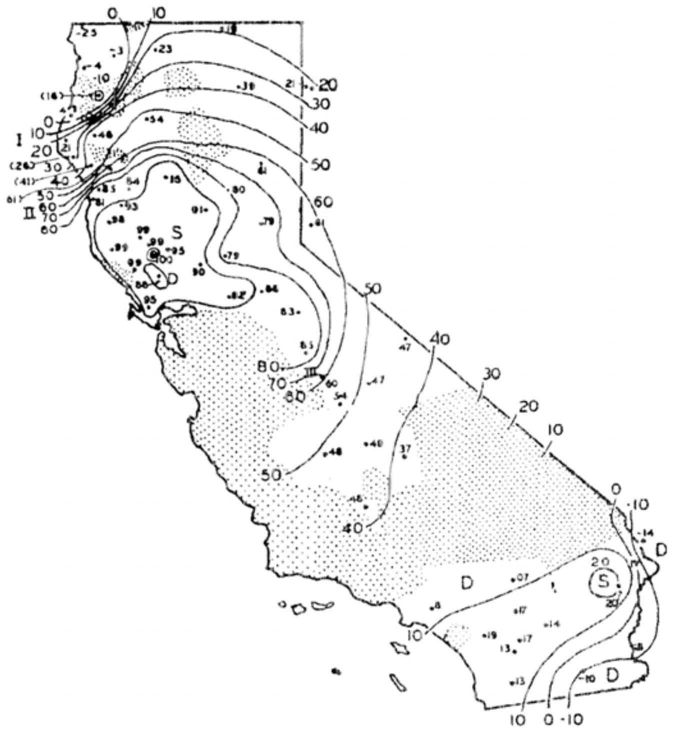

*Figure 9: Paleo-indian cultures on the California peninsula (Mielke 1949).*

  viewsheds,

  etc.

- reconstitution of the peopling system:

  carrying capacity models,

  localisation models,

  system dynamics.

Nevertheless, intersite spatial analysis has to support numerous constraints such as contemporaneousness and representative spatial sampling of archaeological sites.

A historical example is the result of the study performed by Mielke (1949) concerning Paleoindian cultures on the Californian peninsula. Cultural regional facies are revealed on a map by level curves drawn from a cultural similarity measure computed from artefact analysis (figure 9).

## 14. Conclusions: A three step cognitive model: Acquisition, structuration and reconstitution

For each archaeological problem, which has been analysed in this paper, I have demonstrated the fundamental role of artefacts and their intrinsic information in the success of the construction of the archaeological interpretation.

For each archaeological problem, I have also demonstrated the efficiency of a three-step model: acquisition, structuration, reconstitution, following a framework already known in numerous social and human sciences (amongst others: Pierce 1992).

This model may be applied at each level where the re-entering concept of "logical" artefact is used.

From the level of the physical find

- acquisition:

  perception, description, recording, coding intrinsic information,

- structuration:

  partition,

- object reconstitution:

  intrinsic and extrinsic added explanations.

To the site level

- acquisition:

  survey, excavations, extrinsic data recording, intrinsic artefact analysis,

- structuration:

  artefact classification, intrasite spatial analysis,

  seriation, raw material origins, subsistence resources, distribution network,

- system reconstitution:

  technology, settlement, craft production, exchange and trading, subsistence, defence…

In the formalisation of any archaeological problem with a three-step framework: acquisition, structuration and reconstitution (modelling), the cognitive approach has reconciled the empirical-inductive approach (structuration) and the hypothetical-deductive approach (modelling). In emphasising the role of acquisition, the cognitive approach has changed the role of the artefacts in archaeological constructs, from the concept of the artefact as a whole, to the concept of artefact as an element of a system. In that way, artefact analysis is a modern concept in the present archaeological method and theory.

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