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DIALOGUE WITH THE DATA: THE ARCHAEOLOGY OF COMPLEX SOCIETIES AND ITS CONTEXT IN THE '90s

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MATHEMATICS AND LOGICISM IN ARCHAEOLOGY: A HISTORICAL APPROACH

by

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This article attempts to provide a historical survey of the use of mathematics in archaeology and to study the relations existing between this type of approach and the logicist current developed in France by Jean-Claude Gardin. We will limit ourselves to post-war archaeology, basing ourselves essentially on Anglo-American and French works. This reflection, which is a "continental view" of the development of archaeological theory (as opposed to the Anglo-American view which is now predominant), should lead to a more "reasonable" (in the strongest meaning of the term) perception of the potentialities, and above all the limits, of our discipline.

In situating the use of mathematics in archaeological procedure as a whole, we would like to render explicit the interactions that have always existed between the mathematical approach and the semiological trend, the term of semiology being understood as the study of the languages of scientific procedure.

As a first approximation, let us make the following hypotheses:

1. Semiology attempts to solve questions concerning the representation and description of archaeological data. It also undertakes to study the logical mechanisms that enable us to give an explanation and an interpretation of such data.
2. The quantitative and mathematical trend essentially attempts to solve questions concerning data acquisition (sampling techniques) and their ordering (classification techniques).

This opposition is not of course so radical (for example, logical sampling procedures can exist), but corresponds, we think, to two historically distinct kinds of work.

Already, this assessment shows that it is quite impossible to dissociate these two approaches, which should be absolutely complementary. The deadlocks with which archaeology has until now been confronted are due in part to the fact that this complementarity was unrecognised, and also that procedures were founded on one type of approach only.

We mainly based ourselves on the works of Jean-Claude Gardin (1979; 1991) and François Djindjian, whose book *Méthodes pour l'archéologie* (1991) provided the documentary basis that was indispensable to our reflections, and more par-

ticularly, a very complete bibliography. We will present our analysis by decades starting in 1950 according to the following classic distinctions (Gardin 1979):

- Archaeological procedure can be divided into four successive stages: acquisition, description, ordering and explanation of data. We will leave aside an ultimate stage, that of validation, since very few works discuss this nevertheless essential question.
- From a semiological point of view, three sorts of languages are used:
  the *natural language* (NL) or everyday language,
  the *scientific language* (SL) which uses the same syntactic structure as the natural language, but is lexically more precise, and lastly
  the *documentary language* (DL) which covers the different descriptive systems used to describe data contained in corpora and data banks so as to facilitate their identification and sorting.

1. THE FIFTIES: THEORETICAL DEBATE IN ARCHAEOLOGY MADE A NEW START

DESCRIPTION

One recognised the importance archaeologists gave to data compilations through the proliferation of catalogues and corpora concerning very diverse materials: coins, statues, pottery, monuments, inscriptions etc. Research then developed in two directions, the first concerned the question of object representation, the second, that of the representation of (non)-scholarly texts written in natural language.

OBJECT REPRESENTATION

As early as 1955, Gardin, then at the French Institute of Archaeology in Beirut, examined the question of DL representations of artefacts as a tool for describing the elements of a corpus in a coherent and unified manner. This reflection led to a first experiment in mechanical documentation, concerning *Bronze Age tools from the Balkans to the Indus* (Christophe and Deshayes 1964), based on a code for the morphological analysis of metal arms and tools (Christophe, Deshayes and Gardin 1956, revised in 1962). This was followed by other codes aiming at a unified and "universal" description of highly miscellaneous objects, such as:

- oriental cylinder seals (Gardin 1956, Digard et al. 1975)
- coins (Le Rider 1956, published in 1975)
- pottery shapes (Gardin et al. 1956, published in 1976)
- geometric ornaments (Gardin 1956, published in 1978).

REPRESENTATION OF TEXTS WRITTEN IN NATURAL LANGUAGE

A reflection of the same type was then addressed to the analysis of texts written in natural language. The first application concerned ancient oriental texts (Christophe et al. 1958; Salomé 1958 published in 1978); later studies extended to the

analysis of texts published in the scientific literature, for instance the bibliography of prehistory (Schmieder 1959).

ORDERING

In a totally different sphere, the fifties saw the first attempts to quantify archaeological data and the application of the first statistical tests. In prehistory, quantification was then based on lists of types that permit the construction of cumulative diagrams supposed to be representative of various prehistoric cultures. These lists bear upon the Mousterian (Bordes 1953), or the French Upper Palaeolithic (de Sonneville-Bordes and Perrot 1954-56). Bohmers (1956) proposed a theoretical reflection on such lists. This quantification, however, developed independently of any test of statistical significance, and only yielded interpretations founded on visual (non) analogies.

The first computations of correlation (with Chi^2 tests) were nevertheless applied to some series of objects so as to highlight morphological "types" (Spaulding 1953; Bohmers 1956; Tugby 1958). As to Brainerd (1951) and Robinson (1951), they used Chi^2 tests to propose a first algorithm of chronological seriation.

Thus, the illusion developed that the quantification of any data and the application of mathematical procedures led to an identification of types of objects that corresponded to ancient realities. The objects produced by human cultures were supposed to be "naturally" distributed into distinct types that the scholars' mathematical arsenal should be capable of identifying.

EXPLANATION

In France, as early as 1956, Leroi-Gourhan's book *Les Religions de la Préhistoire* led to a contestation of ethnographic comparatism. He also insisted on the necessity of a better exploitation of data acquired during excavations.

One believed that an "exhaustive" excavation would make it possible to discover a great many clues that would permit us to reconstruct our ancestors' daily life without having to refer to the arsenal of knowledge provided by ethnographic studies of traditional populations.

OVERALL VIEW

The three types of approaches that characterised the archaeology of the fifties apparently had no points in common and were developed by independent research teams between which scientific collaboration was absent. In all three cases however, we can perceive the same overall philosophy.

All research developed with the idea (and the illusion) that it is possible to give a unique and exhaustive description of reality through unique documentary languages and what is more that this DL representation of reality can by itself generate an interpretation, provided that one applies strictly controlled description and ordering procedures, with or without the help of statistical tests.

This close convergence strengthens our conviction that the opposition that appears to be detectable as early as the fifties between Anglo-American and French archaeology may not be as radical as one might think.

2. THE SIXTIES: ENTHUSIASM

The movement that began in the fifties increased during the following decade due to the spread of computers in universities. The quantitative trend was amplified and most archaeologists became convinced that computing techniques were going to resolve all the problems they encountered.

ACQUISITION

As early as 1960, the notion of sampling became common in archaeology. Vescelius (1960) wrote his introduction to statistical sampling techniques. Binford (1964) propounded the use of stratified probabilistic sampling plans to optimise the localisation, and thus the discovery of archaeological sites, on the basis of environmental information.

At the same time, Leroi-Gourhan, in France, influenced the development of a more and more exacting archaeology with respect to material collection. The excavation of the hypogeum II of "Les Mournouards" (Leroi-Gourhan, Bailloud, Brézillon 1962) and of the habitation 1 at Pincevent (Leroi-Gourhan and Brézillon 1966) constituted the foundation of a philosophy of "exhaustive" excavations the impact of which would be immense.

DESCRIPTION

Research was concentrated on systems of description of archaeological objects and many documentary descriptive codes were then developed. Reality, so one then thought, can be the object of standard descriptions and this hypothesis allowed one to envisage the creation of large factual data banks capable of meeting the information needs and goals of a large number of different researchers.

Three fields of application were considered: the representation of archaeological materials (M'DL), the representation of texts written in natural language (NL'DL) and the representation of scientific texts (SL'DL). Descriptive codes bearing on archaeological objects multiplied, concerning various subjects such as:

graphic documents (Miquel 1960)
paintings on Greek vases (Salomé 1960, published 1979)
civil monuments (Lagrange 1965, published 1975)
religious monuments (Nivelle 1965; 1969, published 1975)
Roman mosaics (Christophe 1967)

Other analyses bore on the representation of texts written in natural language, for example:

Roman manuscripts (Mattei 1965)
the Koran (Allard et al. 1963)

or were extended to visual documents such as the ethnographic film (Lagrange 1961, published in 1976).

Documentary searches in scientific texts developed through the design of tools for a more or less sophisticated preliminary analysis of textual content, as exemplified by the code for analysing the literature on Roman archaeology and history (Nivelle 1969).

The first fundamental research projects on automatic documentation also date from this period. Syntol (Gardin 1964, Cros et al. 1964) constitutes one of the most sophisticated models of a documentary language applied to scientific texts.

ORDERING

The sixties were characterised by the rise of the quantitative trend, as can be seen from the development of multidimensional statistics (Sokal and Sneath 1963). Mathematical tools were applied to the content of the new documentary data banks in the hope of extracting relevant scientific theories from them. One then believed that a DL representation of reality could lead to the formation of scientific theories, according to the scheme DL'SL. In the United States, these techniques were rapidly incorporated into the heteroclite arsenal of the rising New Archaeology.

Techniques for multidimensional analysis were applied to typological analysis and to the classification of objects based upon their intrinsic characteristics (Ihm 1961 for bronze axes). The Binfords (1966) used factor analysis (using both common and specific factors) to re-evaluate the significance of data supplied by Bordes' type-lists. The observed variability did not correspond to "cultural" differences as Bordes thought, but to functional constraints. This article sparked off a long controversy between American and French prehistorians, but the ambiguity of the data contained in the countings did not prevent French prehistorians from developing and using type-lists, following in the steps of Tixier (1963) for the Maghreb Epipalaeolithic and Laplace (1964) for leptolithic complexes.

The first taxonomic applications essentially used cluster analysis, which builds arborescent constructions that may be cut at any level to obtain a significant partition. In this way, Hodson, Sneath and Doran (1966) published a first classification of fibulae from Münsingen, an Early Iron Age cemetery.

The field of seriation was also touched by the vogue for mathematical techniques (Kendall 1963; Dempsey and Baumhoff 1963), whereas the Cambridge school attempted to develop elementary probabilistic models that could be applied to spatial analysis (Haggett 1965; Chorley and Haggett 1967).

INTERPRETATION

Whereas the refinement of proposed excavation techniques tended to favour an empirical archaeology which had difficulty going further than simply describing the materials, the rise of Anglo-American New Archaeology led to the elaboration of ambitious interpretative models.

The goal of systemic and processual archaeology is to explain the historical evolution of cultures with the help of economic and social "macro-variables" integrated into dynamic systems (Gallay 1986). Elites, social ranking, capital-intensive techniques, prestige objects... were thereafter part of the conceptual arsenal of archaeologists, now transformed into philosophers of history.

The explanatory ideal clearly transpires in the debate which then opposed, in the United States, the partisans of a descriptive cultural history, to archaeologists who believed in an internal comprehension of historical processes (Flannery 1967).

Processual archaeology constantly seeks for independent variables capable of explaining historical phenomena. For example, demographic pressure, linked to the constraints imposed by the environment's carrying capacity, plays an essential role (Boserup 1965).

During the same period, however, there emerged a first perception of the difficulties associated with the interpretation of remains, induced by the first ethnoarchaeological research (Longacre and Ayres 1968). Although this discipline did not yet propose any specific methodology, it brought warnings and appeals for prudence, which incidentally were mostly ignored.

OVERALL VIEW

Incontestably, the sixties appear as a period of enthusiasm provoked by the possibilities offered by the new theories and tools at the archaeologist's disposal (an enthusiasm that the author personally participated in as a Parisian student).

However, this decade is difficult to characterise because of the apparent heterogeneity of approaches and the lack of integration of the various conceptual tools proposed. Nevertheless, it seems to us that three theoretical credos were then dominant, concerning successively description, ordering and interpretation of data.

The first concerned the possibility of giving an exhaustive and unique description of archaeological reality, both through excavation records and the DL coding of the finds; the second concerned the idea that this description could form the basis of a unique interpretation of reality, according to the DL'SL scheme, and that the body of mathematical and statistical tools at one's disposal guarantee the scientific nature of this procedure; the third concerned the hypothesis that the available archaeological documentation enables one to accede to a global and total comprehension of history.

In general, we can consider that these are "blind" research strategies, wherein the finesse in the description of data and the application to them of sophisticated mathematical procedures were considered to ensure efficiency according to the scheme DL'ordering'SL for the quantitative trend, and DL'data banks'SL for the semiological trend.

This empirical approach of reality, which in fact only led to very poor interpretations, was counterbalanced by the introduction of ambitious hypothetico-deductive models, whose links with empirical data were far from clear.

3. THE SEVENTIES: THE DEADLOCKS

The seventies were nevertheless confronted with a surge of methodological difficulties and deadlocks. The movements of enthusiasm died out, and one began to be conscious of the limits of proposed approaches.

ACQUISITION

Material collection guided by probabilistic sampling techniques did not yield the anticipated results, especially in regional surveys. This situation was signalled by the rarity of articles dealing with this question, from 1978 onwards. This failure can be partly explained by the fact that archaeological documents often present phenomena of spatial concentration. Probabilistic methods do not constitute the most economical approach to this type of reality.

Furthermore, mathematical sampling techniques do not constitute a satisfactory approach to the management of an excavation, since they favour the discovery of the most frequent elements to the detriment of the rarer elements which are often more significant; thus, they tend to hinder a progressive approach to reality.

Among the many archaeologists who reflected upon this situation (in: Mueller 1975), Cowgill alone (1975a: 260-261) seemed to perceive the limits of random sampling, as opposed to reasoning:

> "Purposive selection is preferable to sampling whenever selection is feasible, sufficient for one's research objectives, and not wasteful. (...) In contrast to selection, some form of sampling is preferable in situations (1) where there are more potential observations than our resources permit us to make, or we have reason to think that we do not need to make all possible observations in order to obtain convincing tests of competing hypotheses or acceptable estimates of important parameters, and (2) where there are no indications that tell us which of the possible observations are unimportant or unnecessary".

As to excavations, the highly sophisticated excavation techniques promulgated by Leroi-Gourhan (1971) also seemed to lead to dead ends. The volume of information to be processed is often so great that it becomes impossible to treat it in a reasonable period of time. Leroi-Gourhan himself wondered whether the time invested does not in fact lead to trivial interpretations (Leroi-Gourhan and Brézillon 1972: 257).

Many excavations directed according to Leroi-Gourhan's methods were too limited for the spatial structures discovered to be interpretable. The precision of observations may become an obstacle to the discovery of a proper perspective for understanding the structures.

DESCRIPTION

"Exhaustive" description strategies developed in a spectacular fashion in the seventies, recording being aided by the progress of computer techniques. Many data bank projects were evolved, as illustrated by the CNRS conference *Banques de données archéologiques* which took place in Marseilles in 1972 (Borillo and

Gardin 1974). De Lumley-Woodyear et al. (1974: 41-50) in particular proposed therein the creation of a universal data bank containing all the information collected during excavations. This project was never completed. Also during this period Digard et al. (1975) elaborated a very ambitious descriptive system for the iconography of oriental cylinder seals to be used in a large data bank hopefully supposed to be relevant to research topics. Unfortunately, this data bank was hardly ever consulted.

These various failures seemed at the time to be linked to the confusion existing between documentary and scientific targets. In 1977 we observed that a part of the failures encountered by large data-bases came from the impossibility of updating them rapidly enough so as to take into account the evolution of problems posed (Gallay 1977).

ORDERING

Mathematical ordering procedures were at the height of their success by the end of the sixties and the beginning of the seventies. As a result, many international conferences took place on this theme: CNRS conference in Marseilles, 1969, on archaeology and computers (Gardin 1970), Mamaia conference in 1970 on mathematics in historical and archaeological sciences (Hodson et al. 1971).

The French school for data analysis under the leadership of Benzécri (1973) was then fashionable, followed by many authors in the human sciences.

This methodology concerned very diverse kinds of data ordering such as typological analysis (Djindjian 1976), classifications based upon measurements (Hodson 1970; Barker 1975; Djindjian and Croisset 1976; Guénoche and Tchernia 1977), cultural identification (Binford 1972) and seriation (Kendall 1971).

However, from an interpretative point of view, mathematical classifications are disappointing because the analysis takes place separately in the *Q mode* (similarity matrix between *individuals*: analysis of proximity, automatic classification) and in the *R mode* (matrix of correlation between *characters*: factorial analysis).

One of the best examples of the deadlocks that these methods lead to is certainly provided by the often quoted analysis of the fibulae from Münsingen cemetery (Hodson 1970). Specialists of the La Tène period agree that the classifications obtained have been of no use for the progress of knowledge concerning this period (Kaenel, forthcoming).

To counter this situation, one then proposed, in the wake of Benzécri's school, analytical methods that were even more sophisticated, such as correspondence analyses that integrate Q and R matrices, as practised by Djindjian (1977a and b) on Upper Palaeolithic sequences.

Generally, these techniques are well able to bring out the overall structure of given sets of data, but they remain very poor as to interpretation. This situation sounded the knell of blind strategies without offering any solution to the problem of "guided" data description, as exposed below.

INTERPRETATION

Three distinct phenomena marked the seventies, and they all stemmed from the difficulties encountered during the sixties. We have in mind firstly the deadlock of explanatory macromodels, secondly, the development of the logicist trend and the analyses of archaeological constructions that follow in its wake, and lastly the development of ethnoarchaeology.

1. Many problems arise concerning the macromodels proposed by the Anglo-American schools to "explain" societies' historical evolution (Gallay 1986: 82-85).

- The link between the concepts used, which are inherited from anthropology, and the material reality of archaeological remains, is not always very clear.
- The reasonings proposed are often circular and explain nothing. The notions of adaptation and carrying capacity (Zubrow 1975) constitute the best examples of this situation.
- It is possible to doubt the legitimacy of considering certain facts as independent variables. This is the case for demographic growth, the *deus ex machina* of many historical models (Cowgill 1975b).
- The models proposed to explain a phenomenon follow each other, the most recent ones replacing the older ones, but there is no cumulation of knowledge. A good example of this situation is provided by the neolithisation of the Near East, for which many successive authors, following Childe (1952) and Braidwood and Howe (1962), proposed concurrent explanations (Binford 1968; Boserup 1965; Flannery 1969; Smith et al. 1972), without however reaching any consensus. Incidentally, this movement is still continuing today, according to Cauvin's recent work (1994).

2. At the same time, the logicist school observes, on the one hand, the limits of strategies postulating that the formalism of data representation or processing leads to discoveries of an empirical nature; on the other hand, the tactical inconsequences of researches in which one deals separately with representation, ordering and interpretation of data. A deeper consideration is now given to the procedures followed in ascribing a meaning to data and orders.

- Formal analysis of traditional archaeological literature provides a better understanding of the specificities of our discourse (Gardin 1974; Gardin and Lagrange 1975; Lagrange and Bonnet 1978).
- In 1976-77, at Geneva University, Gardin gave a series of lectures that resulted in his book *Une archéologie théorique* (1979) [the French version of *Archaeological Constructs*, 1980] and proposed a scheme for a better integration of the various stages of research, in which three major kinds of constructions were defined: compilations, typologies and explanations.
- For the first time, one became conscious of the importance of external references in the interpretation process. The analysis of Roux's article (Gardin and Lagrange 1975), devoted to the interpretation of a Seljuk stele from Turkey, showed that explanation is always based on the inclusion of knowledge external to the corpus under consideration (Fig. 1). This knowledge can be distributed between notions of universal semantics (considered as an aspect of

common sense) and notions of local semantics that warrant explicit references. This remark was not without consequences on the discipline's future. It showed that there always exists a retroaction between the current scientific discourse (SL) and the manner of describing reality, and also prepared the future integration of ethnoarchaeological research (considered as being one of the possible sources of local semantics) into the archaeological approach.

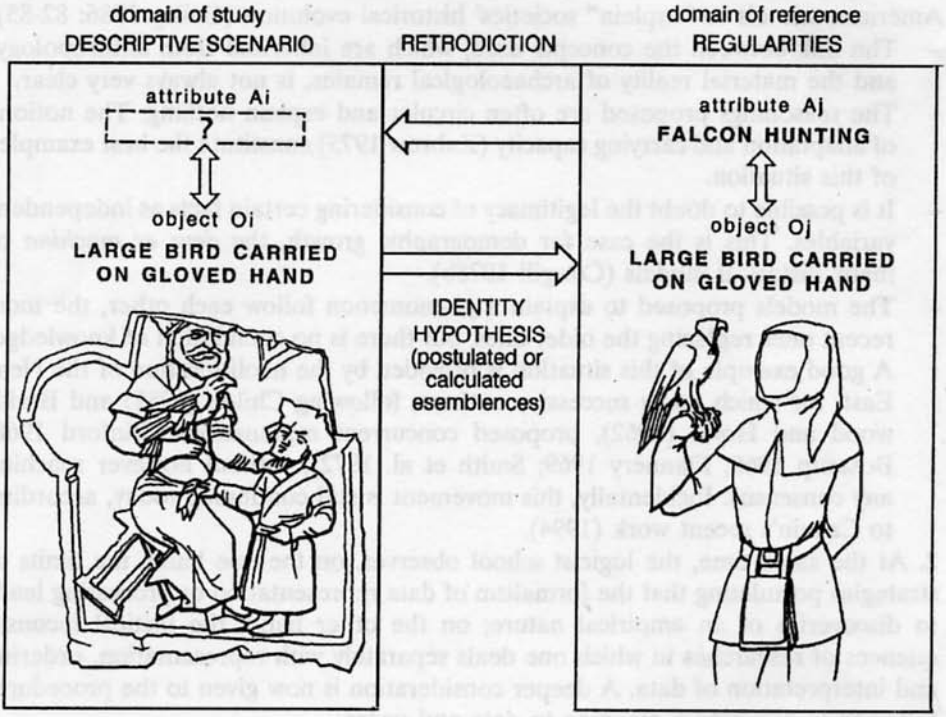

Fig. 1. The mechanism of interpretation according to J.-C. Gardin. The interpretation of archaeological remains (here, on the left, a Seljuk stele) proceeds by a "transfer of attributes" starting from an explicit or implicit context of reference. This operation is called retrodiction (after Gallay 1986, fig. 23, p. 113)

3. We will briefly pass over the parallel development of ethnoarchaeology which is mainly the fruit of Anglo-American works (Binford 1978, Yellen 1977). This research developed somewhat in isolation and has to this day very little influence upon the actual archaeological procedure.

OVERALL VIEW

The seventies were essentially marked by the failure of blind strategies in problems of fact description and ordering as well as by the divorce between

interpretative archaeology, which is essentially Anglo-American, and descriptive archaeology, which is essentially continental.

The semiological trend, however, triggered off a reflection that avoided the deadlock, by insisting on the importance of current knowledge in guiding data description (SL'DL retroaction) and interpretation, thus bringing about the end of blind research strategies and the primacy of reason over technicality.

4. THE EIGHTIES: RETURN TO REASON

After the disappointed hopes of the seventies, the eighties countenanced a return to a more pragmatic procedure, maybe less ambitious, and to a better integration of mathematics in reasoning.

ACQUISITION

New statistical approaches were developed in an attempt to remedy the failures of probabilistic methods (Scholtz-Parker 1981; 1984 for example). Regional surveys and excavations were then seen as an iterative learning process guiding the progressive acquisition of knowledge. This philosophy was applied for example to the explorations that we conducted on the Senegambian megalithism, in which we tried to control our approach logically, from the search of the site to be excavated to our choices in recording and collecting the materials, as well as the selection of excavation units within the sites (Gallay, Pignat, Curdy 1981).

DESCRIPTION

Works developed since the fifties on descriptive codes helped to overcome problems of description. The notion of exhaustivity was progressively abandoned in favour of strategies that allowed descriptions to be guided according to the goals to be attained.

It is now admitted that there is an infinite number of ways to describe the same object, according to the criteria that can only proceed from intuition, previous knowledge, and the goals pursued by the researcher. In the present state of affairs, large banks of scientific data have no meaning in our art.

Thus, it is fitting to limit these great collective enterprises to strictly documentary aspects (retrieval of data that are expected to be useful). Scientific data banks must remain local undertakings, directed towards "individual" problems.

The rise of PCs made it possible to develop this more supple strategy. To sum up, guerrilla action and not war, is now regarded as the best way to resolve our description problems.

ORDERING

Henceforth, the quantitative aspect was better integrated into a more clearly defined archaeological procedure.

- A preliminary reflection on the potential significance of the distinctive features (mainly intrinsic) associated to our objects was deemed necessary.

- The rising sophistication and speed of computers opened the way to iterative methods for the guidance of description and ordering procedures which helped to bring out stable structures. Thus, Djindjian (1980a) built computer assisted knowledge systems and applied these new algorithms to the understanding of Aurignaco-Périgordian lithic assemblages (Djindjian 1980b; 1985; forthcoming).

EXPLANATION

Two features characterised the eighties concerning the quest for explanatory models: the search for a formalisation of reasoning and the importance given to the actualist approach through ethnoarchaeology.

As regards reasoning Gardin observed the formal convergence between the manner in which he rationalised archaeological argument (in the form of chained propositions "If Pi Then Pi + 1") and the format used in expert systems created in the United States since the end of the seventies (Gardin et al. 1981; 1987). Several attempts to formalise reasoning in the form of expert systems are under way; they often go beyond the restricted framework of archaeology to embrace the totality of reasoning in the human sciences.

These local experiments are clearly at variance with the unified approach characteristic of research in artificial intelligence in the sixties, and directed instead towards specific reasonings in the most diverse domains (Gardin et al. 1987): Hellenistic pottery (Gardin), Bactrian Iron Age metallurgy in Central Asia (Guillaume), Cypriote figurines (Herman), Roman amphorae (Hesnard), medieval architecture (Zadora Rio), Seljuk iconography (Lagrange and Renaud). They bring out the discursive practices that make up archaeological argument and the "local" aspect of its demonstrations. On the other hand they show that the cumulation of knowledge is possible among some researchers, leading to a considerably richer approach of specific themes in various fields of research.

Indeed, archaeological constructs are essentially based on factual knowledge that is directly linked to the historical and anthropological context in which research is conducted and are integrated only with difficulty into uniform logical demonstration procedures.

Vialatte (1985) and Laurière (1986) have, however, developed a software for the representation of knowledge named SNARK that makes it possible to formulate different reasonings in a unified manner. The logicist formalism is well suited to the use of expert systems of this sort. It can express the architecture of reasoning in the form of networks, but it does not give a direct answer to the foundations of the relations "If Pi Then Pi + 1". The parallel development of ethnoarchaeology can thus be conceived as a complementary attempt to rest this type of relations on firmer grounds, through an actualistic type of procedure.

In accordance with the local aspect of such explorations, the most conclusive experiments are those that are performed in the framework of well-defined archaeological fields. Thus, Brain (1981) studied the behaviour of African predatory animals so as to improve our understanding of the taphonomy of South

African sites containing Australopithecine remains. Pétrequin and Pétrequin (1984) studied the architecture of the huts of sea- and lake-side settlements of the Cotonou lagoon in Benin in order to resolve the question of peri-alpine "lakeside" dwellings. Roux (1985) analysed the stone grinders in Tichitt in connection with a research project concerning the Neolithic sites of the Dhar, a plateau situated above that small modern town. Roux and Corbetta (1990) studied in India the relationship between the wheel manufacture of pottery and the concept of craft specialisation, which is an important parameter in the process of urbanisation observed in the Middle East during the third millennium B.C.

From a theoretical point of view we have ourselves attempted to situate ethnoarchaeology in relation to archaeology by referring to the three poles around which observation sciences of an historical nature are organised: mechanisms, regularities and scenarios (Gallay 1990; 1991 and Fig. 2).

However, these works leave unanswered the question as to whether it is possible to establish, through an observation of the present, models that are at the same time general enough to be applicable to different contexts and complex enough so as not to be trivial.

OVERALL VIEW

One of the fundamental contributions to research in the eighties was without doubt the acknowledgement of the local character of the problems investigated. At every level of his analysis, be it selecting a corpus, defining descriptive criteria, bringing into play ordering techniques, whether they are mathematical or not, or during interpretation, the archaeologist must take this situation into account.

5. CONCLUSIONS

The assessment that we have presented concerning the evolution of formal and mathematical methods in archaeology since the fifties may seem unfairly critical and moreover unduly pretentious. Thus, it is fitting that we now show how the procedures reviewed, far from being useless, can in fact be integrated into an overall pattern of research that takes into account all previous acquisitions. In spite of this, we will henceforth be more conscious of the limits of our discipline.

CONSTITUTION AND REPRESENTATION OF DATA

Despite the growing power of the mathematical tools developed, research is confronted with two types of difficulties.

- The first concerns the insufficiency of archaeological data, from a qualitative point of view as much as a quantitative one. The facts mobilised often prove unequal to the methods used. Faced with this situation our models can only be caricatural.
- The second derives from the limits encountered in the attempts to give an exhaustive description of reality. One realises today that the rise in the number of descriptive features is not an answer to the limits of thought concerning the

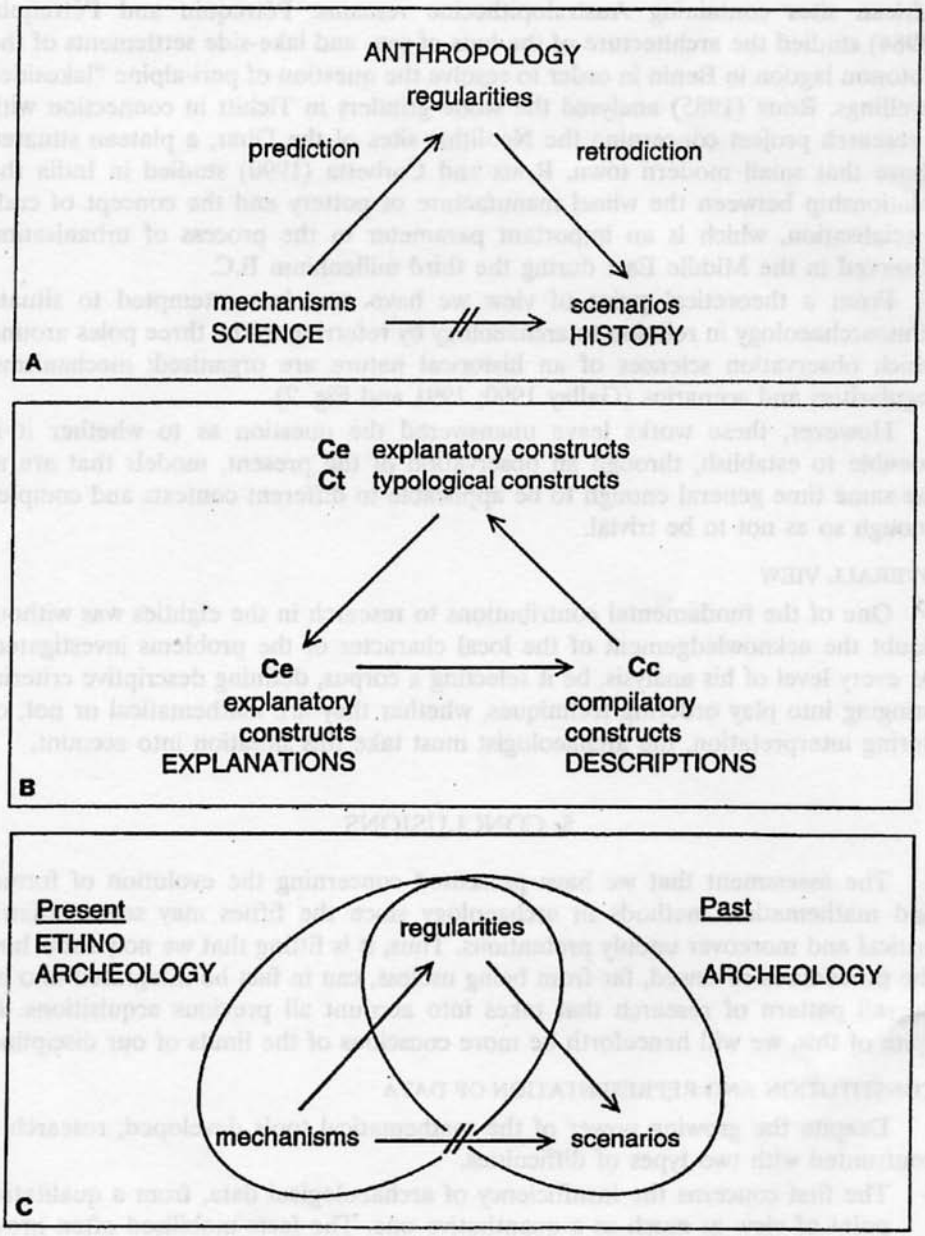

Fig. 2. Articulation of various approaches in sciences of the past. A. Relations between history, anthropology and science. B. Relations between the different stages of archaeological research. C. Relations between archaeology, as a descriptive and typological discipline, and ethnoarchaeology, a typological and explanatory discipline. Notice the perfect homology of the three diagrams (after Gallay 1989, fig. 20, p. 52)

search for relevant criteria. The first descriptive systems innocently mixed characteristics the foundations of which were heterogeneous. The ordering structures built on this basis could hardly have any significance from the historical and/or anthropological viewpoint. Finally, abusive quantification is rapidly countered by a characteristic of reality which too often goes unrecognised: many measurements are correlated, and hence the discriminative power of our descriptors very rapidly reaches a limit.

DATA ORDERING

The failures encountered in interpretation of computed ordering structures show that it is indispensable to guide the description and ordering process on the basis of strong hypotheses that are necessarily intuitive. This situation shows that the mathematical current can survive only if it is subordinated to the logicist current. The discovery of meaningful ordering structures can only be the result of an interactive learning process that links description to interpretation (...).

This guiding process concerns first of all the intrinsic characteristics of objects (from a morphological, physical and semiological standpoint), but the selection of these characteristics depends on their potential extrinsic signification (from the standpoint of space, time or function). Intrinsic description becomes the expression of a problem space rather than the consequence of the chosen measurement technique.

DATA EXPLANATION

Complex working models of the historical evolution of societies result even today in deadlocks insofar as they are built on a succession of *ad hoc* hypotheses that cannot be verified by archaeological facts (Gardin 1991).

Furthermore, the interpretative concepts used all stem from social and anthropological sciences and can hardly be applied to a truncated archaeological reality (Francfort 1988; Francfort, Lagrange and Renaud 1989). Consequently, these models cannot possibly be verified empirically. The main challenges in the years to come are thus linked to the search for a better adequacy between material fact and interpretation, a search that can only be developed in the framework of an actualist approach. This conclusion is moreover strengthened by the results of logicist research, with its emphasis on the question of the foundations of inferences and their necessarily local basis, underlined by all analyses.

Ethnoarchaeology (Pétrequin and Pétrequin 1993) and experimental archaeology will probably bring answers to these essential questions, that clearly reach beyond the domain of archaeology and concern the (utopian ?) quest for a true science of human nature.

TOWARDS A FINAL SCHEME

All the various approaches discussed above present, as we can see, certain limits when they are considered separately. However, we wonder whether their integration into an overall scheme would not allow us to escape, at least partially, from this situation (Fig. 3).

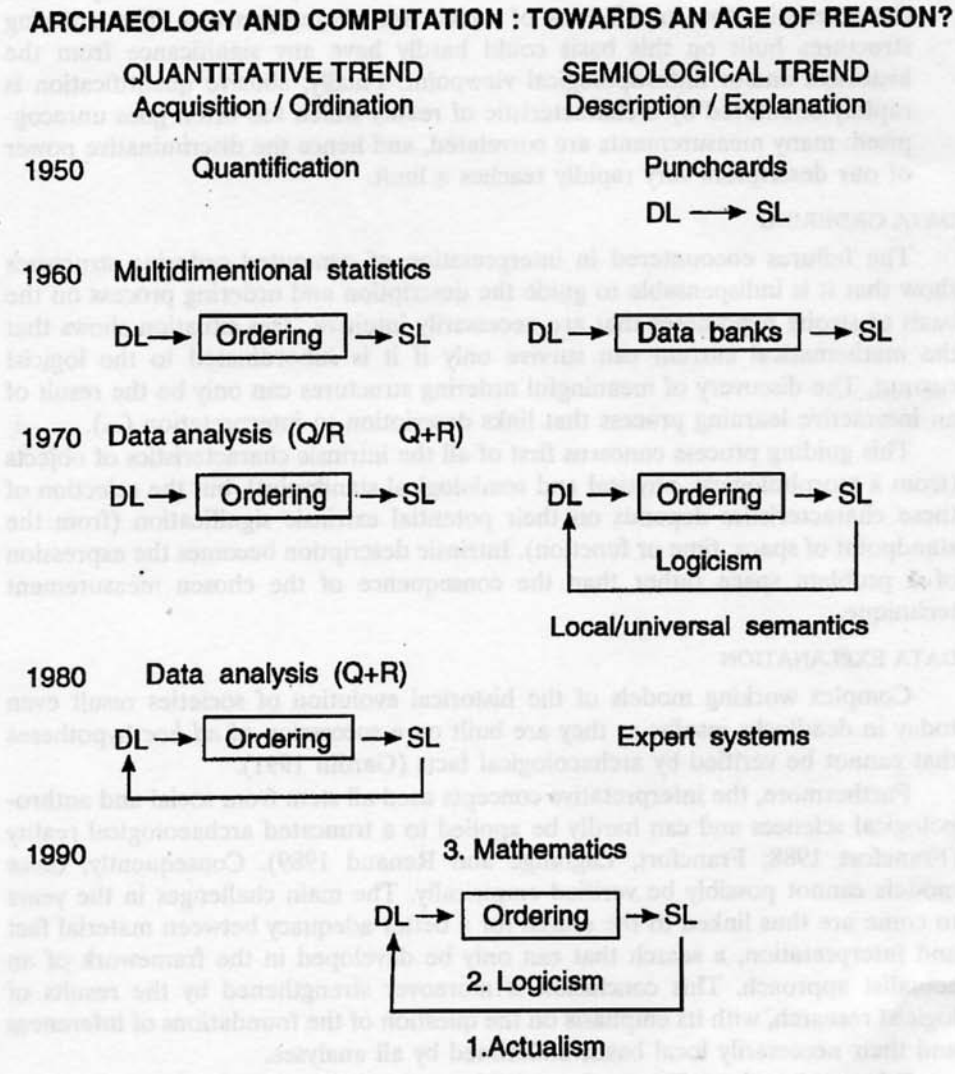

Fig. 3. Diagrams showing the evolution of the semiological and quantitative trends since the fifties. The diagram proposed for the nineties tries to integrate the lessons of the two trends. DL: documentary languages, SL: scientific languages

This scheme could contain three interlocking levels:

– The first level could be the search, in an actualist framework, for a better adequacy between material fact and interpretation through experimental archaeology and ethnoarchaeology. All observation sciences which integrate an

historical point of view (astronomy, geology, palaeontology) are situated in this perspective.

- The second level could integrate, from a formal standpoint, the lessons of logicism by bringing to light the necessary interaction existing between interpretative hypotheses and description, according to the feedback loop SL'DL. Also, logicist schematisations will probably allow us to avoid the deadlock provoked by the modern inflation of an overabundant literature, the contents of which researchers can no longer assimilate materially and intellectually.
- Lastly, there is no reason to reject the advances made in the development of mathematical methods if used properly in data ordering procedures.

Thus, the long road travelled since the 1950s ends in a trivial observation. Archaeology will progress in dealing with its theoretical issues if it conforms to the basic patterns of scientific research; for the scheme which we propose has, we believe, a validity that clearly exceeds the framework of our discipline and is applicable to any domain of reality. Furthermore, it shows that archaeology, like other human sciences, should not be treated as a singular discipline, part science, part literature, and that it would on the contrary profit by being reintegrated into the domain of reasoning illustrated by the sciences of Nature, a position that in no way excludes an acknowledgement of the specificity of man and his cultures*.

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