Introduction to Data Processing and Mathematics Applied to Archaeology

INTRODUCTION

Data processing and mathematics applied to archaeology belong to those few techniques considered as essential to any archaeologist trying to reconstruct past civilisations.

Don't they belong to those information sciences which are among the most important phenomena of the second half of the 20th century ? Archaeology, relieved of the passion for objects (from antiquities and works of art to museum pieces) needs to seek, record, consult, process, reconstruct the truncated and distorted information, bequeathed by our ancestors through some physical finds saved by nature and by man.

But is the association of data processing with mathematics not misleading ? Mathematics applications to archaeology obviously belong to this disciplinary of archaeology called quantitative archaeology.

On the other hand, data processing get, progressively and surely, into every archaeological function that prove suitable for automation as computer techniques develop. Let think of survey and excavations data management, information retrieval processing, study of materials in laboratory, publishing aids, which use data management, computing for quantitative archaeology, and, at least, computing assisted reasoning which drive us to artificial intelligence. All these points will be exposed here but before we go further, the rapid development of techniques oblige us to evoke the chronology of those applications in archaeology during the last twenty years.

1. THE HISTORY OF ARCHAEOLOGICAL DATA PROCESSING APPLICATIONS

To write a history of archaeological data processing applications seems difficult if not impossible. Whereas in quantitative archaeology, applied mathematics follow generally the spread of applied mathematics from the physical sciences to the human and social sciences, on the contrary, about data processing, the applications heterogeneity, the time and costs involved, the dependence on hardware and software, upset the general spread of the computer in every society area.

So we shall distinguish between :

— Applications using packages (information retrieval systems, statistical program packages, data base management systems), allowing archaeologists to concentrate upon the applications - *i.e.* archaeological problem solution clearly exposed by them. As they don't need a computer specialist team, those applications seem the most interesting till now.
— Applications using « ad hoc » software, much rarer and costly, needing both an important pluridisciplinarity effort for which archaeologists were not yet ready, and unexpected technical and financial ressources.

Data processing applications in archaeology appeared during 1965 with the spread of the first computers in the universities, but did not really take off until the 1970s.

We can distinguish three stages :

— The first stage corresponds to the first use of the computer for statistical processing of data tables (with OSIRIS, SPSS, BMDP packages) and for the development of the first algorithms (especially in seriation from 1966 to 1972).
— The second stage, in the 1970s, corresponds to the use (and maybe the misuse) of the word « data banks » which seems differently acquainted in the three following countries : France, United Kingdom, and United States, who had a leading role in these applications development which we will analyze here.
  • In France, owing to the considerable technical ressources of the CADA, which subsequently became URADCA and LISH under J. Cl. Gardin and the M. Borillo computer specialist team impulse, the emphasis is given to applications based on extremely formalised description of archaeological documents, towards documentary systems supporting a cognitive interaction between the archaeologist and its archaeological material. The « Satin system » is the best example of it. Although this team, quickly, moved towards more ambitious problems of formalisation in human sciences, deserting archaeology and archaeologists, their experiment have been useful for simpler realization of a purely documentary nature.

    For example, under the direction of the Culture Ministry, the implementation of an important program of information retrieval systems for the national museums, the General Inventory (see B. Toulier, in this book), the national archaeological map, using MISTRAL software under a DPS-7 computer, from french BULL Company.

Some cases, are known with CNRS, for the « Maison de l'Orient » using the software TEXTO on DPS-8 BULL, for R. Ginouvès using the software SIGMI on IBM (see A.M. Guimier-Sorbets, in this book), and for the C.R.A. developing the DBMS SOFIA for bibliographical and information retrieval applications.

The first successful experiment in excavation data management was realized by O. Buchsenschutz and X. Debanne, in a batch processing mode first using a Philips computer, then on the excavation site using a microcomputer towards the end of the 1970s.

- In the United Kingdom, in the field of information retrieval system, standardized cataloguing systems for the museums began in 1969 with the first work of IRGMA (Information Retrieval Group of the Museum Association) and met many problems connected to the choice of a distributed heterogeneous computer system and a standardized description record (Cutbill, 1973).

  In the field of text analysis, in epigraphy especially, the study of the latin inscription corpus was attempted by Wilcock (1974) with the PLUTARCH system, but also, in France by Chouraqui, Janon and Virbel (1974) using the SYCIL system.

  In the field of excavation data management, the first experiments of recording data, directly in the excavation sites on forms (Shackley and Wilcock, 1974), or on a terminal unit connected with a remote computer announced the early use of microcomputers on the excavation sites (Graham, 1976).

  An English archaeological map was started in 1975, on the basis of standard records, as it had been done in France in 1974 by the CNRS (O. Buchsenschutz *et al.*) and taken over by the Culture Ministry.

- In the United States, major survey projects obliged American archaeologists to create survey data management systems, more oriented towards management than information retrieval as in France or in the United Kingdom. We should mention, about these applications : the ASMADA system (Arkansas archaeological survey) using the software GRIPHOS written in PL1 on IBM (S.C. Sholtz and M.G. Million 1981) ; the AZSITE system (Arizona State Museum) using the SELGEM software written in COBOL (A. Rieger 1981) ; the SARG system using SPSS (F. Plog 1981) ; the ORACLE system (W.F. Limp 1978) from Indiana University ; the KOSTER system (Northwestern University) from J.A. Brown and B. Werner (1974) written in APL on IBM, then CDC ; the ADAM system (S. Gaines 1974) using terminals on the excavation site.

— The third stage, beginning in 1978, is associated with the microcomputer. Until then, archaeologists were dependant of mainframe computers with centralized applications and batch processing. The development of terminal and interactive applications, and their introduction on the excavation site, pointed out to the archaeologist the advantages of the microcomputers.

— In Europe, the microcomputer used on excavation site or near the excavations agrees with needs and financial ressources of small laboratories. It becomes progressively an everyday reality, finding a welcome never obtained by university computer experimentations. But simultaneously mainframe system using grows, because they are proposing very large general software packages, programming comfort for new software development and high ressources of computing, storage and specialized peripherals.

In the early 1980s, the first expert systems appeared, the result of a second generation of artificial intelligence research, which allows non quantitative automatic reasonning. Their application in archaeology is immediate (see M.S. Lagrange, M. Renaud and S. Cerri in this book).

Furthermore, the abusive notion of data bank disappears as applications became more specialised which involves the use of different appropriate data base management systems for :

- archaeological survey and excavation data management,
- information retrieval system,
- quantitative applications (graphical, statistical),
- expert systems,
- computer assisted publishing systems.

By the easy to use more apparent than real, of the microcomputer, the archaeologist thinks he becomes easily a computer expert. We must therefore expect many failures and simplistic uses, compared with the brillant experiment of the 1970s. But is that not the price to be paid temporarily in order that data processing will become an archaeologist's everyday tools ?

2. History of quantitative archaeology

Quantitative archaeology development is the result of three main factors of convergences :

— the development of a general quantitative movement in the social sciences, in the natural sciences, and in the human sciences ;

— the extraordinary burst of applied mathematics to the whole science, after the introduction of computers ;

— and the emergence of new ideas in archaeology, introduced by anthropology, geology and physics.

Before the second world war, the absence of quantification obviously precluded the use of mathematical or statistical techniques. The theoretical approach of the archaeologists was restricted to the spatio-temporal culture identification from physical finds.

The first years following the second world war up to about 1965 saw a profileration of quantitative data : in the United States, for example, by the archaeological research development as part of cultural and social anthropology. In France, in the prehistorical research field, around young prehistorians trained at the geology and palaeontology schools. The progress of excavation methods now made it possible to perform more significative counting operations on which graphical or elementary statistical technics could be applied :

— cumulative diagrams in France, then in Europe, for the prehistoric culture identification, in the 1950s (F. Bordes),
— the first correlation coefficients, and statistical tests for the identification of artifact types (Spaulding, 1953),
— the first seriations to establish relative chronologies (Brainerd and Robinson, 1951).

Methods are simple and developed by the archaeologists themselves.

In the period 1965-70, the first computers freed the mathematicians from algorithm complexity and computing heavyness which limited before applied mathematics development. Conventional statistics were revolutionized by the introduction of multidimensionnal data analysis. Quantitative modelling takes the place of the engineer old techniques of approximation. Applied mathematics invaded every scientific discipline : economic and social sciences (econometry, psychometry), natural sciences (ecology, spatial geography), human sciences, and at the first place, archaeology. Numerical taxonomy, coming from ecology, was applied to typometry ; multidimensionnal data analysis, coming from psychometry, were used for cultural identification ; spatial analysis, coming from geography became spatial archaeology ; classical statistics, with test theory and sampling, supplied apparently an ideal instrument for the inferential ideas of New Archaeology. There was not a technique which finds, or pretends to find, an application field in archaeology, up to the material culture modelling with simulation languages and catastroph theory.

Very soon, still, between the archaeologist, just emerging from the age of texts and objects, and the mathematician trained to information processing, the dialogue proved difficult : the former uses the methods of the latter without a complete understanding whereas the latter takes possession of the data from the former without knowing their place in an archaeological context. Archaeology, and generally human sciences, becomes a field with dangerous misconceptions.

After 1975, a new archaeologist generation, with a better mathematic maturity, bring a kind of comeback to reason, knowing better how to integrate the quantitative techniques used in a well defined archaeological approach. Possibilities and limits of the quantitative methods are recognized, allowing a return to mathematicians : the perception of ingenuous underlying models in spatial analysis, seriation and modelisation, the sampling difficulties perception, and, consequently, the statistical test uncertain results, a more reasonable use of the multidimensionnal data analysis, even if, sometimes, the magical and toy-like attraction of a new technique fires the enthusiasms.

Anyhow, one of the most positive points in quantitative archaeology contribution to archaeology is the conscience of the necessity of formalizing archaeological reasoning, more and more upstream, allowing theoretical archaeology birth.

A similar trend may be seen in data processing approaches in the transition from information retrieval systems to expert systems, following the same way of archaeological reconstitution formalization.

3. The spread of archaeological data processing and applied mathematics to archaeology

The analysis of archaeological data processing and applied mathematics spread shows that archaeology is fairly resistant to new techniques eclosion.

This spread was carried out along conferences and colloques, through books edited with articles from different authors, exceptionnaly through specialized journals.

Few archaeological reviews accept yet today to open their columns to such papers : exceptions include *American Antiquity*, *World Archaeology* (GB), the *Bulletin de la Société Française de Préhistoire*, and the reviews of archaeometry : *Science and Archaeology* (GB) and *Archeophysica* (RFA).

Clark and Stafford paper (from *American Antiquity*) has a graph showing the number of papers published in this journal on this subject between 1935 and 1980 (Fig. 1).

4. Computer applications in archaeology

The considerable development of data processing and telecommunications in the 1980s, as the result of the growing integration of electronic components (particularly the famous microprocessors), involve the appearance of a new hardware generation designed for distributed architectures, communicating by public networks and local networks, the system software standardization (operating system, compilers, data base management system, graphic language, communication protocols), and the application package spread.

Therefore, most of the archaeological data processing applications, developed in the 1970s, may be considered today as experiments, or, for the more ambitious, as research projects, still far from the archaeologist as user.

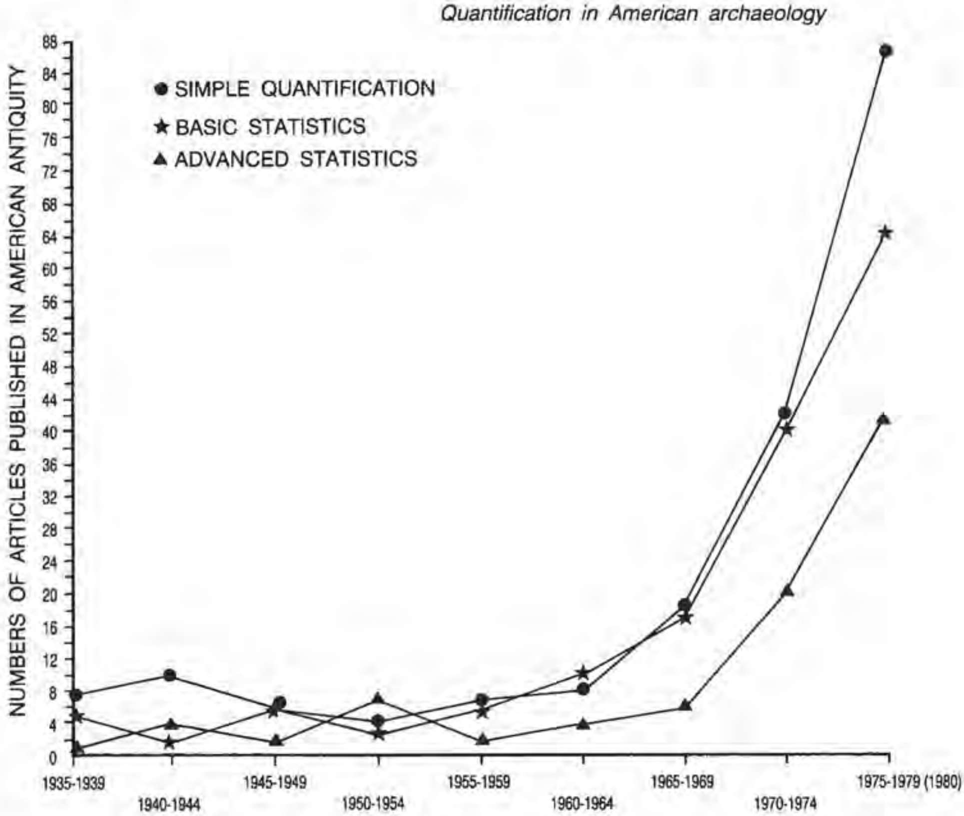

Fig. 1. The American Antiquity *survey results.*

4.1 The functional approach

Computerizing archaeology means simply enumerating these of archaeologist's tasks which are suitable for automation, and assessing the cost, in terms of time and money saved in order to allow the archaeologist to devote his energy completely to reconstitution constructions.

Generally, archaeological tasks may be described as *fieldwork* (survey, excavations), *laboratory work* (from physical finds analysis to spatial distribution analysis), *information retrieving* (corpus, inventory), *quantitative processing*, even *computer assisted reasoning*, at last *publishing aids* (text, picture, map, ...).

The functional analysis let see a task standardization, suitable for processing by general software :

On the field or in the laboratory, the archaeologist is performing *recording* functions (physical finds, comments, samples, maps, photographs, site) with acquisition, checking, correction, consultation, updating, on site or remote back-up storage. Records are analyzed by key-word query (record selection), report writing (sorted inventory), counts (sorting, cross-sorting with filters), analytical mapping, etc... ; *documentation* function allows information retrieving in specialized data banks (corpus, inventories, bibliographies).

Cognitive constructions are realized with *data matrices* for quantitative processing, with facts and rule banks for expert systems.

Lastly publishing aids function involves word writing, picture drawing, distribution or geographical mapping, before photocomposition.

4.2 Data processing distribution

The archaeologist must decide however the selection of the precedent functions for its own needs, and the function distribution on the site, or in the laboratory.

Current communication ressources between micro or mainframe computers, by data transmission networks, involve that the distribution choice is now only a question of cost and quality of service. Then, it is usually considered that mainframe computers will be used as specialized servers : computer centre, information retrieval centre (data, picture, voice), publishing centre, ...

Other operations will be running in local workstations (with 16 bits microprocessors, up to 2 Mø main memory, 40 Mø mass storage, color graphic display, communication software, quality printers), of which microcomputers are today the prefiguration.

Hence the distribution of functions between the excavation site and the laboratory depends only on the interactivity degree which the archaeologist requires between data recording and data processing. It is possible, for example, to define several excavation strategies involving needs for a more or less important interactivity between data recording and data processing. An exploratory excavation or survey involves only data recording, well made by a checked recording on a portable microcomputer.

An excavation project with defined objectives involves a preliminary data analysis at the end of the excavations, even during the excavations, requiring then inventories, charts, stratigraphical or geographical maps.

Moreover, file consultation from previous excavations, remote data banks querying, file transmission involve a greater storage capacity, and a data transmission network connection.

Lastly the need to perform complex statistical computing, a sophisticated sampling control, simulation computing for modelling, transforms an excavation method into a real time experimental design. In this last case, we may see the great possibilities of data processing in modern excavation methodology.

4.3 The information system

Let us consider now a defined archaeological problem, with appropriate necessary informations, involving a survey and excavation project.

The archaeologist, after a site aknowledging phase, must resolve an information recording and organising problem for processing : it is, classically, which is called to define the information system.

The definition of the information system involves the creation of a data dictionnary, a logical and physical data organization file, and the evaluation of the necessary ressources in terms of computing power, main memory and mass storage size, printing capacity. It is then possible to determine the computer hardware configuration (central unit, memory, storage, peripherals, transmission), and the software configuration (Operating system, package, « ad hoc » software), then installation and maintenance costs.

4.4 Hardware and software

The use of mainframe computers affords several advantages :

— system and exploitation teams, who liberate user from technical problems, provide training, sometimes services, and plan the hardware evolution,

— general software and utilities (especially on IBM), which make unnecessary specific developments : statistical programs packages, data base management systems, information retrieval systems, graphic software, software development tools, ...),

— special peripherals possibility, which do not exist on small computers (plotters, color printers, graphic consoles, ...).

Mainframe computer learning needs therefore an important time investment.

At the opposite, the personal microcomputer is an excellent learning machine, which explains its growing success in archaeology.

This first generation, built around 8 bits microprocessors, few hundred kø floppy disk drive, offers insufficient ressources and services for professional use. The second generation, with cost about 6000 $, built around 16 or 32 bits microprocessors, 40 Mø 5 p ¼ Winchester disk drives, graphic consoles, is an attractive solution for data management on excavation site or in the laboratory. New connection possibilities to remote computers, involve the simultaneous use of mainframe computers and microcomputers.

Nevertheless, short-range introduction of communicating workstations, using the same components, will revolutionise the market and its products.

The 1980s will see also the development of Videotex technics, for the use of cheap centralized or distributed information retrieval systems. Digitalized picture storage and diffusion systems will find a great application field in the cultural heritage field.

If today Operating systems and packages are more and more standardized, it may be expected new important developments in the expert system field which put artificial intelligence near the user, in publishing aids packages, and in survey or excavations data management packages.

4.5 Services

Archaeologist's critical problem is not to be obliged to write himself applications software. An application generally needs general software involving the choice of computer satisfying the requirements, but also needs « ad hoc » application software, to be written by the archaeologist himself, unless he buys packages. Application package idea just appears (Minark from J. Johnson for survey applications), and should slowly spread in the 1980s.

So, data processing using in archaeology may be structured more rationally :

— users defining products ; service laboratories developing software, distributing them with training and maintenance, and even managing computing, information retrieving and publishing centers ; research laboratories developing new techniques.

5. Quantitative archaeology applications

Quantitative archaeology applications today cover quite all the archaeological field varying but generally increasing. It may be considered that quantitative approach is characterized by information coding justified by the use of mathematical and graphical methods to process this information in a cognitive and synthetic perspective.

Quantification in the human sciences is not always justified, especially when the measurements are not enough repetitive and with the precision required for the projected construction. The quantification technics and the data preparation are the most important point in this stage as they are generally underestimate : syntaxic description, coding, tabulation, checking, estimation.

Graphical and mathematical methods cover a whole arsenal of quantitative methods that are not specific to archaeology : graphs, descriptive statistics, test theory, multidimensional data analysis, spatial analysis, clustering, modelling, sampling, ...

Anyhow, in some rare cases, statistic methods, specific to archaeology, have been developed, especially in seriation, in spatial analysis, in sampling, even if these methods are based on a classical mathematical substratum. It may even be said that, in a future, archaeology will be able to control enough quantitative techniques in order to develop her own methods.

It will be noted, however, that the quality of quantitative applications does not depend on the sophistication of the mathematics used. Many of these applications are using simple technics, which are part of traditional quantitative methods : indices, counts, graphs, descriptive statistics, tests. Examples of successful applications, where the quantitative spirit is very present, may be found for example in B. Soudsky work, in the study of the neolithic site of Bylany, and in A. Leroi-Gourhan for the franco-cantabrian cave art study.

In the 1980s, the best explored areas of the quantitative archaeology are the typometry of material remains, the material culture identification, and study of their spatio-temporal evolution, the chronological ordering by seriation, the spatial analysis in the sense of spatial geography, the spatial analysis of the material remains distribution on the archaeological site, the archaeological site sampling in a survey, the material remains sampling in an archaeological site or in a corpus, the construction of estimators, the culture system modelling : settlement process, exchange process, site-catchment analysis, social organization system process, cultural change process.

The outline below will be the opportunity for a preliminary review of a nearly thirty years of quantitative archaeology.

5.1 Typometry

We find the same four stages of technics development as above :

- Before 1940, the typometric determinations were empirical and dependent of the confidence in the archaeologist's expertise.
- Then, after the war, the first graphical techniques (histogram, scattergram) appear, with also the matrices manipulation, and the first statistic computing (attribute association tests by Spaulding).
- After 1966, clustering technics are used, with well known problems.
- Today, the typological analysis techniques, which combine several Q+R multidimensionnal data analysis, provide satisfying results when they are employed in an interactive manner between artifact description and the quantitative processing which shows the clusters, their characteristics and their stability.

5.2 Identification, characterization and evolution of material cultures

The culture identification of prehistoric cultures appeared with its first formal approach during the 1950s with the type-list and cumulative diagram (Bordes).

In 1966, the multidimensional analysis was introduced in the United States (Binford) and in the United Kingdom (Doran and Hodson).

In 1975 correspondence analysis, used simultaneously with cluster analysis, provided a more satisfying method which allows moreover to characterize cultures from more general descriptions (types or attributes) and to study their evolution, generalizing then seriation methods (Djindjian).

5.3 Seriation

Seriation, except with the pioneering work of F. Petrie (1899), began around 1950. Seriation is one of the rare quantitative techniques specific to archaeology, specially in the beginning.

Two stages may be distinguished in the seriation techniques :

— the first stage corresponds to the development of ordering algorithms on the basis of the method proposed by Brainerd and Robinson in 1951, and which found soon theorical underlying in operational research. Several computer-based algorithms, were developed between 1965 and 1972 ;

— the second stage corresponds to the multidimensional analysis approach, based on the work of Kendall in 1970, which offers the advantage of putting previously in evidence the seriation (horse-shoe curve, parabola). More detailed investigation (Djindjian, 1980) of these techniques showed that complex evolutionnary, archaeologically more realistic models, could be easily detected.

5.4 Sampling in archaeology

Under the statistical term, in fact comes out one of the archaeological major methodological problems. Indeed, archaeological data recording, during surveys, surface exploration, excavations, even artefact description, is never neutral : this is sampling. In most cases, the overriding importance of relevant data perception, or the obligatory transition to a learning mecanism on the site, seem to leave behind the rigorous formalization necessity for sampling process.

It is simply that sampling techniques in archaeology are more complex and more specific than the standard techniques from sampling theory and ecology.

It is principally in the United States during the years 1965-70, that sampling idea appears with a statistical connotation, essentially in relation with the american regional survey project and with the New Archaeology inferential approaches. European archaeology till now, has not been receptive to this approach, preferring important exhaustive excavations of archaeological sites.

Archaeology needs concern specially :

— Archaeological sites sampling in a survey,
— Archaeological data sampling in a site,
— Sampling in a collection of material remains,
— Construction of various estimators.

About sampling for a survey, the efficacy and limits of sampling techniques by quadrats or transects, then by random sampling or systematic sampling, are well studied in J.W. Mueller's book, and depend paradoxically on the perfect knowledge of the sampled populations. This fundamental constraint in archaeology can be only accepted by a multistage stratified sampling which uses the progressive learning of the site data.

Kriging methods seem today a more satisfactory solution to these survey problems, allowing to measure the density in archaeological sites in the unsurveyed areas by interpolation between surveying areas and, then, to guide the site research with more efficacy from a small percentage of surveyed areas (Zubrow and Harbough, in Hodder, 1977).

Sampling inside a site shows up the difficult problem of the site learning. The sampling approach don't bring any solution less biassed than traditional non statistical approach. The specificity of each site (surface dwellings, stratified levels, urban settlements), the remain conservation processus knowledge, and the site progressive learning, involve imperatively the use of site specific sampling techniques.

Finally, the construction of estimations seems today a potentially rich way of research, still unexplored, except by Orton's work on the entire pottery number estimation from ceramic potsherds (Orton in *World Archaeology*, 1982). With any doubt, inferential approaches could find lastly with estimation, the good informations necessary for several causality ambitious researches.

5.5 Spatial archaeology

If archaeology, since the 19th century, has studied material remains distributions over large geographical areas, it was not until the 1970s that a spatial archaeology emerged, using mathematical techniques, especially in the United Kingdom, at Cambridge, following quantitative geography techniques (Chorley and Haggett) with I. Hodder (1972) and with the site-catchment analysis applications by Vita-Finzi and Higgs (1970), then, in the United States, with Whallon (1973) and Cowgill who used the methods of ecology for material remains spatial distribution analysis.

Spatial analysis in archaeology can be applied at several levels :

— pattern level in a settlement, where it is concerned by social or personal factors and for which are employed distribution analysis techniques as Nearest Neighbour Analysis or derived ;

— archaeological site level where it takes an interest in cultural and economic factors and for which are employed the same methods allowing activity identification (material remain association) and settlement pattern (post hole distribution by example) ;

— territory level, where geographical and economical models may be used : locational analysis, gravitational models, central place theory, rank size rule, site-catchment analysis, random walk process, polynomial adjustment, joining modelling techniques of cultural systems.

The underlying model knowledge, especially those derived from quantitative geography, and a complete control of the data used in the spatial sampling are strong constraints which limit their application scope.

5.6 Cultural systems modelling and simulation

Cultural systems modelling is indoubtedly the most ambitious and therefore the most difficult of all quantitative archaeology techniques.

Lately appeared, ten years ago, its applications, or rather its experiences may be counted on the fingers. Whether they involve the cultural model adjustement for a prediction allowing a validation a *posteriori* or the simulation of a hypotheses set (cf. expert system for non-mathematical approaches), those techniques need today an important investment of problem formalization, which is the first (but often the only) reward.

The principal applications approached settlement process modelling (for example early neolithic colonization in occidental and central Europe from Ammermann and Cavalli-Sforza), diffusion and exchange process, culture change modelling (for example, applications by Renfrew using Catastroph Theory of R. Thom), subsistence processes modelling (hunter-gatherer economy by A.S. Keene), socio-political organization, etc.

Those applications are described in details in Hodder (1977), and Renfrew and Cooke (1979). Their implementation requires an important conceptualization effort and the disponibility of sufficient data to construct models able to reflect cultural complex realities, which limit till today their scope, but which make them potentially a method with a future in quantitative archaeology.

François Djindjian
rue Boussingault, 32
F - 75013 PARIS

General Bibliography

General works

BINFORD, S.R., and BINFORD, L.R., 1968, *New Perspective in Archaeology*, Aldine, Chicago.

CLARKE, D.L., 1968, *Analytical Archaeology*, Methuen, London.

DORAN, J.E., and HODSON, F.R., 1975, *Mathematics and Computers in Archaeology*, Edinburgh University Press, London.

GARDIN, J. Cl., 1979, *Une archéologie théorique*, Hachette, Paris.

HODDER, I., and ORTON, C., 1976, *Spatial Analysis in Archaeology*, Cambridge University Press, Cambridge.

IHM, P., 1978, *Statistik in der Archäologie*, in *Archäophysica*, 9, Bonn.

SCHIFFER, M.B., 1976, *Behavioral Archaeology*, Academic Press, New-York.

Collective works, Colloquies, Congresses :

BORILLO, M., (ed.), 1977, *Raisonnement et méthodes mathématiques en archéologie*, Paris Marseille, CNRS.

BORILLO, M., (ed.), 1978, *Archéologie et calcul*, (Collection 10/18), Paris.

CLARKE, D.L., (ed.), 1972, *Models in Archaeology*, Methuen, London.

CLARKE, D.L., (ed.), 1977, *Spatial Archaeology*, Academic Press, London.

EARLE, T.K., and ERICSON, J.E., (eds), 1977, *Exchange Systems in Prehistory*, Academic Press, New-York.

GAINES, S.N., 1981, *Data Bank Applications in Archaeology*, The University of Arizona Press, Tucson, Arizona.

GARDIN, J. Cl. (ed.), 1970, *Archéologie et calculateurs*, Paris, CNRS.

GARDIN, J. Cl, (ed.), 1974, *Les banques de données en Archéologie*, Paris, CNRS.

HODDER, I., (ed.), 1977, *Simulation Studies in Archaeology*, Cambridge University Press, Cambridge.

HODSON, F.R., KENDALL, D.G., and TAUTU, P., (eds), 1971, *Mathematics in the Archaeological and Historical Sciences*, (Congrès de Mamaïa).

IX[e] CONGRÈS UISPP, 1976, Colloque IV et thème spécialisé 1, *Banques de données et méthodes formelles en archéologie préhistorique et protohistorique*

MUELLER, J.W., (ed.), 1972, *Sampling in Archaeology*, The University of Arizona Press, Tucson, Arizona.

Quantitative Methods in Archaeology, 1982, *World Archaeology*, 14 (1).

REDMAN, C.L., (ed.), 1973, *Research and Theory in Current Archaeology*, J. Wiley, New-York.

RENFREW, C., (ed.), 1973, *The Explanation of the Culture Change : Models in Prehistory*, Duckworth, London.

RENFREW, C., and COOKE, K.L., 1979, *Transformations, Mathematical Approaches to Culture Change*, Academic Press, London.

RENFREW, C., ROWLANDS, M.J., and ABBOTT SEGRAVES B., (eds), 1982, *Theory and Explanation in Archaeology*, Academic Press, New-York.

SCHIFFER, M.B., (ed.), 1978, *Advances in Archaeological Method and Theory* 1, Academic Press, New-York.

Traitements automatiques des données en Archéologie, 1980, *Les Dossiers de l'Archéologie*, 42.

X^{e} CONGRÈS UISPP, Mexico, 1981, *Colloquium on data management and mathematical methods in Archaeology*.

Specialised reviews or general reviews publishing articles on data processing and mathematics applied to archaeology

American Antiquity (U.S.A.)

Archéologie et Ordinateurs : Lettre d'information du C.R.A (FR).

Computer Applications in Archaeology (G.B)

Newsletter of Computer Archaeology : becomes : *Advances in Computer Archaeology* (U.S.A.)

World Archaeology (G.B).