Archaeologia Polona, vol. 39: 2001, 5-16
PL ISSN 0066-5924

Archaeology and archaeological science: past, present and future

Arkadiusz Marciniak[a] and Włodzimierz Rączkowski[a]

The paper gives a general overview of the major aspects of relations between archaeology and archaeological science. It sketches a history of application of scientific techniques and methods in prehistoric archaeology since the end of the nineteenth century. More specifically, it discusses impact of processual archaeology on the dynamic development of archaeological science. The paper further discusses current relations between archaeology and archaeological science, especially in the light of issues advocated by postprocessual critique. It concludes by formulation a proposal to include the results of archaeological science into the main body of archaeological theory.

KEY-WORDS: archaeology, archaeological science, culture-history approach, processual archaeology, postprocessual archaeology

I

The last few decades have brought about a dynamic growth of archaeological science, which, to a large extent, has become a self-contained and self-sufficient academic branch. It may be defined as a set of scientific disciplines, whose object of study are archaeological materials obtained during the archaeological research. A number of scientists initially trained in physics, chemistry, geology, biology, *etc.* have focused their interests on various categories of records discovered through archaeology. One of the important aspects of their interests is found in a detailed measurement of various materials such as clay, stone, metal, bone, *etc.*, using modern techniques and increasingly sophisticated equipment. The other covers a study of the formation processes. Despite these dynamic developments, the results of archaeological science is by no means an integral part of archaeological enquiry and the relations between these two fields need to be much closer in the future than they are now.

This volume is not intended to present a complete overview of relations between archaeology and archaeological sciences in all branches in which this co-

[a] Institute of Prehistory, Adam Mickiewicz University of Poznań

operation exists in contemporary archaeology. Rather, it tries to show how this co-operation is of mutual benefit as it expands the cognitive possibilities of archaeology by creating new sets of data and indicates their possible interpretation. Thus, particular contributions are aimed at showing this unexplored potential that such a co-operation potentially brings about.

These two approaches to studying the past remain largely disintegrated. The difficulties in contacts between archaeologists and archaeological scientists are caused by a lack of understating of scientific procedures from the archaeologist's side and a lack of understanding of the complexity of social, economic and cultural relations of prehistoric groups on the part of the scientist. Moreover, the complexity and diversity of these two fields and accompanying literature is so large that it makes efficient co-operation between these two disciplines very difficult. Scientists use increasingly sophisticated equipment and techniques and perform increasingly detailed analyses of particular categories of archaeological material, far removed from the social, economic and cultural dimension of human existence (*cf.* Lock 1995). At the same time, the majority of archaeologists are still ignorant of many scientific methods and their objectives, potential and limits. They often perceive exact data and measurements offered by archaeological science as a fetish. At the same time, these are often treated with reluctance and then easily rejected when the results they provide are contradictory to the prejudices and expectations of archaeologists. Moreover, in some theoretical milieus, *e.g.,* among postprocessualists, these methods are completely rejected and even caricaturized. A lack of integration between archaeology and archaeological science is also caused by system of education where science-based archaeology is almost non-existent, the British system being exceptional in this respect (Killick and Young 1997).

The first scientific techniques introduced to archaeology were related in large extent to so called field archaeology, which dealt especially with non-invasive methods. Methods of bosing, phosphate determination, resistivity survey, echo-sounding were introduced already in the nineteenth century. The beginning of the twentieth century brought about implementation of new techniques, especially aerial photography, widely accepted as the greatest single technical advance in archaeological discovery (Crawford 1953; Daniel 1978: 294).

Different scientific methods were also used for the interpretation of archaeological data. Notable in this respect was geology, which led to the development of stratigraphy. The introduction of diffusionism resulted in the application of a number of methods of spatial analysis. Most important in this regard was the "geographical-statistical method" introduced into archaeology by Leo Frobenius at the beginning of the twentieth century (Daniel 1978: 242). Diffusionism was also interested in the environmental context of culture development and the interpretation of spatially and temporally differentiated clusters that appeared in the archaeological

record. This clearly geographical approach to the interpretation of archaeological data involved two aspects: 1) the study of distribution patterns of archaeological data, and 2) the study of archaeological monuments or artifacts with relation to the prehistoric landscape. As a result, distribution maps have become a standard tool in documenting and analyzing prehistoric phenomena.

At the same time, the study of the paleoenvironment achieved primary importance as, "prehistoric cultural landscapes must be studied against the background of a prehistoric, not modern, natural landscape" (Daniel 1978: 305). This approach has found many followers, *cf.* R. Gradmann, H. Jacob-Friesen, E. Wahle in Germany or O.G.S. Crawford, C. Fox in the UK. The postulated focus on the reconstruction of the paleoenvironment along with a study of subsistence and economy has resulted in the incorporation of new categories of evidence into the archaeological data that have proven to be efficient tools in the recognition of these aspects of prehistoric communities. In addition to already known artifacts, archaeologists have given attention to floral and faunal data as evidence of subsistence patterns and environmental conditions of human development. As a result, new methods such as archaeozoology, paleobotany and pollen analysis have been widely introduced into archaeology. The concept of the interdisciplinary approach has become very common and was successfully realized by *e.g.,* J. Kostrzewski in Biskupin or G. Clark in Star Carr.

The post-war period is marked by a dynamic development of scientific techniques. This tendency has been well exemplified in the United Kingdom, *e.g.,* by the foundation of the Research Laboratory for Archaeology in Oxford and the works of E.T. Hall and Martin Aitken. The Laboratory started to publish the journal *"Archaeometry"* in 1958 and to organize archaeometry conferences. In 1977 a Science-Based Archaeology Committee was set up in the United Kingdom, by which archaeological science was funded through the Research Councils (Renfrew 1992a: 287).

Major contributions to archaeological science have come from the physical sciences and have been focused on dating methods. Methods of dating comprise radiocarbon, dendrochronology, thermoluminenscence, archaeomagnetism, electron spin resonance, potassium-argon, fission track, obsidian hydration, *etc.* The radiocarbon dating method may be regarded as the most significant contribution to the field of archaeological science (Renfrew 1992a: 285). The chronological interests of the archaeological sciences are now smaller, compared to earlier period, although this has been accompanied by a continued strong interest among archaeologists to employ these results. This is due to the fact that they have, to a large extent, been satisfactorily resolved thanks to the successful development of radiocarbon and dendrochronologcial methods, more recently by the introduction of new techniques such as accelerator mass spectrometry (*e.g.,* Hedges 1987). This interest in dating methods is being replaced by other issues and new methods that follow the wide extension and scope of contemporary archaeology.

2

These early interests in dating techniques were the result of the then dominant interests in the diachronic scope of human development advocated, *e.g.,* by the culture-history approach. These studies were intended to reconstruct and explain subsequent steps in human cultural development, which required a precise location of certain events and episodes on a chronological scale (*cf.* Daniel 1978; Trigger 1989). That is why Libby's discovery was met with such enthusiasm. Later developments in archaeological theory, more precisely, the creation of processual archaeology with its functional and neoevolutionary program, focused most archaeological interests on the synchronic dimension of human existence. Accordingly, various categories of archaeological data have been used to address these issues and this tendency has been developed and strengthened by dynamically expanding science. Consequently, an increasing amount of archaeological data is studied using scientific techniques, and the results of this inquiry can address much more efficiently issues being of interest for processual archaeology.

Processual archaeology has considerably changed both the object of studies as well as research strategies. It was formed in the 1960s as a result of rejecting culture-history archaeology regarded as "chaotically unsystematic, undisciplined, intuitive and empirical" (Champion 1991: 30). This was accompanied by an explicit attempt to formulate a new theoretical and methodological background enabling avoidance of limitations posed by the "arts". This postulated a rejection of description and induction as a basis of the research procedure and their replacement by an explicit introduction of theory and a hypothetical-deductive model of explanation. Consequently, all steps in this procedure have been changed, including the research objectives, hypothesis formulation, and collection and analysis of empirical data. This enables falsification of the hypothesis and consequently offer a reliable explanation of prehistoric phenomena.

The major contribution of processual archaeology was its introduction of explicit explanatory procedures aimed at the formulation of objective regularities in different prehistoric phenomena. It postulated the introduction of scientific methods at all levels of study of prehistoric phenomena such as material objects used by people, their spatial distribution, human behavior as well as economic, social, and cultural components of human system. It advocated explicit formulation, testing, and use of laws. Scientific knowledge was a postulated goal of archaeology defined as a set of tested statements adequately explaining prehistoric reality. It advocated scientific explanation as proposed by Carl Hempel (1965) and regarded it a useful model for comprehending the structure of archaeological knowledge. This is based upon an explicit definition of law, hypothesis, explanation, and confirmation. Laws of a deterministic and causal nature were believed to provide universal connections between the studied phenomena. More particularly, these include universal laws of

human behavior not tied to any specific time and/or place. Accordingly, they are a basis for explanations. The hypothetical-deductive model assumes that proposed hypothesis is associated with a statement of initial conditions from which observational predications are deduced. The explanation is divided between the *explanans* and the *explanandum*, where the latter is a logical consequence of the former. In the words of Fritz and Plog (1970: 407), "laws refer to phenomena abstractly and universally, but explanations refer to phenomena concretely and particularly."

This research program further led to the pursuit of a correlation between various long-term behavioral and cultural phenomena and its material consequences, preferably of a universal character. Precise measurements of variables and the introduction of mathematical tools were believed to provide an objectification of the results and a possibility for conducting intercultural comparative studies, and consequently, of formulating a law of cultural dynamics. This formalization of analytical tools, leading to a standardization of methods, fits ideally into a belief in the objectivity of cognition, potential for the formulation of universal laws and a general theory. These methods from the natural sciences were believed to secure the objectivity of cognition (Johnson 1999: 20-1; Hodder 1999: 2-3). This caused a dynamic development of experimental and ethnoarchaeological studies. Their results revealed, however, that the correlation between behavior and material culture does not have an absolute character and can only be viewed as a regularity of certain statistical certainty.

Thus, archaeological science developed into a highly respected subdiscipline of processual archaeology. This is fully understandable, considering its postulate of making archaeology an interdisciplinary science. The research interests of these numerous approaches (*e.g.,* ^{14}C) stemmed from the positivistic understanding of science advocated by this paradigm (Knapp 2000: 34). Introducing such a model is intended to leave aside and overcome the prescientific practice of culture-history archaeology (Fritz and Plog 1970; Salomon 1976; 1978). According to the external causality of cultural changes advocated by processual archaeology, this has lead to a development of techniques of environmental reconstruction. These are linked with the works of Grahame Clark and Eric Higgs. Another dynamic field included spatial analysis (*e.g.,* Hodder and Orton 1976).

Contemporary archaeological science is embedded in this tradition and is mainly concentrated on the analysis of many categories of archaeological data. Considerable interests are focused on ecofacts, which became an important kind of archaeological data. These comprise faunal analysis, micro and macro botanical remains, coprolites, phytoliths, pollen analysis, diatom, shells, skins and many others. An important aspect of these studies includes dietary reconstructions based on an analysis of isotopes and lipids (*e.g.,* Byrne and Parris 1987; Farnesworth *et al.* 1985; Hancock *et al.* 1989; Runia 1987; Sillen and Kavanagh 1982). The others

include DNA techniques and other bimolecular methods (*e.g.*, Cavalli-Sforza, Menozzi and Piazza 1994; Renfrew 1992b). New techniques of this kind also incorporate provenance studies as, e.g. lead isotope analysis (*e.g.*, Stos-Gale 1989). Other techniques embrace non-destructive microanalyses such as X-ray and the electron micro-probe (Jope 1989: xii). An important branch of archaeological science includes the taphonomy of both botanical and faunal material (*e.g.*, Miksicek 1987; Lyman 1994). The process of site formation in general has been employed with notable success at hunter-gatherers sites (*e.g.*, Brain 1981; Shipman 1981). This is the result of Schiffer's (*e.g.*, 1976, 1987) conceptualization of the formation processes.

Archaeological science had rather a small impact upon excavation techniques except for remote sensing and surveying methods and their development was quite independent from it (Renfrew 1992a: 288). More recent developments of methods of excavations also include soil micromorphology (Courty 1992). In Renfrew's (1992a: 289) opinion, archaeological science in the future will impact most considerably on prospecting and excavation methods in the form, *e.g.*, of remote sensing methods (aerial surveys, satellite imagery, geophysical methods), ground surveys, quantitative methods or tomographic interpretation of data.

The dynamic development of archaeological science is accompanied by a debate on the foundation of scientific methods as well as the impact of postdepositonal processes, e.g. as contamination and natural transport of certain raw materials. These clearly require a different level of analysis that must be addressed by specialists involved in specific kinds of analysis (see debate about usefulness of lead isotope analysis – *e.g.*, Gale and Stos-Gale 1992; Pernicka 1992; Sayre *et al.* 1992). However, the potential impact of these factors has to be recognized and brought to the attention of archaeologists, who are to critically evaluate certain methods being offered to archaeology along with the foundations and the interpretation of their results. This problem is exemplified by discrepancies between historical and radiocarbon dates from the period before which they were calibrated. These concerns have been hotly debated and satisfactory solution is being offered by the calibration of radiocarbon dates.

New methods developed by archaeological science have, in many cases, led to a reformulation of archaeologists' claims about the past, the definition of new research programs, and a different interpretation of various prehistoric phenomena. Thus, archaeology and archaeological science remain within a network of mutually dependent relations and inspirations, which nonetheless, is still far from being satisfactory. All these developments have yet to be followed by equally deep considerations of their consequences on the interpretation of certain changes and transformations implied by the results of these methods as well as ways whereby these results might be incorporated into the main body of archaeological theory. A few attempts to link these two branches have already been undertaken, *e.g.*, Lock's (1995)

proposal to link the development of digital technologies with changing archaeological theory, which may bear fruitful results. This may be achieved by "increasing contextualism and data-rich environments that encompass both the technology and the archaeological theory" (Lock 1995: 13). It is difficult, at this point, to say how and to what extent an increasing development of new media such as Internet, the CD-ROM, virtual reality or laser-pantography would influence archaeological interpretation and enhance the development of archaeological theory (*e.g.*, Biehl 2001). For the time being, it shapes data and information flow, the transfer of knowledge, and the availability of data and publications. Rapidly developing measuring devices abound, *i.e.*, total stations, GPS, laser-pantographs, and 3D laser-scanners that, in the immediate future, will lead to full 3D-measuerements (Schaich 2001). The development of these new techniques will shape excavation techniques and redefine the potential use of large databases.

3

The emergence of postprocessual archaeology in the 1980's brought on considerable criticism of the processual paradigm (see, *e.g.*, Marciniak 1997) including the foundations of archaeological science. More particularly, it has rejected the systemic view of social relations and advocated the importance of structures and an agency rather than behavior. This new perspective has also challenged the reliability of hypothetical-deductive models of explanation along with possibility of formulating laws and law-like generalizations. This new way of practicing archaeology has focused more on interpretation than explanation. Interests in the individual scope of human actions and activity have led to the marginalization of more detailed technological considerations such as, *e.g.*, the molecular structures of metal objects, trace elements and isotopes, the technology of pottery production, *etc.* This new tendency is well epitomized in the study of landscape. Interests in artifacts distribution, the hierarchy of factors shaping settlements patterns were replaced by, *e.g.*, the phenomenology of landscapes (see Tilley 1994), which in the long run, led to changes in the use of GIS (*e.g.*, Wheatley and Gillings 2000; Llobera 2000; Zapłata and Tschan 2001). A lack of interest in archaeological science in this milieu was the result of fundamental changes in the perception of archaeology and its objectives. It questioned a possibility to produce "objective" results by both archaeology and archaeological science and stressed that these results are socially constituted.

This tendency of the last two decades has been accompanied by an increased separation of interests in archaeology and archaeological science. This is manifested in the existence of specialized journals, meetings, conferences, workshops, *etc.*, which have been organized by both of these disciplines, yet have hardly been pene-

trated by the other side. This is well exemplified by two large journals *"Archaeometry"* and *"Journal of Archaeological Science"*. Articles published in these journals reveal the enormous variability of methods used for analysis of increasingly diverse sets of archaeological data. Subsequent years bring about increasingly more specialized and detailed analyses. This makes their reception in the archaeological world more and more difficult; consequently, their use in archaeological practice is very limited since their comprehension clearly needs specialized knowledge from an ever-growing number of fields. In some cases their use is dictated by the rhetorical requirements of the archaeological narrative. When employed for such purposes, they can no longer serve as a way of hypothesis verification aimed at the formulation of general laws and regularities, as was postulated in the 1960s and the 1970s. It is argued that archaeological science strengthens the mechanistic understanding of prehistoric phenomena, leading to the further dehumanization of archaeology. This is because science, dealing with a predictable and limited physical system, is at one end of the spectrum while archaeology is at the other (Chippindale 2000: 606).

A lack of communication between these two disciplines appears to have been caused by a general lack of interest from the side of archaeology to include results of archaeological science within explanatory and/or interpretative frameworks or to use them in only a very superficial way. This opposition needs to be broken down and incorporation of results of archaeological science is a necessity. The most efficient way to achieve this goal is to join these two disciplines at the theoretical and methodological levels (*cf.* Marciniak 1996a, 1996b, 1999; Rączkowski 2001a). This is the sole way to reach a plausible merger of these two trends of research on the past. Disregarding or dismissing the dynamic development of archaeological science will certainly not cause its disappearance. Its development will be continued, but the results it provides will be continuously distanced from the interests and needs of archaeologists.

4

One of the biggest failures of postprocessual archaeology was the almost total rejection of science as a proper tool for analyzing the past. A postulate to withdraw from such an approach, which deals with archaeological evidence arbitrarily with no comprehension of its nature, has been brought up in more recent publications (*e.g.*, Bintliff 1991; Hodder 1991). We observe today an increasing complementation on the part of processual and postprocessual archaeology. These attempts leave behind previous misunderstandings by trying to be more effective in their contribution to a wide range of commonly shared issues (*e.g.*, Hodder 1991b; Preucel 1991; Skibo *et al.* 1995). As indicated previously, it is clear that postprocessual archaeology does

not notice and thereby omits achievements of archaeological science. This is manifested for example in its reluctance to take into consideration formation processes so successfully developed by archaeological science, clearly evident in the phenomenology of landscapes by Tilley (1994) or interpretations of the British Neolithic by Thomas (1996). Attempts to overcome these limitations exist and are seen, *e.g.*, in using viewshed analysis to comprehend changes in vegetation (*e.g.*, Tschan *et al.* 2000) or aerial archaeology (*e.g.*, Rączkowski 2001b). Certainly there is a need to look for a common ground. What we postulate is a bridging of this gap, an initiative that must certainly come from the archaeologist.

We would argue that results of archaeological science could "guide the objectivity" (Hodder 1991a: 10) of archaeological interpretation, which may also lead to preventing relativistic claims about the past that interpretive archaeology has sometimes been accused of. This shows that the fusion of these scientific and interpretive perspectives is possible. The results of scientific methods may be regarded as a necessary inferential component of the interpretive procedure.

The "objectivity" of interpretation remains an important topic in the humanities of the last decades. According to Umberto Eco (*e.g.*, 1979, 1990, 1992), the limits of interpretive discretion are situated within the text. Eco argues that it is possible to establish the intention of the text, albeit not precisely, and it is therefore possible to evaluate which interpretations of the text are incorrect. These include those that do not take into account the coherence of the text and the meaningful system it uses. In the same direction go some proposals in historiography and ethnography, which merge the textualist challenge with the requirements of scientific analysis. Stress in ethnography is laid on the nature and quality of data prior to the inferential step. The two-step analysis comprises reflexive analysis followed by a comparative even historical approach, because "storytelling and science are necessary to a complete understanding of ethnographic realities" (Aunger 1995: 12). In order to link together the narrativist and scientific approaches to history in historiography, the research procedure has to consist of "the chronicler's layer and the layer of story and/or interpretation" (Topolski 1994: 34). The former is based on so-called "base sentences" and give the narrative its temporal expansion. This is the sole basis for any kind of narration that it the next step of the research procedure.

Changes in the theoretical climate of archaeology in the last two decades define the place of archaeological science in its panorama. Multiple ways of knowing the past are inevitable and an increasing number of archaeologists seem to understand this. Their larger part, however, still remain in the well fortified defensive camps of their own paradigms. It is obvious that today there are at least three major approaches to the past – culture-history, processual, postprocessual and a number of attempts to link them in different ways. Archaeological science is finding its way into all these traditions.

Even when we reject ecological determinism, mechanistic laws and regularities, the "How do you turn this on?" functionality of the human system, we do not reject the results of archaeological science aimed at an analysis of increasingly diverse archaeological data and, consequently, a deepening interpretation and comprehension of various prehistoric phenomena. Scientific analysis of archaeological data is advisable even when the evidence is far distanced from human culture and even considering that their results cannot any longer be treated as objective but defined by theory (Knapp 2000: 35). Consequently, it is clear that the results of scientific methods cannot give us direct simple answers to questions asked by archaeologists, though they can provide some analytical results that may be subject to various interpretations within different theoretical frameworks. It is an archaeologist's job to integrate the results of archaeological data with the body of archaeological theory. These results have to be interpreted in the social, technological, economic and cultural context of human group's existence. Interpretation of scientific data needs also to consider the impact of recovery and formation processes.

REFERENCES

Augner, R. 1995. On ethnography. Storytelling or science? *Current Anthropology* 36(1): 97-114.

Biehl, P.F. 2001. Hypermedia and archaeology. A methodological and theoretical framework. Paper presented at the 7th Annual Meeting of the European Association of Archaeologists in Esslingen (Germany).

Brain, C.K. 1981. *The hunters or the hunted? An introduction to African cave taphonomy*. Chicago.

Byrne, K.B. and D.C. Parris 1987. Reconstruction of the diet of the Middle Woodland Amerindian population at Abbott Farm by bone trace-element analysis. *American Journal of Physical Anthropology* 74: 373-84.

Cavalli-Sforza, L.L., P. Menozzi and A. Piazza. 1994. *The history and geography of human genes*. Princeton.

Chippindale, C. 2000. Capta and data: on the nature of archaeological information. *American Antiquity* 65(4): 605-12.

Coutry, M.-A. 1992. Soil micromorphology in archaeology. In *New developments in archaeological science*, A.M. Pollard (ed.), 39-59. Oxford.

Crawford, O.G.S. 1953. *Archaeology in the field*. London.

Daniel, G. 1978. *A hundred and fifty years of archaeology*. London.

Eco, U. 1979. *Lector in fabula. La cooperazione interpretativa nei testi narrativi*. Milano.

– 1990. *The limitation of interpretation*. Bloomington, Indiana.

– 1992. Interpretation and history. In *Interpretation and overinterpretation*, S. Collini (ed.), 24-44. Cambridge.

Farnsworth, P., J.E. Brady, M.J. DeNiro and R.S. MacNeish 1985. A re-evaluation of the isotopic and archaeological reconstructions of diet in the Tehuacan valley. *American Antiquity* 50(1): 102-16.

Fritz, J.M. and F.T. Plog 1970. The nature of archaeological explanation. *American Antiquity* 35(4): 405-12.

Gale, N.H. and S.A. Stos-Gale. 1992. Evaluating lead isotope data. *Archaeometry* 34: 311-17.

Hancock, R.G.V., M.D. Grynpas and K.P.H. Pritzker 1989. The abuse of bone analyses for archaeological dietary studies. *Archaeometry* 31(2); 169-179.

Hempel, C.G. 1965. *Aspects of scientific explanation.* New York.
Hedges, R.E.M. 1987. Radiocarbon dating by accelerator mass spectrometry: some recent results and applications. *Philosophical transactions of the Royal Society of London.*323: 57-73.
Hodder, I. 1991a. Interpretive archaeology and its role. *American Antiquity* 56(1): 7-18.
– 1991b. Postprocessual archaeology and the current debate. In *Processual and postprocessual archaeologies.* Multiply ways of knowing the past, R.W. Preucel (ed.), 30-41. Carbondale.
Hodder, I. and C. Orton 1976. *Spatial analysis in archaeology.* Cambridge.
Jope, E.M. 1989. Preface. In *Scientific analysis in archaeology and its interpretation*, J. Henderson (ed.), xi-xv. Oxford.
Killick, D. and S.M.M. Young 1997. Archaeology and archaeometry: from casual dating to meaningful relationship? *Antiquity* 71: 518-24.
Knapp, A.B. 2000. Archaeology, science-based archaeology and the Mediterranean Bronze Age metals trade. *European Journal of Archaeology* 3(1): 31-56.
Llobera, M. 2000. Understanding movement: a pilot model towards the sociology of movement. In *Beyond the map: archaeology and spatial technologies*, G. Lock (ed.), 65-84. Amsterdam.
Lock, G. 1995. Archaeological computing, archaeological theory and moves towards contextualism. In *Computer applications and quantitative methods in archaeology*, J. Huggett and N. Ryan (eds), 13-8. Oxford.
Lyman, R.L. 1994. *Vertebrate taphonomy.* Cambridge.
Marciniak, A. 1996a. *Archeologia i jej źródła. Materiały faunistyczne w praktyce badawczej archeologii.* Poznań, Warszawa.
– 1996b. Archaeological science and cultural interpretation – how could the two meet together? An example from analysis of faunal remains. Paper presented at 29th Annual Chacmool Conference in Calgary (Canada).
– 1997. Setting a new agenda. Ian Hodder and his contribution to archaeological theory. *Archaeologia Polona* 35-36, 409-26.
– 1999. Faunal materials and interpretive archaeology – epistemology reconsidered. *Journal of Archaeological Method and Theory* 6(4): 293-320.
Miksicek, C.H. 1987. Formation processes of the archaeobotanical record. In *Advances of Archaeological Theory and Method*, vol. 10, M.B. Schiffer (ed.) 211-47. New York.
Pernicka, E. 1992. Evaluating lead isotope data. *Archaeometry* 34: 322-6.
Preucel, R.W. 1991. The philosophy of archaeology. In *Processual and postprocessual archaeologies. Multiply ways of knowing the past*, R.W. Preucel (ed.) 17-29. Carbondale.
Rączkowski, W. 2001a. Beyond the technology: do we need "meta-aerial archaeology"? In *Aerial archaeology – developing future practice*, R. Bewley and W. Rączkowski (eds). Amsterdam (in press).
– 2001b. Post-processual landscape: the lost world of aerial archaeology? In *One land, many landscapes*, T. Darvill and M. Gojda (eds). Oxford (in press).
Renfrew, C.A. 1992a. The identity and future of archaeological science. In *New developments in archaeological science*, A.M. Pollard (ed.), 285-93. Oxford.
– 1992b. Archaeology, genetics and linguistic diversity. *Man* 27: 445-78.
Runia, L.T. 1987. Strontium and calcium distribution in plants. Effects on paleodietary studies. *Journal of Archaeological Science* 14: 599-608.
Salmon, M.H. 1976. "Deductive" versus "inductive" archaeology. *American Antiquity* 41(3): 376-81.
– 1978. What can systems theory do for archaeology? *American Antiquity* 43(2): 174-83.
Sayre, E.V., K.A.Yener and E.C. Joel 1992. Evaluating lead isotope data. *Archaeometry* 34: 330-6.

Schaich, M. 2001. 3D-measurements and archaeological information system. Computer based methods for the documentation of archaeological excavations. Paper presented at the 7th Annual Meeting of the European Association of Archaeologists in Esslingen (Germany).

Schiffer, M.B. 1976. *Behavioral archaeology*. New York.

– 1987. *Formation processes of the archaeological record*. Albuquerque.

Shipman, P. 1981. *Life history of a fossil. An introduction to taphonomy and paleoecology*. Cambridge, Ma.

Sillen, A. and M. Kavanagh 1982. Strontium and paleodietary research: a review. *Yearbook of Physical Anthropology* 25: 67-90.

Skibo, E, W.H. Walker and A.E. Nielsen 1995. *Expanding archaeology*. Salt Lake City.

Stos-Gale, Z. 1989. Lead isotope studies of metals and the metal trade in the Bronze Age Mediterranean. In *Scientific analysis in archaeology and its interpretation*, J. Henderson (ed.), 274-301. Oxford.

Thomas, J. 1996. *Time, culture and identity. An interpretative archaeology*. London.

Tilley, C. 1994. *A phenomenology of landscape: places, paths and monuments*. Oxford.

Topolski, J. 1994. A non-postmodernist analysis of historical narratives. In *Historiography between modernism and postmodernism. Contributions to the methodology of the historical research*, J. Topolski (ed.) 9-85. Amsterdam, Atlanta.

Trigger, B. 1989. *A history of archaeological thought*. Cambridge.

Tschan, A., W. Rączkowski and M. Latałowa 2000. Perception and viewsheds: are they mutually inclusive? In *Beyond the map: archaeology and spatial technologies*, G. Lock (ed.), 28-48. Amsterdam.

Wheatley D. and M. Gillings 2000. Vision, perception and GIS: developing enriched approaches to the study of archaeological visibility. In *Beyond the map: archaeology and spatial technologies*, G. Lock (ed.), 1-27. Amsterdam.

Zapłata R. and A. Tschan 2001. An "integrated space" approach for the interpretation of a Medieval stronghold in Middle Pomerania, Poland. In *Computing archaeology for understanding the past. CAA 2000. Computer Applications and Quantitative Methods in Archaeology. Proceedings of the 28th Conference, Ljubljana, April 2000*, Z. Stančič and T. Veljanovski (eds), 197-203. Oxford.