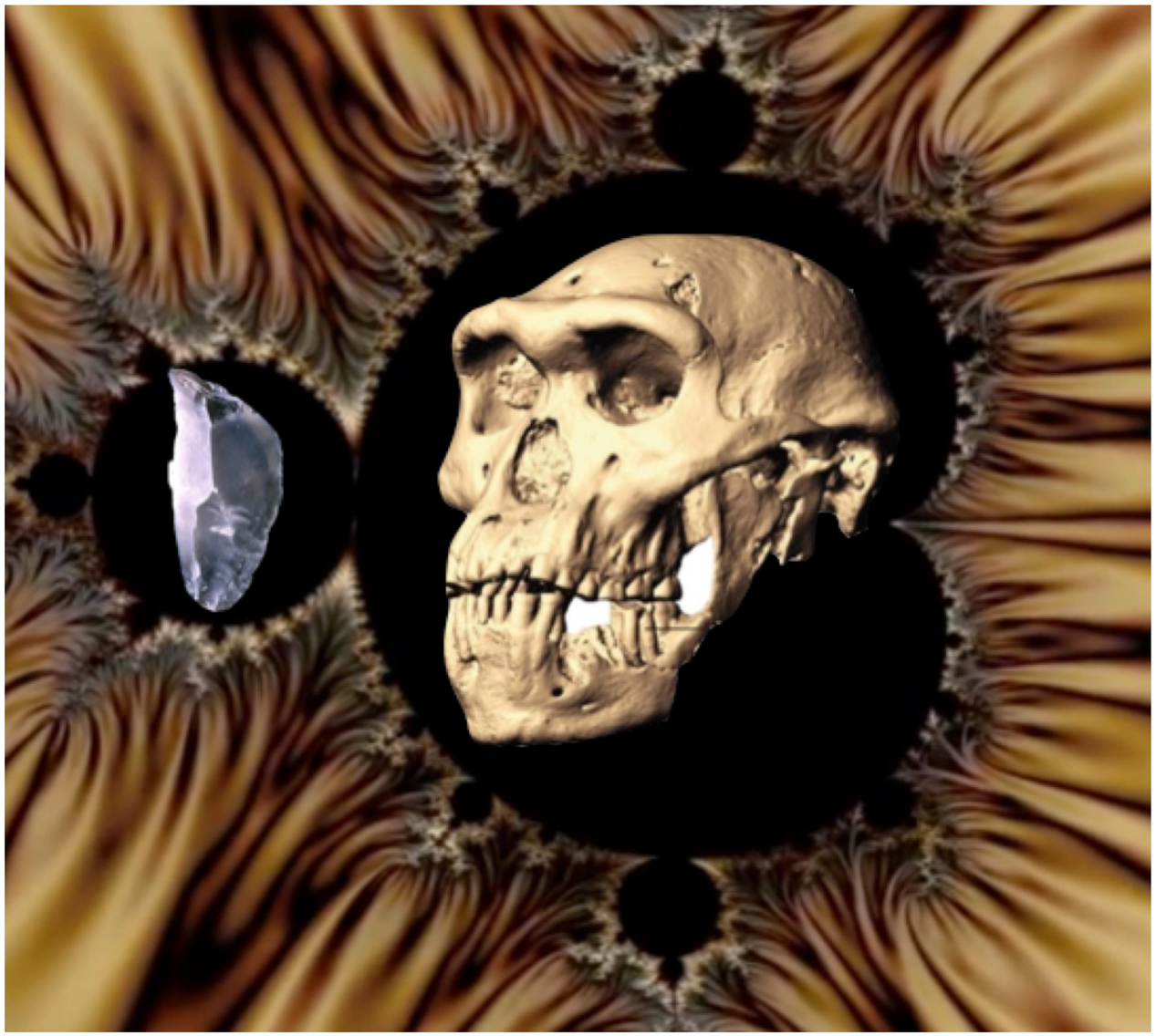
ROGER GRACE

Chaos in Archaeology



AND WHAT HAPPENED TO NEANDERTHALS ?

Preface

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Chaos in Archaeology

Speculation on the potential of Complexity Theory for the conceptual study of Palaeolithic Archaeology.

With new sections on recent developments in hominid evolution.

This 2nd edition includes a number of updates and a new section on the discoveries of the human skulls at Dmanisi.

CHAPTER 1

chaos in archaeology

Speculation on the potential of Complexity Theory for the conceptual study of Palaeolithic Archaeology.

This paper is based on a seminar given in 1991 at the University of Oslo.

With new sections on recent developments in hominid evolution.

Introduction

Introduction

Complexity is about the study of non-linear dynamic systems and deals with irregular and unpredictable behaviour rather than trying to reduce complex systems to linear cause and effect relationships. Complexity has been referred to as 'chaos, though appropriate to our perception of such systems, 'chaos' is perhaps an unfortunate title because the normal usage of the word implies randomness; chaotic dynamics are not random, there is a pattern lying beneath the apparent disorder.

"It's a bit like a bus which tours a city, repeatedly passing through a central square, but each time choosing at random from a million bus stops in the square itself. You can see the bus coming round again, you know it will stop in the square - but you've no idea at all which stop to wait at." (Stewart 1989, 286). This unpredictable, but cyclic behaviour, is analogous to lithic studies. A society cannot be reconstructed in detail when all you have is the lithic material, and if preservation is good, a few bones. But prehistoric archaeology is concerned with long term behaviour of social systems over millennia. Such long term behaviour does have order, but is unpredictable in particulars.

Rather than trying to reduce the data to simple cause and effect relationships, perhaps the complex nature

of archaeological data should be accepted where the internal dynamics of the system produces change of its own volition, without recourse to any external cause. The environment for example, has been seen as an external cause producing the effect of different lithic technologies or functions of tools. Complexity places the environment within the system as a part of the interactive dynamics, not as some kind of deus ex machina ruling the lives of prehistoric people. Complexity suggests that there is no prime cause of change, change comes from the internal dynamics of self-organizing systems so that the system has to be studied as a whole, not reduced to it's component parts.

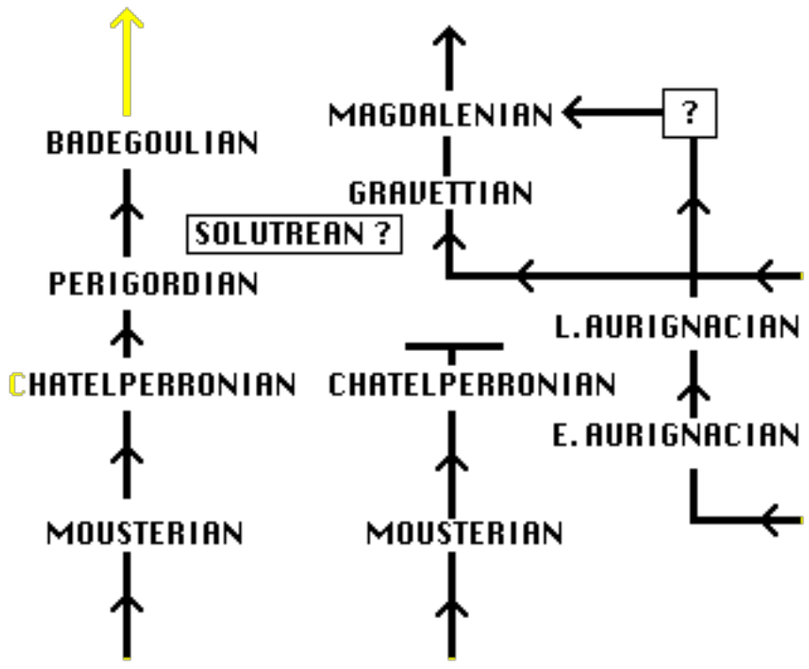
Archaeology has been concerned with reducing the data that represents human behaviour into simple, neat, linear relationships. Lithic technology has been seen as progressive through time, separated into divisions of flake technology, blade technology, etc., or, by using classification schemes such as typology, into 'cultures' (or techno-complexes), such as Acheulian, Mousterian, Magdalenian, Magelamosian, etc. These divisions have always been artificial and are perhaps no longer tenable as sequential chronological indicators. Time is not a straight line and forcing lithic variability into simple linear arrangements is a distortion. Human development has long been seen as multi-rather than uni-linear, but still linear. Time should no longer be seen as linear according to Einstein's relativity, and from the study of anthropology itself, which has demonstrated that, "cultures differ sharply in the way they conceive of time. For some, time is cyclical - history endlessly recurrent. For other cultures, our own indeed, time is a highway stretched between past and future, and people or whole societies march along it. In still other cultures, human lives are seen as stationary in time; the future advances toward us, instead of us toward it." (Prigogine and Stengers 1984, p.xviii). If time is not linear then prehistory should be studied as a non-linear dynamic system for which Complexity provides a concept within which to understand prehistoric behaviour.

Complexity marks a major departure in the development of science, "Where Chaos begins, classical science stops. For as long as the world has had physicists inquiring into the laws of nature, it has suffered a special ignorance about disorder... The irregular side of nature, the discontinuous and erratic side - these have been puzzles to science, or worse, monstrosities." (Gleick 1987, 3). Disorderly and erratic are good descriptions of the developments in lithic variability throughout prehistory. If the real complexity of human development is accepted, rather than argued away or ignored, then many aspects of human devel-

opment, as reflected by archaeology, are certainly a puzzle.

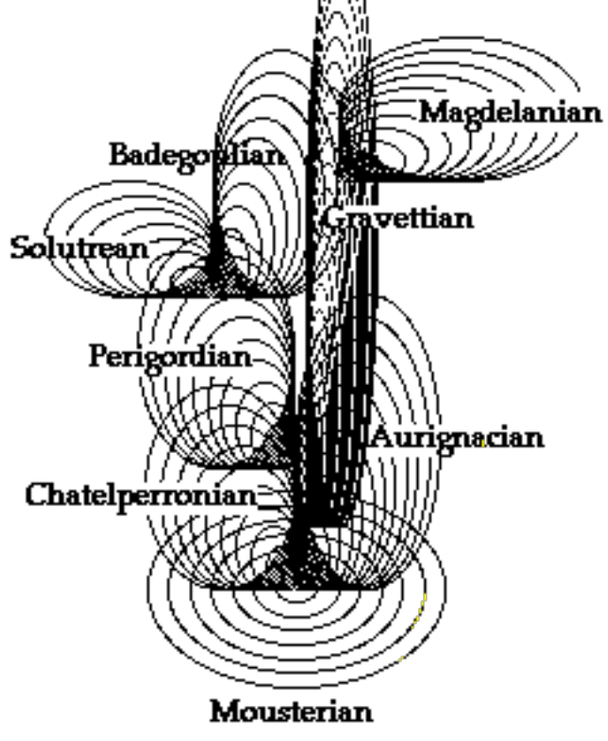
Figure 1 illustrates a 'simplified' version of possible linear schemes for Upper Palaeolithic industries in South West France.

Figure 1



Some researchers consider that there is a continuation from Mousterian through Chatelperronian, other consider that this line came to an end with the demise of Neanderthal Man. We have the alternatives of continuous indigenous development, intrusion of the Aurignacian (either of a people or a technology from the Middle East) and 'invasion' of the Gravettians from central Europe. The Solutrean may have come in from the Iberian peninsula. There are many more schemes and the timing of these changes is disputed, altogether a confusing and 'chaotic' picture. Figure 2 is a schematic of a model where different industries are seen as overlapping variations on a theme rather than discreet entities. Function, different raw materials or social structure, rather than being possible causes of lithic variability, are considered along with the environment, as integral to the system as a whole.

Figure 2



The confusion comes from attempting to put these changes in lithic assemblages into linear relationships which depends as much on the classification scheme employed (morphological typology, technology, style , etc.) and the a priori theories that individual research-ers are attempting to prove. These schemes are as much an artifact as the stone tools themselves.

Complexity and lithic variability

Complexity and lithic variability

If flint technology is considered as a non-linear dynamic system, it can be studied within the concept of chaotic dynamics. A fundamental quality of chaotic dynamics is iteration, in mathematics this involves simply repeating a non-linear formulae by feeding back the answer into the formulae, the minor changes in the result eventually produce dramatically different outcomes (Stewart 1989, 112).

In terms of prehistoric behaviour this means repeatedly doing the same thing (e.g. flint knapping) but slight changes in initial conditions can cause significant different results. For example the development of blade technology. The repetition of blows on a core will produce blade blanks, so blade technology does not need to be 'invented' but simply recognized as being useful and systematically exploited. It does not require any advancement of skill, because the skill required to produce handaxes of the refinement of the middle and late Acheulian, or Levallois technique in the middle Palaeolithic, requires as much technical ability and hand/eye coordination as is required for blade technology. "There is no fundamental conceptual differences between the blade core reduction techniques of the Upper Palaeolithic (e.g., of the Gravettian) and those that produced Levallois blades." (Rigaud 1989, 145). If blade technology is seen as a

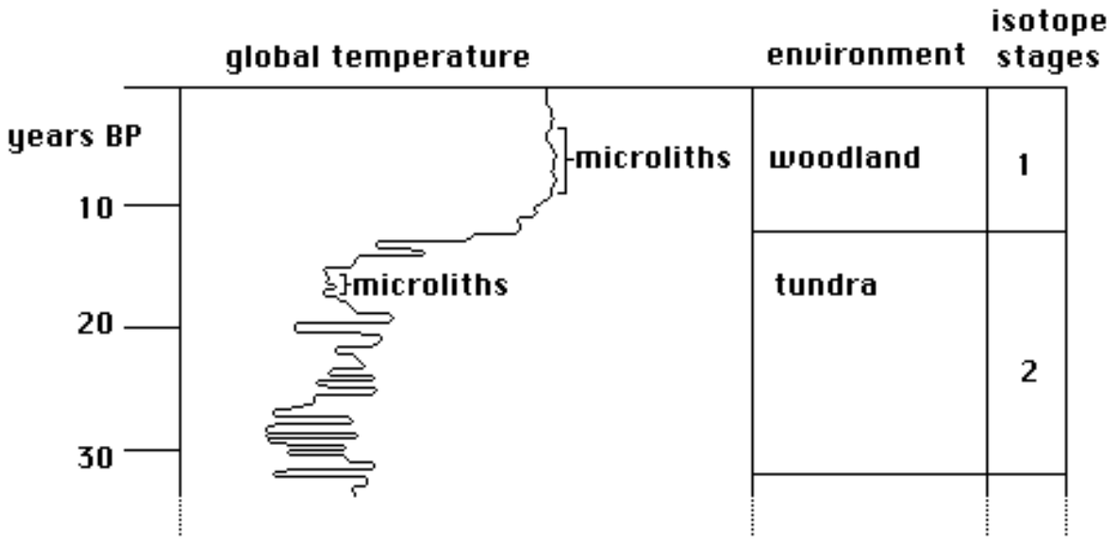
natural outcome, or inevitable development, of the dynamics of knapping than it can arise in any situation where such a dynamic system occurs and hence is independent of 'culture' or hominid type.

So independent occurrences in space-time of similar technologies are not surprising. The occurrence of blade technology among Neanderthals (the Chatelperronian), or within a sequence of otherwise non-blade technology (the Hummalian at El-Kowm in the Middle East, (Bar-Yosef 1989), can be seen as a natural consequence of flint knapping. The occurrence of Levallois in different space-time coordinates and independent of hominid type is another example. In the Levant, Levallois technique is found with the Neanderthals at Kebara and Amud and with early modern humans at Skhul and Qafzeh. Most developments in knapping techniques could be perceived within chaotic dynamics rather than linear progressions.

The recognition of their usefulness is the new phenomenon that occurs. This might be related to function, in that the systematic use of these techniques became useful as being more efficient for a particular task than other techniques within the different contexts. For example burins where made, and presumably used, prior to the Upper Palaeolithic, but not until then do we have the abundance and complexity of burins. At the same time we find a significant increase in the development of bone/antler working. The two things are not coincidental, but also one is not 'caused' by the other, as both existed in earlier periods. The recognition of the juxtaposition of burin technology and antler/bone working is what is 'new'; that is, the recognition of the usefulness of allying these two processes. This recognition is the adaptive feature rather than a mechanistic response to environmental pressure.

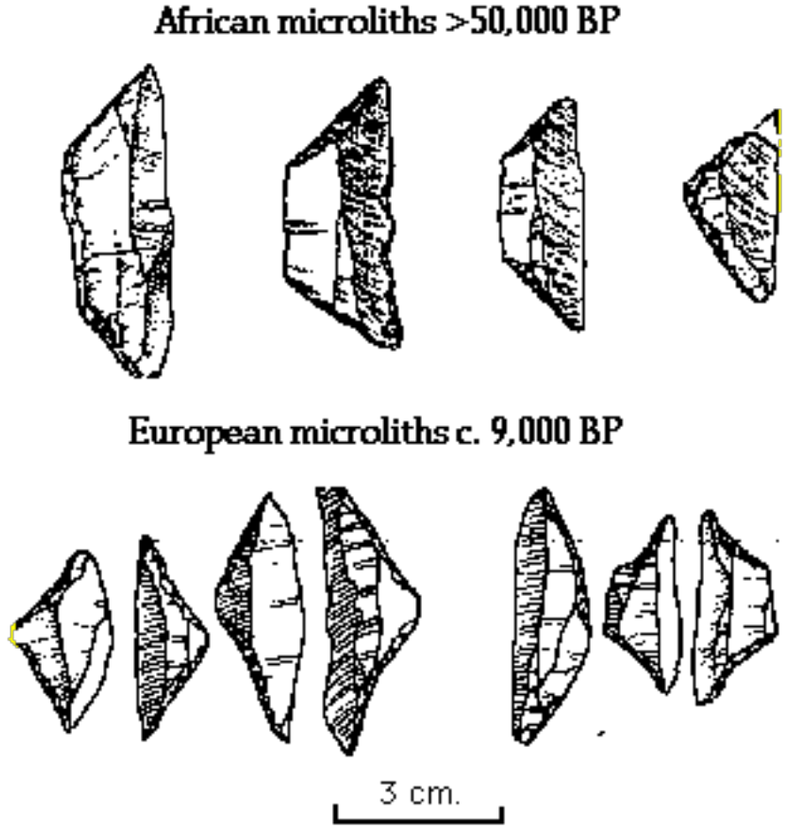
The exploitation of such techniques are not environmentally determined as they do not correlate with environmental and climatic change. Microliths developed before the climatic change at the beginning of the Post-glacial period, and similar climatic and environmental contexts occurred before, when microliths were not produced The often referred to correlation of microliths and the wooded environment of the Post-glacial period existed generally in western Europe, as with the Magelamosian tradition, but with exceptions such as the continuing blade tradition of the Gravettian in Italy, which continued for some time through the same climatic changes. (see Figure 3)

Figure 3:
Microliths found in different environments



Microliths were also produced at the southern tip of Africa during the Middle Stone Age in a very different environment (Fig. 4).

Figure 4



The production of microliths has been suggested as a consequence of the scarcity of raw material, but microliths are produced in the same areas as non microlithic assemblages which had the same raw material availability. It is possible local conditions of raw material availability could have affected microlithic production (it is suggested that only small nodules were available for microlithic production in Norway), but such 'local' conditions could not have prevailed over such wide areas as covered by the Magelamosian tradition, for example.

There remains the question, why do certain techniques develop in different areas among different cultures broadly contemporaneously? The obvious answer is that they do not (see microliths above). They only appear to develop contemporaneously because archaeologists are looking for regularities in lithic developments, and often see regularities and linear developments because of assumptions from environmental determinism, eco-functionalism, uni-linear cultural development, diffusion, invasion, etc.

It has been pointed out that ecologists, for example, model the world in just such a way, "...no good ecologist ever forgot that his equations were vastly oversimplified versions of the real phenomena. The whole point of oversimplifying was to model regularity. Why go to all that trouble just to see Chaos?" (Gleick 1987, 65). The intention is to oversimplify in order to study assumed regularities.

The unpredictable development of knapping techniques, and hence tool types (defined ether technologically like Levallois and burins, or morphologically like scraper types) is simply a product of the dynamic system so that the occurrence of these techniques can appear to be chaotic but with underlying regularities hence the apparent periodicity of tool types.

In keeping with a deterministic paradigm, periodicity and regularity are assumed and therefore will be 'discovered' by ignoring what are considered to be minor fluctuations in the overall pattern, or simply disregarding them as anomalies. The concept of cyclic patterns within non equilibrium systems accounts for this more complex picture of stone tool variability. This has been demonstrated in such phenomenon as oscillating chemical reactions. "We know now that non equilibrium, the flow of matter and energy, may be a source of order."(Prigogine and Stengers 1984).

Accepting the chaotic dynamics of lithic variability means Mousterian burins, Chatelperronian blades, Magdalenian microliths, etc., are to be expected rather than seen as anomalies, and hence should not be seen as a problem to be explained away because they do not fit the current paradigm. When sufficient

discrepancies exist within a paradigm then it is time to change the paradigm rather than trying to explain away the anomalies. The paradigm of Complexity reconciles the apparent periodicity in stone tool development together with the apparent anomalies and neither cultural, climatic or functional generators for stone tool developments are required. They are merely variables within the dynamic system rather than external causes of change.

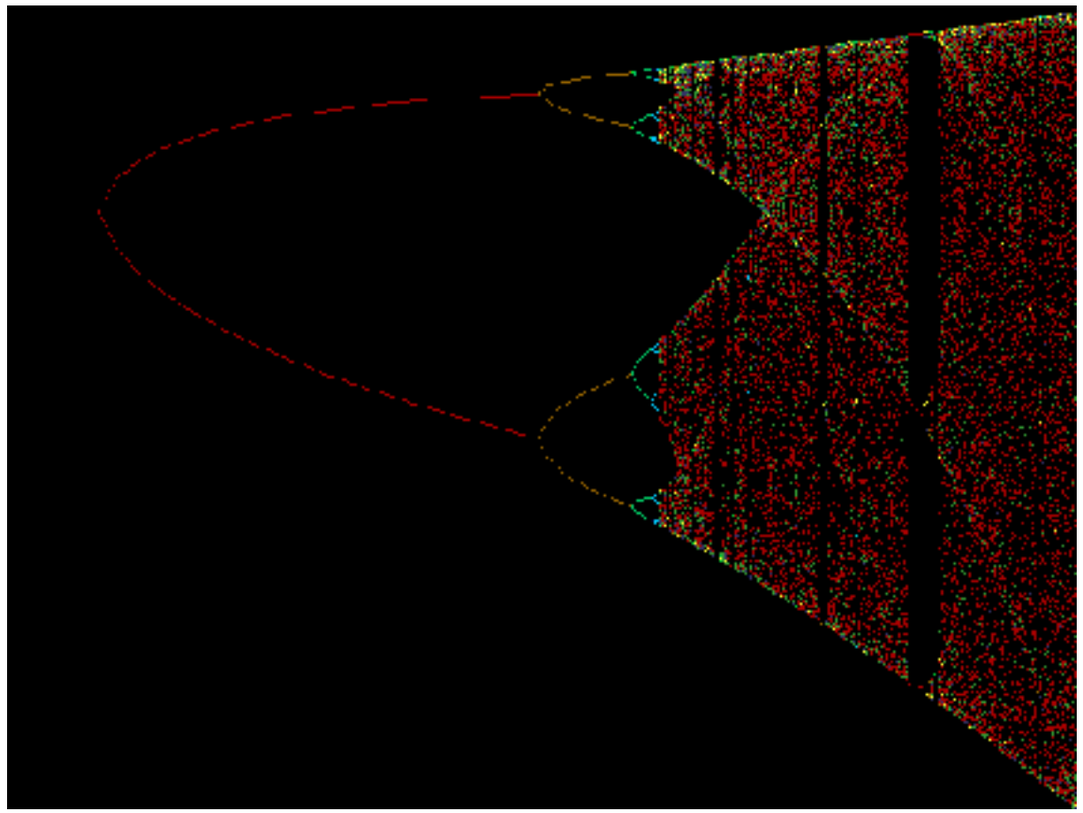
Rather than Mousterian variability being caused or explained by different cultures (Bordes 1961; 1973) or function (Binford 1973) or as a uni-linear chronological sequence (Mellars 1969; 1970) the Mousterian is simply chaotic dynamics in action. The problem is of our own making by perceiving stone tools as discrete entities and imposing typological classification schemes onto the data. By perceiving the Mousterian as a non-linear dynamic system, with cyclic, but unpredictable results changing of its own volition, the problem disappears. It is our perception of the nature of the data that is the problem. Contemporary cultural differences, different functional tasks and chronological developments all play a part, but as internal relationships within chaotic dynamics, not as external causes or explanations.

Complexity does not explain the details of lithic variability but provides a paradigm within which we may be able to understand it. In relation to weather forecasting it has been said that, "I see no evidence that chaotic dynamics is likely to improve the quality of weather-forecasts. Its main contribution to date is to suggest that we're asking a silly question." (Stewart 1989, 286). Searching for simplistic causes of lithic variability and development may also be a 'silly question'.

The emphasis here is on understanding rather than explanation, the two are not the same thing (see Dommasnes 1987, 8). The search for an explanation of why stone tools vary in terms of external causes may be fatuous; excepting that they do, and that this is a natural outcome of any non-linear dynamic system provides a theoretical base for understanding lithic variability.

Almost-intransitive systems

bifurcation diagram



Almost-intransitive systems

Chaotic dynamics have a pattern of periods of unpredictable disorder followed by bifurcations. The system then settles down to an orderly pattern for a while before breaking down into disorder again (see bifurcation diagram of non-linear dynamics). This cyclic pattern is often seen in intransitive systems. "An almost-intransitive system displays some sort of average behaviour for a very long time, fluctuating within certain bounds. Then, for no apparent reason whatever, it shifts into a different sort of behaviour, still fluctuating but producing a different average." (Gleick 1987, 170). This concept has been used in order to understand a problem related to Palaeolithic archaeology. "... to explain large changes in climate, they look for external causes - changes in the earth's orbit around the sun, for example. Yet it takes no great imagination for a climatologist to see that almost-intransitivity might well explain why the earth's climate has drifted in and out of long Ice Ages at mysterious, irregular intervals. If so, no physical cause need be found for the timing. The Ice Ages may simply be a by-product of Chaos." (ibid, 170).

Changes in lithic technology and typology can be understood in similar terms of an almost-intransitive system that requires no external physical cause. The extreme duration of Lower Palaeolithic technology, and

then the apparent rapid change to flake technology in the Middle Palaeolithic, then the emphasis on blade technology in the Upper Palaeolithic and the dominance of microlithic technology in the Mesolithic, are descriptions of average behaviors 'fluctuating within certain bounds' and follow the above pattern of an almost-intransitive system.

see bifurcation movie

This aspect of chaotic dynamics can also be applied to to human evolution. Recent evidence that variation in hominids is far more common than is implied by the tendency to classify every new bone as yet another species. See new section on Dmanisi.

The Neanderthal Problem

The Neanderthal Problem

Chaotic dynamics can also be applied to one of the intriguing questions in Palaeolithic Archaeology; the transition from Middle to Upper Palaeolithic and the Neanderthal problem. Here we not only have questions of stone tool variability, both technologically and typologically, but also variation in hominid type or sub-species. This question of what happened to Neanderthals and the emergence of modern humans has come to the fore in recent years with a number of specialist conferences on the subject (e.g. Mellars & Stringer 1989; Trinkhaus 1989). The only consensus that has been achieved is the acceptance that it is a difficult and complex problem. The main protagonists in the issue offer their models and attempt to support them from the archaeological and paleontological evidence. This procedure appears to mainly consist of arguing away or dismissing any evidence that is contrary to their pre-conceived theory (Binford 1987, Binford 1989,41; 1987, on Torralba). We have here a global problem with a number of apparent anomalies that researchers have had to struggle hard to place in linear relationships. The evidence presents a complex and erratic picture of this important transition in human development and seems an ideal area for the consideration of chaotic dynamics. No matter how hard researchers try, the evidence suggests that simple cause and effect models cannot accommodate the

data. The development of Neanderthals and modern humans does not correlate with climatic change and simple Darwinian adaptation to changing environmental resources fails to explain the data.

The old way of looking at changes in species has been seen as a branching tree and different species by definition must be discreet. By assigning Neanderthals to Homo Sapiens Neanderthalis (i.e. sub species status) interbreeding between Neanderthals and Homo Sapiens Sapiens becomes a possibility with the potential for hybrids. Some researchers have assigned certain specimens to hybrid status from the products of gene flow (Wolpoff 1989), but most have treated the two groups as separate (Stringer 1989), seeing Homo Sapiens Sapiens as replacing Neanderthals rather than the two groups being assimilated.

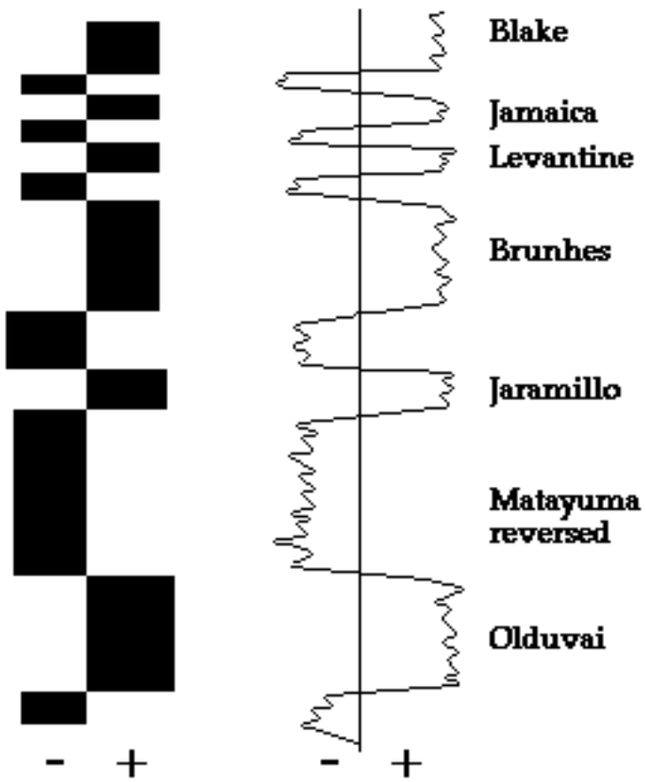
However if we apply chaotic dynamics, particularly the aspect of almost-intransitive systems, to Neanderthal/Homo sapiens sapiens relationships it could be seen as an average fluctuating within certain bounds i.e. the same population with oscillating anatomical traits rather than separate sub-species. The oscillation among west European Neanderthals, often referred to as 'classic' Neanderthals, may have been much less, especially as any potential gene flow would have been restricted by the peripheral nature of the geographical area. The emergence of modern humans then becomes a relatively rapid shift in average behaviour. In the Near East this shift manifests itself as the dominance of Homo Sapiens Sapiens traits away from Neanderthal traits. In Western Europe the apparent shift is more dramatic from one state to another because of the extreme nature of west European Neanderthals. The Darwinian evolutionary model means that this transition is too rapid in that there is insufficient time (numbers of generations) for the required genetic mutations. But the evolutionary theory of punctuated equilibria would allow for such a rapid transition. "The new theory [punctuated equilibria] recognizes the occurrence of long periods of stasis, during which the catalytic cycles that maintain organic species in their environments perform adequately and correct for a limited range of perturbation, and it claims that when the epochs of stasis come to an end, evolution is sudden and unpredictable in detail (Laszlo 1987, 77).

Such rapid shifts are not unknown in almost intransitive systems. The polar reversals in palaeomagnetism are just such a case. As with the timing of glacial periods, the polar reversals do not seem to correlate with any proposed outside mechanism, so the reversal may be self-generating within the chaotic dynamics of the Earth's magnetic field. This particular shift is rapid, almost instantaneous, in that there is no record of a west or east pole, the fluctuations of magnetic

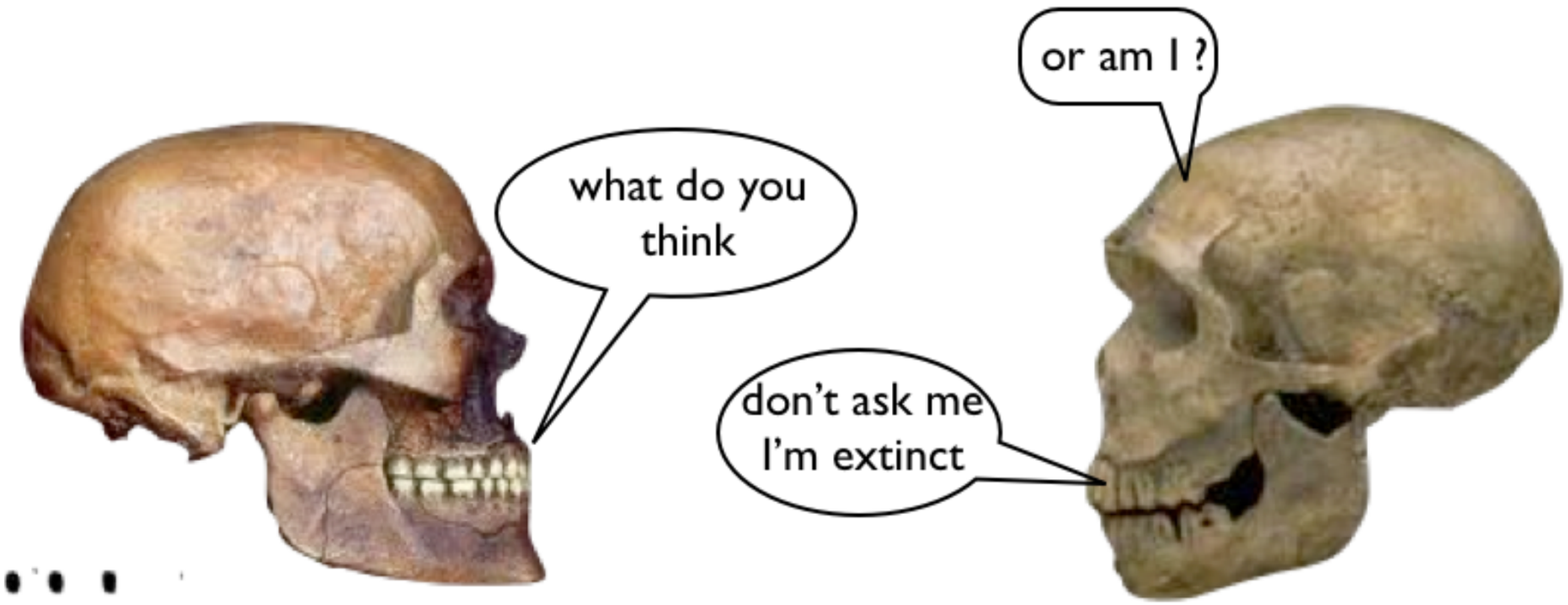
north around true north, as in an almost-intransitive system, are, of course, well known.

Figure 5: Palaeomagnetism

usually displayed as north or south, here displayed with fluctuations as with an almost-intransitive system



It has been suggested that the situation in western Europe (extended by some to encompass the whole world) may be a case of simple replacement by incoming Homo Sapiens Sapiens. This simplistic interpretation has been seriously challenged and the attempts are being made to deal with the complexity of Neanderthal/Homo Sapiens Sapiens relationships, "We are far from fully understanding the details of what happened in Europe during this period of adaptive, cultural, and morphological change. However, recognizing that there was a process and not a parade, is surely the best way to begin" (Wolpoff 1989, 138). Papers on this Middle to Upper Palaeolithic transition represent individual researchers desperate attempts to force the data into simple cause and effect relationships, none of which can be clearly substantiated. Perhaps chaotic dynamics presents a possibly solution to this seemingly conflicting evidence concerning the 'causes' of the Middle to Upper Palaeolithic transition of biological evolution and technological development.



See new section on Recent research on hominid evolution

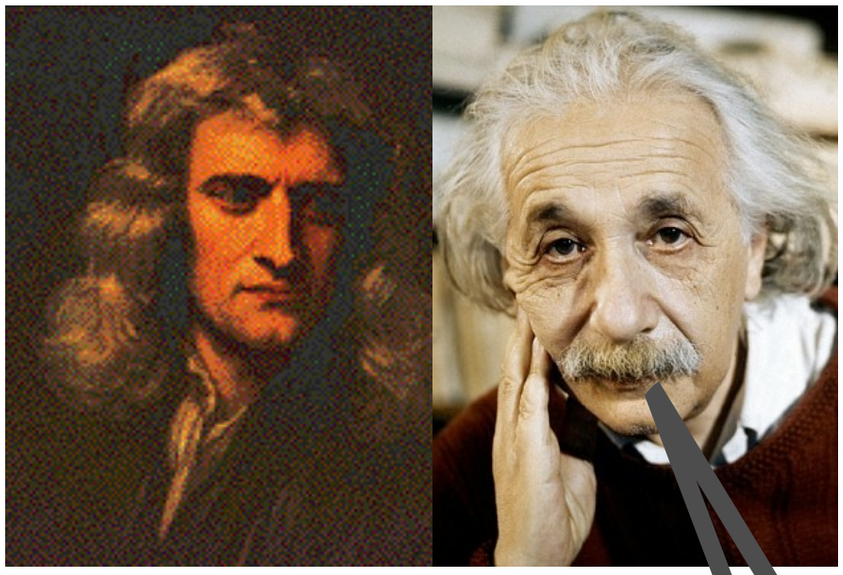
The 'Butterfly Effect'

The 'butterfly effect'

The 'butterfly effect' which is an essential element in chaotic dynamics, may be invoked to explain apparent anomalies in lithic technology (and perhaps to models of gene flow in archaic humans). The 'butterfly effect' is named from the parable of the flapping of a butterfly's wings that creates a minor air current in China, that adds to the cumulative effect in global wind systems, that ends with a hurricane in the Caribbean. Or in more scientific jargon, 'sensitive dependence on initial conditions' (Gleick 1987, 8).

A slight change in the configuration of the original stone block, or a knapping error, can change what was intended to be a prismatic blade core into a globular core, with the resulting flakes within an otherwise blade industry. Unlike modern flint knappers who are determined to produce the perfect blade core, prehistoric man is likely to continue to produce usable lithic material rather than abandon the piece of flint. This procedure is more likely when flint is scarce.

Determinism or probability?



Determinism or probability?

Complexity reflects a paradigm shift from a reductionist and deterministic approach to a more holistic and probability based approach that is analogous to the paradigm shift that is occurring in physics. A shift from the mechanical universe of Newton, which is deterministic and rendered comprehensible by reductionism, to a more holistic view through relativity, to the acceptance of the particle/wave duality of matter and the probability statements of quantum mechanics (see Zukav 1979). This paradigm shift is already occurring in the hard sciences but, "the machine paradigm is still the "reference point", ... so powerful is its continuing influence that much of social science,... remains under its spell. (Prigogine and Stengers 1984, p.xiv).

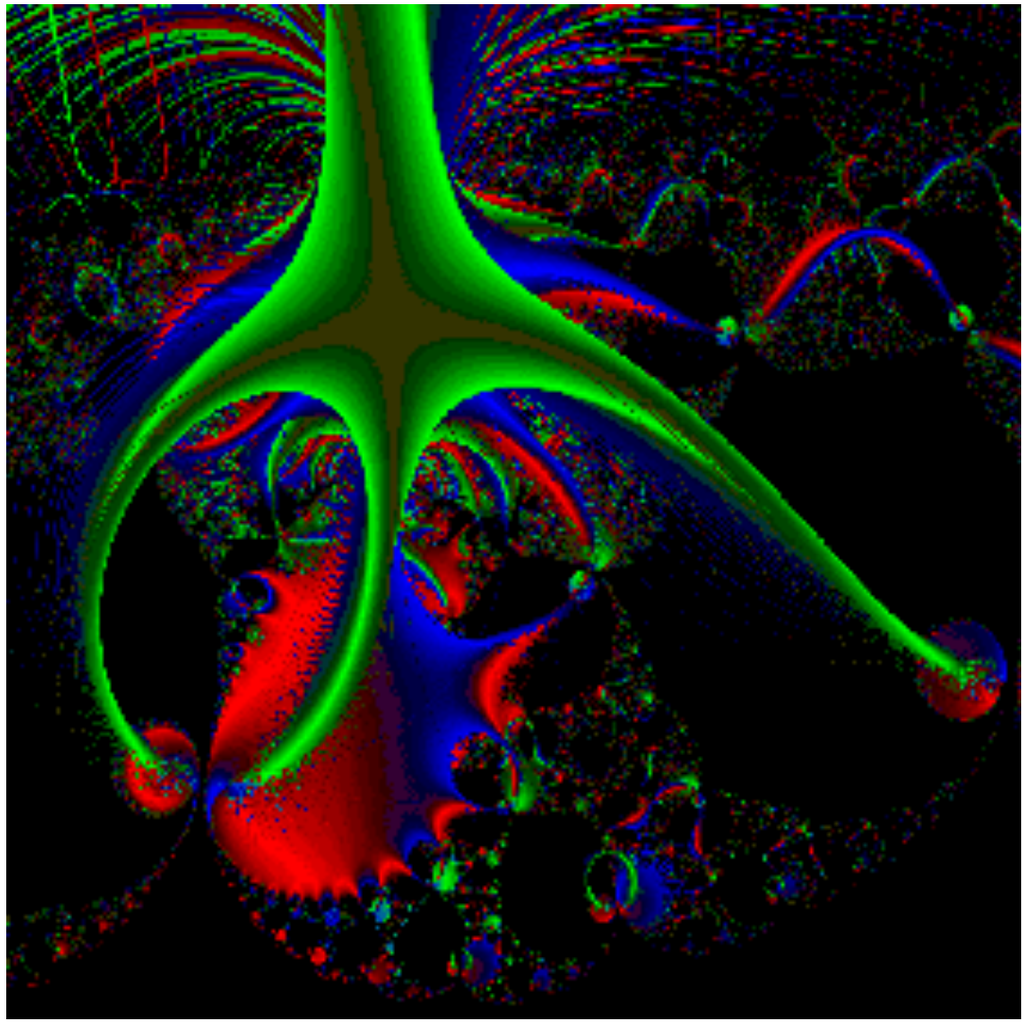
In physics reductionism has led to not being able say anything about the objective properties of a sub-atomic particle but only to be able to calculate probabilities because of the Heisenberg Uncertainty Principle (Zukav 1979, 133). This states that the more you know about one aspect, the less you know about the other. In the case of particle physics sub-atomic particles moving in space have a position and momentum. If you locate the particle in space nothing can be known about it's momentum, conversely if the momentum is known you cannot locate it in space. The

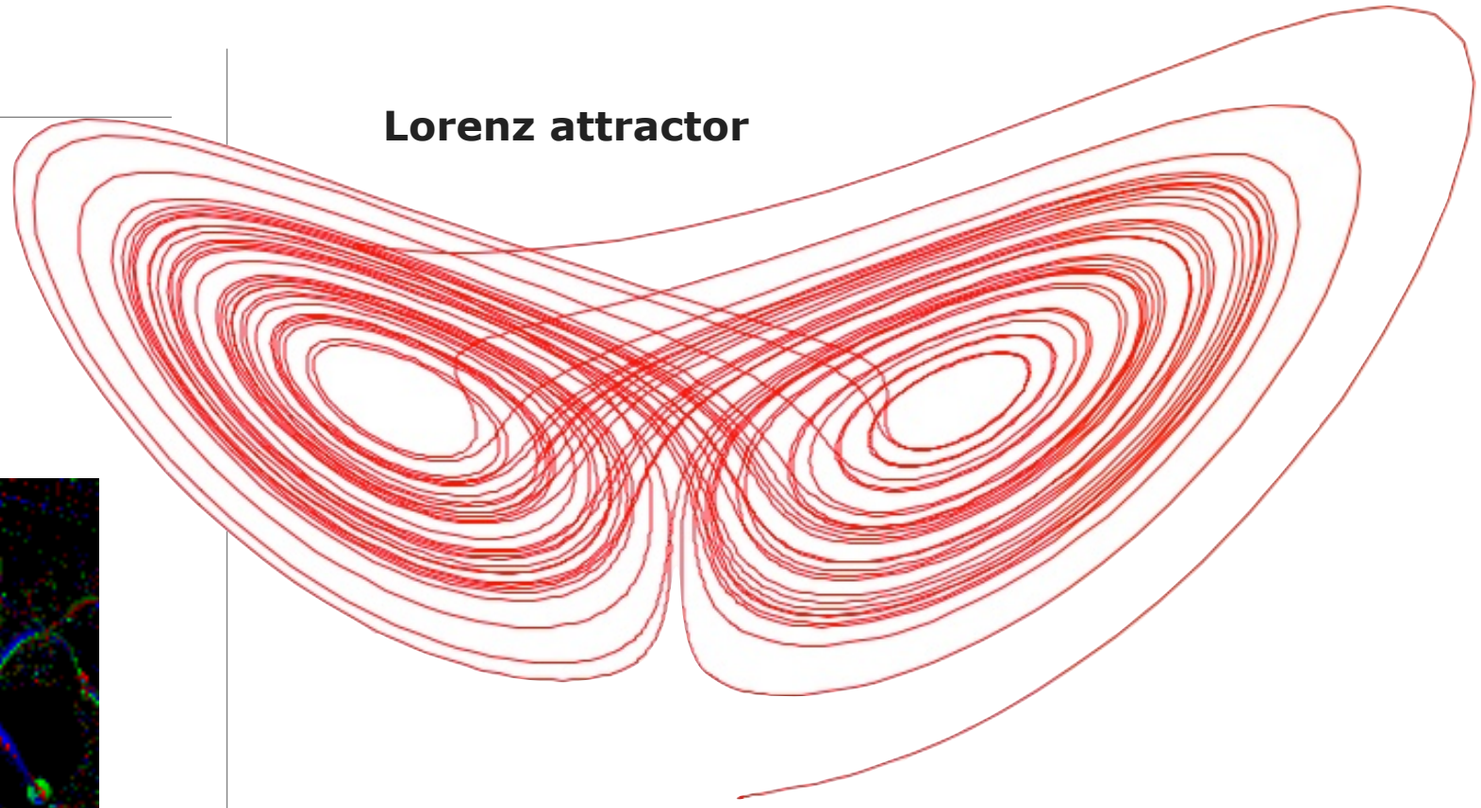
only way in which to understand the interactions of particles is by taking a more holistic view of looking for patterns in the whole based on probabilities, rather than trying to determine objective facts about the particular. This view has been expressed as, "... reducing buildings to piles of bricks. Yet out of the same bricks we may construct a factory, a palace, or a cathedral. It is on the level of the building as a whole that we apprehend it as a creature of time, as a product of culture, a society, a style." (Prigogine and Stengers 1984, 7).

The developments in the microwear analysis of stone tools are a good example of the changes that are occurring in Archaeology generally and in lithic studies in particular. From simple deterministic models ('wood polish' in microwear; stone tool assemblages equal ethnic groups in lithic studies), through attempts at precise quantification (image processing in microwear; the sixties vogue for attribute analysis where measurements were used as the basis for stone tool classification in lithic studies), to an awareness and acceptance of the complexity of the phenomenon that is being studied (multidimensional approaches and expert systems in microwear; multi-disciplinary approaches incorporating environmental and geological information within more complex theories in lithic studies).

An extension of this trend in the future may be the placing of lithic studies within the awareness of Complexity enabling archaeology to deal with large scale developments rather than particular events. "Chaos breaks across the lines of separate scientific disciplines. Because it is a science of global nature of systems, it has brought together thinkers from fields that have been widely separated ... science was heading for a crisis of increasing specialization." (Gleick 1987, 5). An example of this crisis of specialization in archaeology can be seen from the two latest reinterpretations of the Mesolithic site of Star Carr. One attempts to interpret the site on the basis of bones alone, largely ignoring the lithic material (Legge and Rowley-Conwy 1985), and the other concentrates on the tools, using the specialized technique of microwear analysis alone (Dumont 1985).

Strange attractors





Lorenz attractor

Strange attractors

A Complexity model applied to the activities of man might seem inappropriate, but archaeology is full of examples of taking methods and theories from the hard sciences and applying them to cultural behaviour. "Complexity came out of Mathematical Imagination, sired by Physics. But where is it going? Into every natural phenomenon that exhibits irregularity, but in circumstances that suggest there ought to be underlying patterns." (Stewart 1989, 292). The latter part of this statement would appear to be entirely relevant to Archaeology and lithic studies in particular.

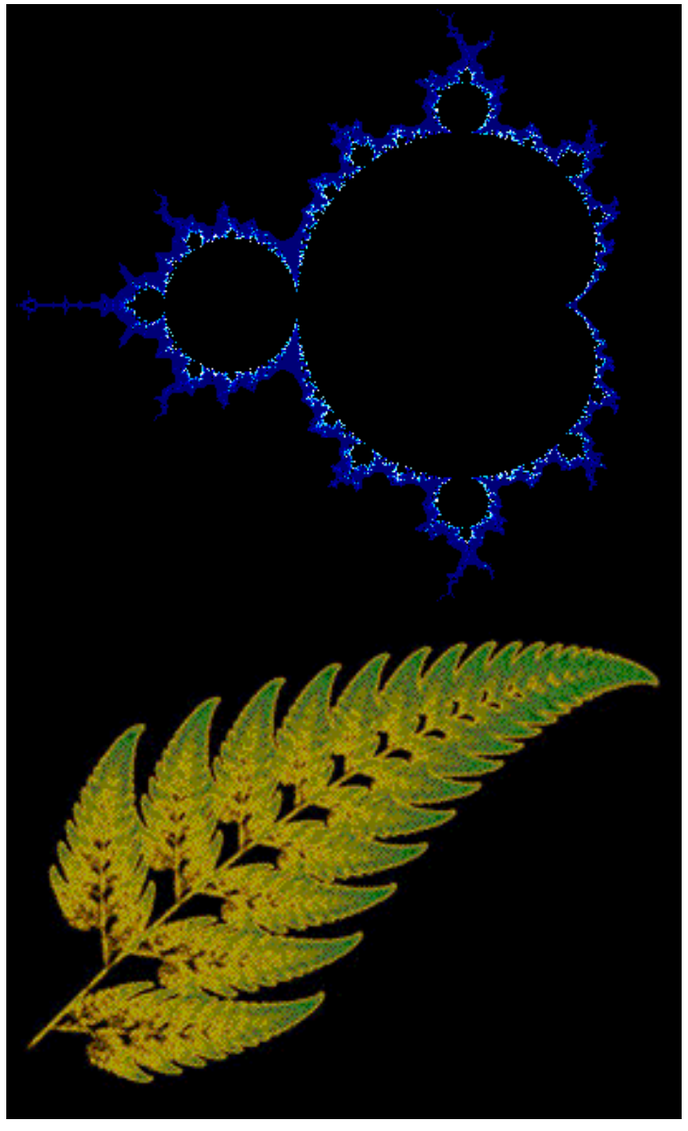
Chaotic patterns are sometimes related to strange attractors (see Gleick 1987, 119); attractors because they act as the focus for the non-periodicity and strange because that's what they are. But however strange, "Strange attractors are not just topological confections. They're really there, in simple equations, in equations that model aspects of the real world." (Stewart 1989, 154). Attractors are the stable factors within chaotic dynamics. They represent the general trend of a system around which the details oscillate. They have been likened to the basin of a river system. The flow of water, and changes in water courses produce transient change within the stability of the watershed region. They can be visualized in order to represent the chaotic dynamics of a system. Perhaps the most famous, and one of the earliest strange attractors to be discovered, is the Lorenz attractor that represents the output from a series of simple non linear equations. (see Gleick 1987, 140). This can be compared with the attractor of a regular system such as the classic pendulum.

see movie on Lorentz attractor

Lithic variability could be conceptualized as repeating oscillation around a strange attractor, that would account for the apparent or 'invented' periodic developments in lithic material. For example the occurrence of convergence in technology and tool types might be understood by reference to the influence of a strange attractor, as convergence of tool forms occurs in otherwise different environmental and cultural contexts. Australian Aboriginal adzes can resemble Quina scrapers which are similar to scrapers from the Yabrudian of the Middle East.

In this movie each point represents the output of a chaotic equation. The points can occur anywhere but they end up following an attractor so each point is individually unpredictable but within the Lorentz attractor.

Fractal geometry



Fractal geometry

Also one of the central aspects of Complexity is the application of Fractal geometry (Mandelbrot 1982). In the same way that strange attractors represent the unpredictable patterns of chaotic dynamics, as opposed to Newtonian determinism and the 'machine' paradigm, fractals are outside Euclidean geometry. Instead of being constricted to the three dimensions of space, fractals exist within 'fractions' of dimensions. That is they can be 1.2 or 2.4 dimensions. An essential quality of fractals is that they are self similar at different scales, so that the fractal dimension of a mountain range can be the same as that of the microscopic surface of a flint tool. The irregularity of the topography is of the same order but different in scale. This has already been applied to technical problems in microwear analysis (Rees et al. 1991), but it has also been found that the fluctuation in cotton prices on the New York stock exchange are fractal (see Gleick 1987, 84). That is, the pattern has self similarity at different scales. Complexity and fractals are relevant to modern human behaviour. Perhaps prehistoric man should not be seen in the same way as modern man in that we tend to overlay our prejudices and philosophical concepts (our scientific paradigms!) on to earlier people who had a more fully integrated relationship and behaviour with nature and environmental resources. In this case prehistoric behaviour is even more likely

to reflect the natural dynamic systems that have been studied with Complexity, strange attractors and fractal geometry.

This movie illustrates the fractal property of self similarity at different scales as it zooms in on these mathematically produced fractal patterns.

see movie Zooming in on the Mandelbrot set

Expert systems

Expert systems

One practical approach to lithic studies within the concept of Complexity is the use of rule based expert systems (Grace 1989, Grace 1993, Grace 1996, Dries 1994) The key here is rules; not laws which are inviolate, but rules that can be changed and indeed are always changing in a reflexive relationship allowing the expert system to accommodate new information.

The rules of the expert system are subjective, but they are explicit in that they are written down and incorporated into a computer program. The observations are defined and the rules are explicit therefore anyone can produce the same results, so that though the system is subjective it is consistent when different subjectivities i.e. different individuals use it. The acceptance of the assumptions on which the program is based leads to consistency, and direct comparability between results produced by different people; this fulfills the basic requirements of objective data within the consensus reality of mutual users of the program. Therefore expert systems can extract objective-like data, but the complexity of the dynamic process is retained and the data is produced in the form of probabilities that can be compared as if they are objective data within a defined consensus reality.

The use of probabilities as the basis for discussion is not new in archaeology. Absolute dating techniques such as Carbon 14 express the age of a sample in probabilities. Some, if not most, archaeologists seem to need reminding that a carbon date has only a 68% probability of falling within the range of plus one, and minus one, standard deviation of the mean date. Furthermore one of the central assumptions of carbon dating, that of the constancy of C14 in the atmosphere through time, has had to be revised and hence the calibration from dendrochronology. The fluctuation in atmospheric C14 is an example of chaotic dynamics and the resulting pattern may well be fractal. Further experimentation and precision quantification only reveals greater complexity so that smoothing programs have to be used to make the calibrated dates comprehensible. Smoothing of the calibration curves is an approximation, so that a calibrated carbon 14 date is a probability based on an approximation, and therefore far from an 'absolute' or precise date. Statistical probabilities or distortion by smoothing should not be abandoned, but they should be recognized for what they are, rather than pretending that they are objectively determined 'facts'. Therefore the acceptance of probability statements from expert systems can be treated in the same way as C14 dates. The performance of expert systems in blind tests of the function of stone tools have produced results more accurate then 68%, so that the probability is higher than for C14 dates (see Grace 1989, 223).

Expert systems operate within the Complexity paradigm because they attempt to model open, non linear systems and retain the dynamics of the system, rather than reducing the system to individual aspects. Reduction to variables is involved, and to some extent quantification, but the interactions between the variables (the dynamics of the system) are retained within the program rules and the results are in the form of interpretations rather than determinations.

Expert systems are so called because they are designed to model the behaviour of a human expert. So they are modeling human behaviour, in fact an individuals behaviour. By extension expert systems can be used to model the more complex behaviour of societies within the Complexity paradigm.

Alternative interpretations can be modeled with expert systems so rather than postulating a theory and then testing it, a number of alternatives can be tested and matched against the data.

Use wear analysis can be used to interpret activities at the sites and techniques such as technological analysis that relate activities to the mode of production; faunal and environmental analysis, where possi-

ble, to enable the available resources to be established, refitting within sites giving the 'life history' of tools and nodules that reflect behaviour on the site, and re-fitting between sites that helps to establish the movement of people across the landscape.

By comparing types of sites to geographical location and resource availability the behaviour of a whole group of people can be studied through time in order to understand the changes that took place, either functionally according to changing resources, or changes in technology allowing for different exploitation of resources or new resources (the development of the Neolithic, for example). Or changes in lithic variation of typology that may reflect influx of ethnic groups or typological/technological acculturation, or changes in 'fashion', or technological innovation.

The use of such suites of experts systems is seen as a practical approach to trying to understand the anthropological behaviour that lies behind the archaeological data within the concept of chaotic dynamics.

For one approach to this kind of analysis see:

Chaine Operatoire by Roger Grace

For a full description of expert systems for the analysis of typology and function of stone tools see:

Interpreting the Function of Stone Tools by Roger Grace

at IKARUS BOOKS

Recent research on hominid evolution

Or What Happened to Neanderthals?

I was tempted to call this section, I told you so, on the grounds that I advocated that Neanderthals should be considered as part of the human species at least 30 years ago, significantly in discussions with Prof Chris Stringer of the Natural History Museum, when we were excavating a cave in Wales (incidentally were we found no signs of human habitation).

Chris had relatively recently completed his Ph.D., involving measurements of Neanderthals and 'early modern' skulls and had concluded that the difference was so significant they must be separate species with no interbreeding. (Stringer 2011)

The difference between us was that my argument was based on the stone tools being a palaeolithic archaeologist, and Chris's argument was based on the bones, as a paleontologist.

This was largely based on my contention that the sophistication of tools made by Neanderthals, in particular things like the levallois technique meant that they were as cognizant as early moderns, or even later moderns.

When I was working at the Netherlands Institute in Turkey, the director always used to ask a question whenever we discussed archaeology, and in particular individual archaeologists, he would ask "are they a serious archaeologist?" This meant where they serious about archaeology, rather than simply people who be-

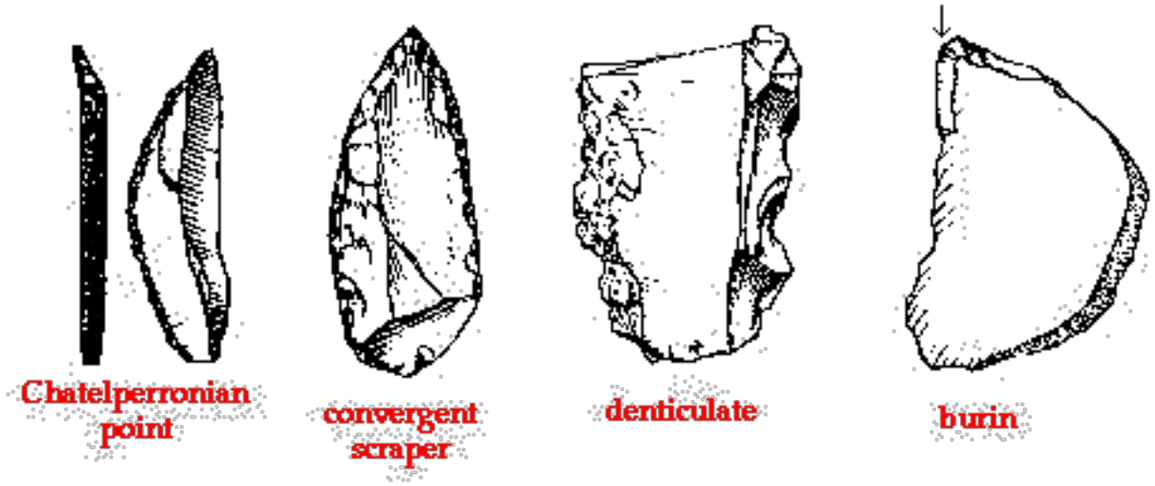
came archaeologists because they think it's going to be interesting or glamourous, having seen too many Indiana Jones films, but it also meant where they good at what they did. He used this question of seriousness as a way of testing other archaeologists. I remember an incident when I had been to the museum in Istanbul to look at some material with an American archaeologist. When I returned to the Institute, almost the first thing he said to me was “Do you think she's a serious archaeologist?” I paused, because I knew my standing in his eyes rested on my answer. I thought about it and said “not really”. He simply nodded and said “no, she is not a serious archaeologist”

I relate this anecdote because in my opinion Chris Stringer is a ‘serious’ paleontologist and a nice guy, however that doesn't mean he is right.

I remember a later discussion with Chris about the then recent discovery of Neanderthal burials at Saint-Césaire with a Châtelperronian stone tool industry.

Châtelperronian

Characterized by the presence of backed knives known as Chatelperronian points or knives. Has Mousterian type tools e.g.. Mousterian points, scrapers on flakes, denticulate tools. A predominantly blade technology.



Chattelperronian knife

Then the Châtelperronian industry was regarded as a transitional between the middle palaeolithic industries of Neanderthals and upper palaeolithic industries of modern humans particularly according to the theories of François Bordes.

My argument was that there was no real major break between Neanderthal industries and upper palaeolithic industries. This break has been suggested because of the early moderns coming in with an already developed upper palaeolithic industry and replacing Neanderthals. Further research has demonstrated that rather than a rapid replacement of Neanderthals there was a long period of overlap when both Neanderthals and early moderns lived contemporaneously.

A series of sites in the Levant were originally dated based on the assumption of this replacement model in that Neanderthal sites were assumed to be earlier then early moderns sites. The sites under discussion are with in a small area in the Levant.

The importance of these sites has become paramount because of the reinterpretation of the sequences from modern dating techniques such as Electron Spin Resonance (ESR), and thermoluminescence (TL).

The following movie illustrates how the new dating techniques have led to a reinterpretation of the chronology of these sites.

see movie

'Out of Africa' theory.

Put simply, the Out of Africa theory is the idea that all of human evolution up to modern humans occurred in Africa and these people did not emerge from Africa until about 100,000 years ago. They then replaced all other hominids that existed in Europe and Asia.

It is accepted by most archaeologists that the species referred to as Homo erectus emerged from Africa over a million years ago. These people then evolved into other forms like the Neanderthals in Europe and other forms in Asia from finds of bones in China and Java. The presence of stone tools also indicates the occupation by these people even when we don't find any bones.

The competing theory is what we call multiregionalism is that is they also accept that Homo erectus was the first species to emerge out of Africa, but then there was indigenous evolution in areas like Asia and Europe.

So in multiregionalism hominids continued to evolve and develop in these areas, but not separate development because of what is referred to as gene flow.

There were connections between these different groups and they interbred resulting in all modern human beings have the same genome.

Concentrating on the European situation we have the very simplistic view of supporters of the Out of Africa theory of Homo erectus, emerging out of Africa over 1 million years ago, which then evolved into Neanderthals. In Africa Homo erectus evolves through such species as heidelbergensis into fully modern humans and then around 30-40,000 years ago modern humans emerge out of Africa and replace the Neanderthals.

It was accepted that for relatively short period the modern humans emerging out of Africa overlapped with Neanderthals, particularly with the re-dating of sites in the Levant mentioned earlier.

So the question became why was it that modern humans could replace Neanderthals, and relatively quickly.

Much of archaeological interpretation is based on assumptions because of a belief in a particular theory, so that the Out of Africa theory led to the search for explanations of how the modern humans could replace Neanderthals. Various reasons were put forward.

One of the major ones is based on the stone tools with the idea that modern humans had developed a more advanced technology. If we go back to the situation in the Levant where we now except that we have Neanderthals and modern humans as contemporaries,

the stone tools at those sites are classified as the same, what we call Levalloisian Mousterian, in other words modern humans coming from Africa have the same technology as the Neanderthals. The example previously mentioned of the Chatellperronian demonstrates that Neanderthals were developing upper palaeolithic technology in Western Europe.

Another reason put forward is changes in climate. However this is very difficult to sustain in the sense that when modern humans entered Europe, Europe was in the middle of an ice age and most people would accept that the Neanderthal body structure is better adapted to cold conditions than people who evolved in the warmer conditions of Africa, so it seems unlikely that the modern humans would be better adapted to cold conditions than Neanderthals, who had survived ice age conditions for tens of thousands of years.

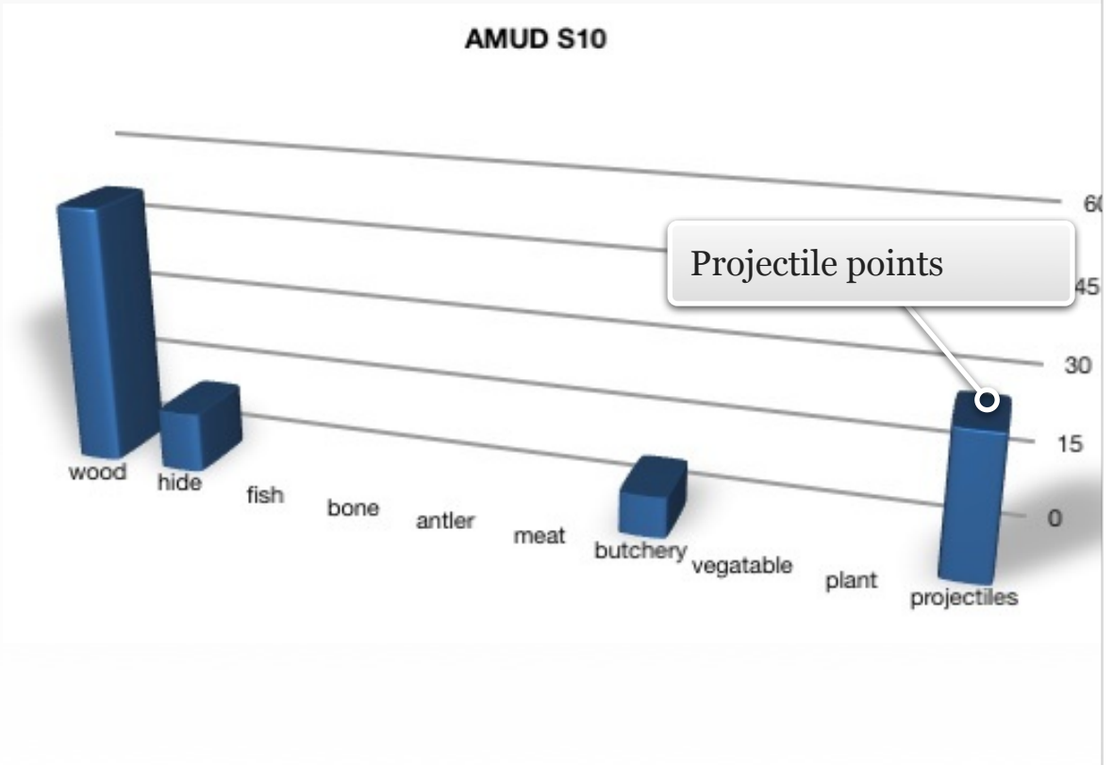
Neanderthal burials, previously excepted as deliberate burials, were then questioned, implying that these finds were just throwing a body away in the back of the Cave, and yet quite clearly burials like the ones from Shanidar strongly indicate deliberate burial and even ritual activity.

Another argument put forward was that Neanderthals did not hunt but were scavengers, it is quite clear that hide scraping and butchering animals took place, but it was suggested that they didn't have the level of social organization required to carry out organized hunting.

In 1994 I was invited to join the international team working on the middle Paleolithic site at Amud Cave in Israel. After carrying out a pilot scheme I received a grant from the Levi-Sala CARE foundation to study recently excavated material from Amud in Jerusalem for a period of three weeks. During that time 647 flints were analysed from 2 areas S10 and K3/L3. S10 had 28 used, 27 unused, 30 insufficient data. K3/L3 had 49 used, 37 unused, 28 insufficient data. The activities consisted of S10: wood 12, hide (butchering) 6, projectiles 7, unidentified 3. K3/L3: wood 24, hide (butchering) 14, fish 3, bone 1, meat, projectiles 8, unidentified 1.

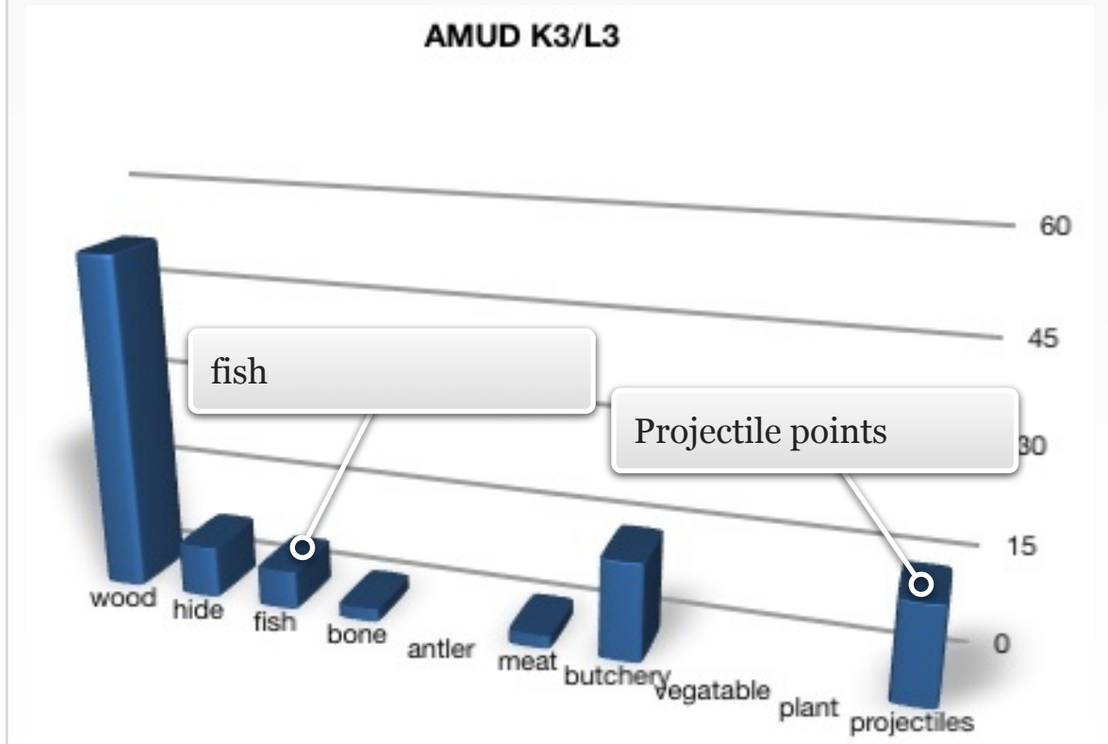
Amud Cave

INTERACTIVE 1.1 **Amud S10 functional analysis**



Direct evidence from you use wear analysis that some of the points were used as projectiles with clear impact fractures showing that they were used as spears.

INTERACTIVE 1.2 **Amud K3/L3 functional analysis**



An example of where use-wear analysis can give direct information, rather than the interpretative evidence from the faunal assemblage, is the discovery of tools used for processing fish during the preliminary analysis of the material from the Neanderthal site of Amud.

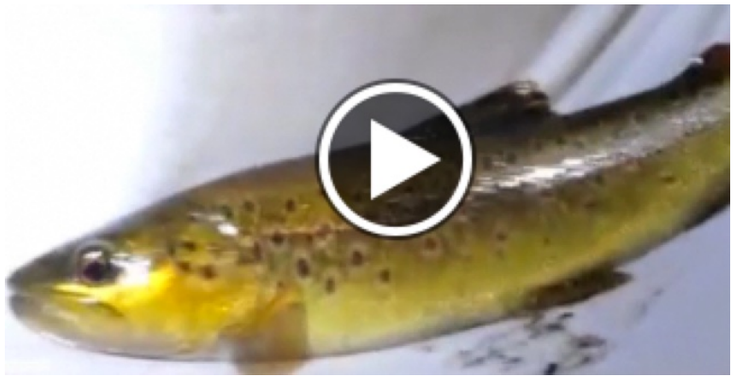
After discovering these fish processing tools, corroborative evidence was found. Fish bones had been recovered during excavation, but at that time it had been assumed to have been brought on to the site by birds.

This interpretation was based on the assumption that Neanderthals did not fish, because the technology required for fishing (hooks, nets, etc.), was considered too advanced for Neanderthals and no such material has been found. However such material, being organic, is unlikely to be preserved and fishing does not necessarily require such sophisticated technology as we know from the observation of bears 'scooping' fish from rivers, as well as the well known procedure of ‘trout tickling’

At the time of the occupation of the site there was a large lake nearby, so we have fish available nearby, fishbones were found on the site and direct evidence of processing fish from the use wear analysis of the stone tools leads to the conclusion that the Neanderthals were fishing.

click here to see bears ‘fishing’ movie

click here to see trout ‘tickling’ movie



Though we don't have direct evidence of organized hunting by Neanderthals, we don't have any direct evidence for organized hunting with early moderns until much later. It is just an assumption that Neanderthals could not do this, however we now know chimpanzees engage in organized hunting.

movie of chimps hunting

So it would be ridiculous to assume that Neanderthals did not have the capability to carry out organized hunting because they were far more advanced than chimpanzees. The use wear evidence demonstrates that they were using projectile points and butchery tools.

So the evidence would support the conclusion that modern human subsistence strategies of hunting and fishing were no more advanced than those of Neanderthals.

So we have a situation where modern humans and Neanderthals are living in the same places, at the same time, under the same environmental conditions, making the same stone tools and using those stone tools for the same purposes, then behaviorally they are the same people.

In 1987 a paper was published that marked the beginnings of genetic evidence for evolution and particular that of the relationship between Neanderthals and modern humans (Cann, R.L., Stoneking. M. And Wilson, A.C. 1987). This led to some people to go as far as saying that the paper was considered proof of the 'Out of Africa' theory. The reliance and esteem given to genetic evidence is a classic case of one of the problems of the social sciences, like archaeology, and one that I will call 'science envy'. Section 6 on determinism and probability refers to the machine paradigm still dominating the social sciences. Because the paper was about genetics and used statistics, this was real science. In fact it turns out that the paper was 'over interpreted' which is the polite academic way of saying it was wrong.

"the biggest single impact of genetic data on research on human evolution came in 1987 with the publication of Cann, Stoneking and Wilson's study of mitochondrial DNA variation in modern humans. I described how the work came under heavy attack especially from disgruntled multiregionalists, but the increas-

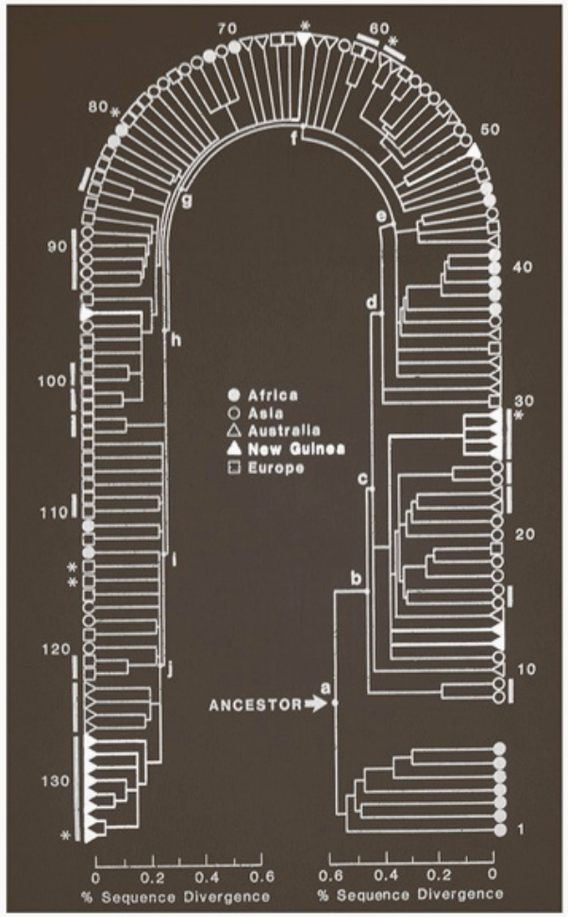
ingly detailed analysis carried out since then have shown that the 1987 conclusions were essentially correct, even if they were somewhat over-interpreted."

(Stringer 2011)

Stringers statement also mentions criticism by "disgruntled multiregionalists" but it was far more than multiregionalists, as it was criticized for the incorrect use of statistics and computer science, in that the program used an algorithm that, by changing the original configuration of the data, could have produced a result showing Africa was not the origin. Other problems were that it was based on mitochondrial DNA that is only past down through the female side and, of course, nowhere near as reliable as the full DNA profile. The dating was based on an estimate of the number of generations it would have taken for these genetic mutations to take place, implying a constant rate of genetic mutation that even Darwin did not support. If we look at alternative theories like punctuated equilibrium, mentioned in section 4, then the dates could be seriously wrong. Because of these flaws the results were eventually withdrawn by the authors.

Subsequent papers on mitochondrial DNA then claimed that there were correct and there was no interbreeding between Neanderthals and modern humans and therefore Neanderthals must be a separate species.

The difference with the latest information is that it is based on actual analysis of genetic evidence taken from the Neanderthal bones, rather than extrapolated from data of mitochondrial DNA from modern populations.



The famous mtDNA tree published in 1987.

By Cann, Stoneking and Wilson from Stringer 2001

The recent research based on extracting DNA from actual specimens as shown conclusively that there was interbreeding between Neanderthals and modern hu-

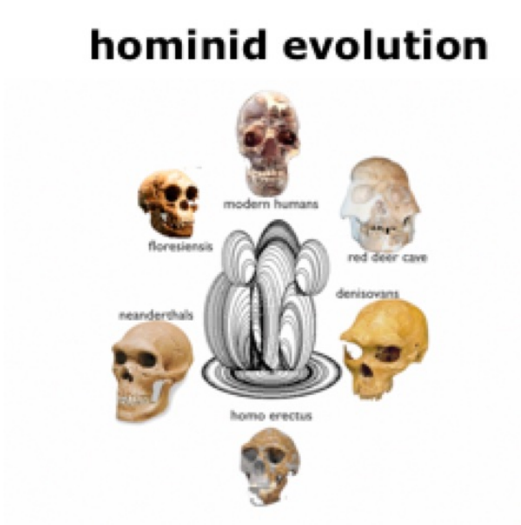
mans so one of the main claims of the Out of Africa theory that these two are different species and did not interbreed is now proved wrong. (Green et al. 2010, Burbano et al. 2010).

So if we look at the situation in Europe the early modern humans that emerged from Africa interbred with Neanderthals, so that rather than Neanderthals being replaced the two groups merged. The fact that they can interbreed, by definition means they are the same species. The biological definition of species is if they can interbreed and produce fertile offspring, then they are the same species.

Figure 2 from the introduction is a schematic of a model where different industries are seen as overlapping variations on a theme rather than discreet entities. If we apply chaotic dynamics, particularly the aspect of almost-intransitive systems, to Neanderthal/ Homo sapiens sapiens relationships it could be seen as an average fluctuating within certain bounds i.e. the same population with oscillating anatomical traits rather than separate species. Since this idea was presented recent studies have demonstrated that modern humans have Neanderthal DNA, thus confirming the concept of fluctuating anatomical traits within the same species. With the discovery of the Denisovans, which also have common DNA with Neanderthals and modern humans, this concept has gained credibility. The now general acceptance of the 'Hobbits' of Floris as part of the human family and the discovery of the red deer cave people further enhances this concept.

The standard approach to human evolution has involved attempts to construct relationships based on the model of family trees. This has led to a tendency to separate hominid specimens into different species, each discoverer claiming their specimen is the ancestor to modern man. Perhaps this model is now redundant, considering the relative few specimens we have to reconstruct a family tree, over a period that extends for millions of years. A more holistic approach, based on the concepts of chaotic dynamics, would enable us to understand the complexity of human evolution, rather than the approach that has led to an inability to reconcile different hominid specimens into the simplistic schemes that have been proposed.

see movie on 'chaotic' evolution model



see movie on 'out of africa' and multiregionalism

Web links

Homo erectus

Neanderthals

Denisovans

Homo floresiensis

Red deer cave people

Internet references

Trout tickling video
http://www.youtube.com/watch?v=V7Go9A7q0TA

Chimpanzees hunting video
http://www.youtube.com/watch?v=WDFh5JdYh7I

Bears fishing video
http://www.youtube.com/watch?v=i4pToiis67E&feature=related

http://www.youtube.com/watch?v=83lo0b-AciM&feature=related

Addendum

The most recent desperate attempt to continue to claim that Neanderthals are separate from modern humans and became extinct, involves measuring the eye sockets.

see movie

First point to mention about the movie is the statement that there is not much difference between the endocast sizes when it's quite clear that the Neanderthal endocast is larger. It is a well-known phenomenon that Neanderthals had larger brains than modern humans.

The idea that the development of a particular aspect, such as larger eyes, requires more brain to operate to the detriment of other parts of the brain, is suggested in this video. In fact there is no evidence of this.

There are many ways in which a functional part of the brain can be made bigger. Increase in surface area could be accomplished by more convolutions, rather than by taking up more volume inside the cranium.

Research has been carried out that shows pianists and violinists have larger parts of their sensorimotor cortex dedicated to the playing fingers, compared to non-musicians, but do not show a decline in some other (somatic or cognitive) function as a consequence. (Schwenkreis et al. 2007)

More recent research has also indicated the demise of the 'Out of Africa' theory.

DNA evidence of a Neanderthal having human genes, again indicating interbreeding, and dated to 100,000 years ago, i.e. long before the proposed c.60,000 years ago of 'Out of Africa'.

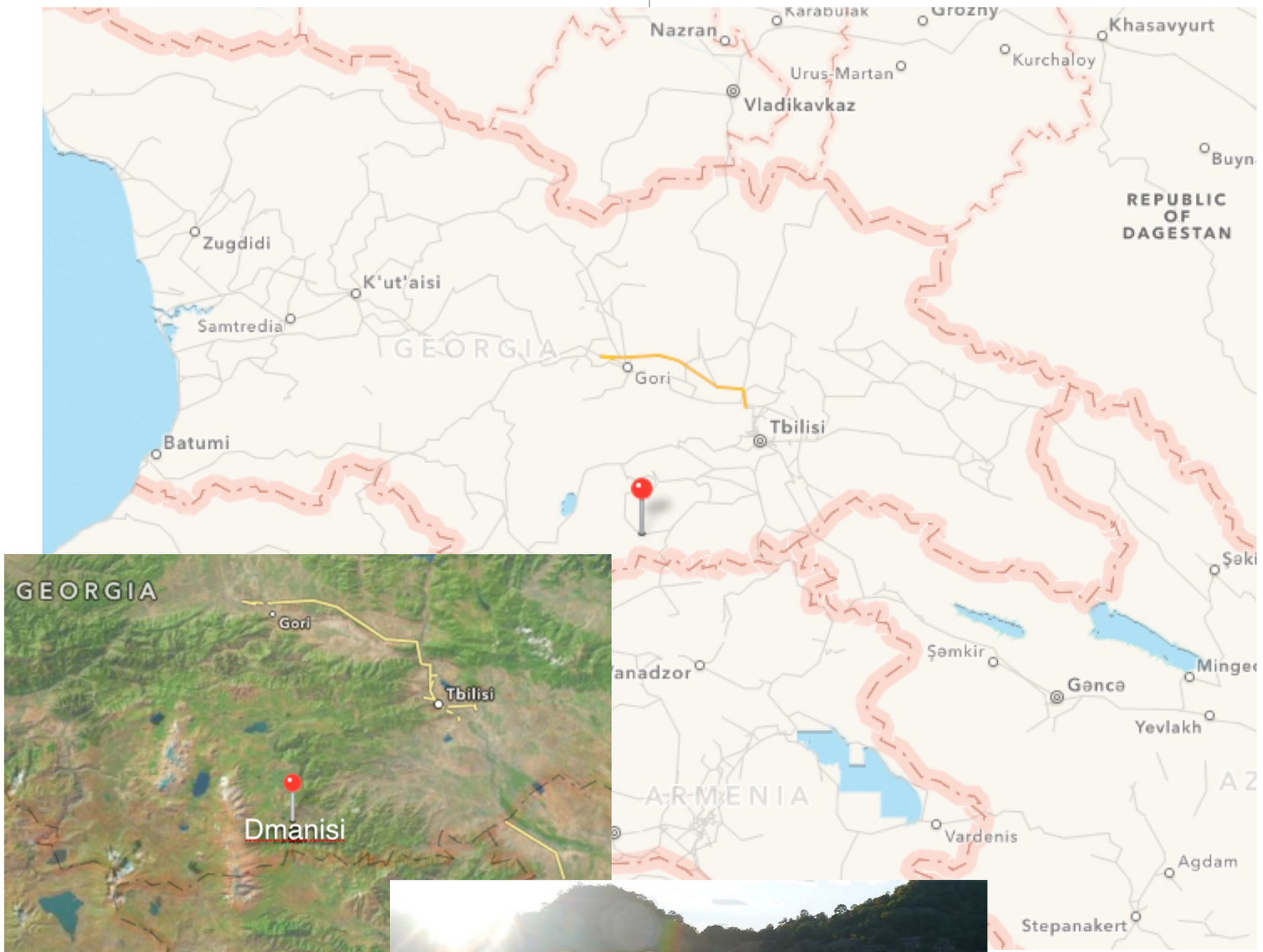
http://www.bbc.co.uk/news/science-environment-35595661

Fossil teeth of 'modern humans' have been discovered in China dated to 80,000 years ago.

http://www.bbc.co.uk/news/science-environment-34531861

Dmanisi

Since section 10 of this book was written a major discovery was made at the site of Dmanisi in Georgia. A collection of 5 skulls from the same deposit dated to 1.8 million years ago.


Nazran
Karabulak
Grozny
Khasavyurt
Kurchaloy
Urus-Martan
Vladikavkaz
REPUBLIC OF DAGESTAN
Zugdidi
K'ut'aisi
Samtredia
GEORGIA
Gori
Tbilisi
Batumi
Şəki
Şəmkir
Gəncə
Yevlakh
ARMENIA
Vardenis
Agdam
Stepanakert
GEORGIA
Gori
Tbilisi
Dmanisi
Vanadzor

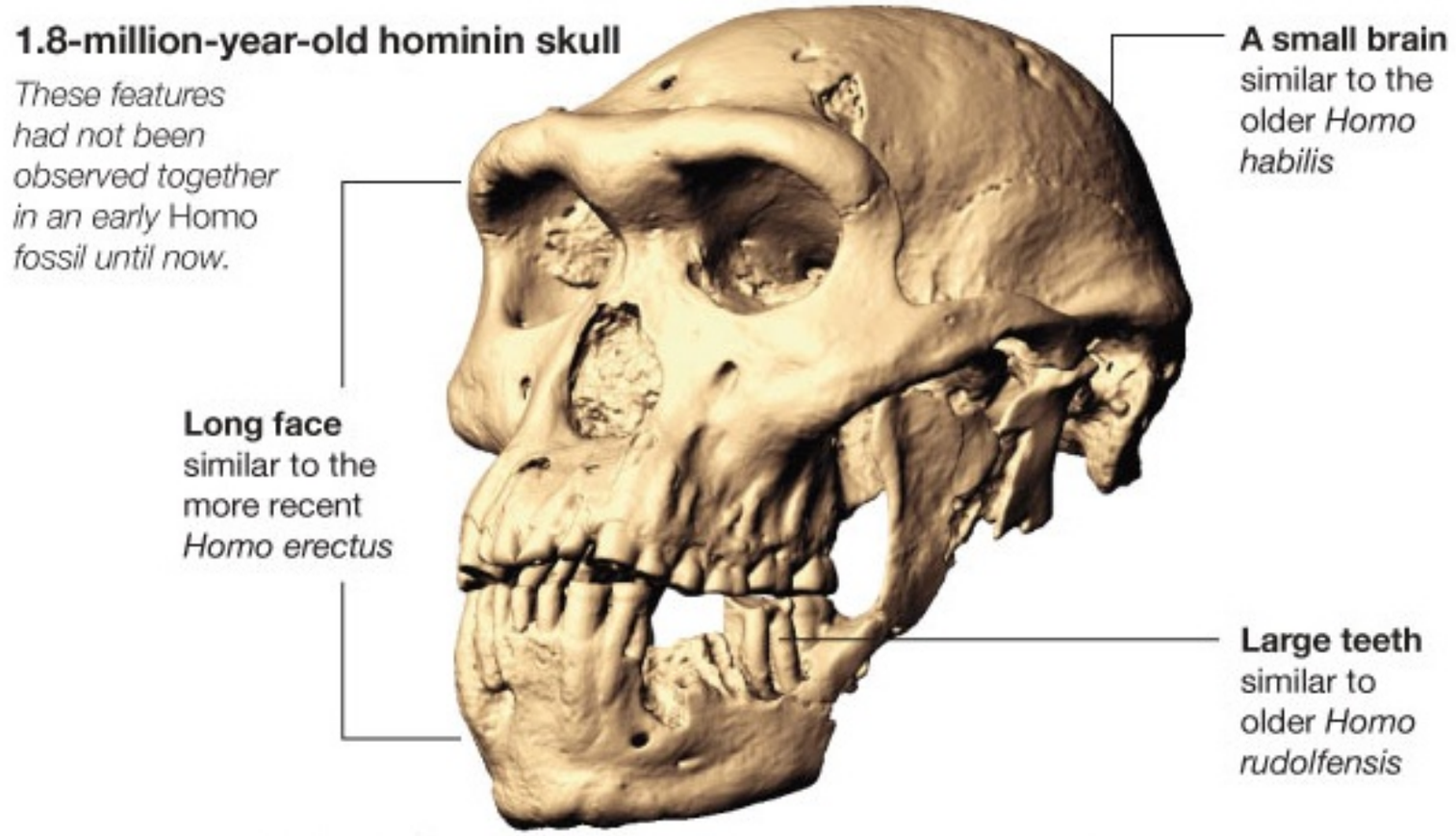
Including skull 5 the most complete skull of this age ever found.

The general picture of the implications of these discoveries are made in this BBC video.

see movie

A co-author of the study, Christoph Zollikofer from the Anthropological Institute and Museum in Zurich, Switzerland, said that if the braincase and the face of "Skull 5" had been found as separate fossils at different sites in Africa, they might have been attributed to different species.

see article on Skull 5



The blend of features suggests early humans were one species that had diverse facial and cranial characteristics.

These important finding from the analysis of the skulls from Dmanisi demonstrate that the views expressed in section 10, that human evolution should be viewed as a complex adaptive system rather than the stress on individual 'family trees', is as relevant in this earlier period as in the middle palaeolithic relationship between neanderthals and modern humans. These revelations support the chaotic dynamic model of human evolution.

A population bottleneck (or genetic bottleneck) is a sharp reduction in the size of a population due to environmental events (such as earthquakes, floods, fires, disease, or droughts) or human activities (such as genocide). Such events can reduce the variation in the gene pool of a population; thereafter, a smaller population (of animals/people) with a correspondingly smaller genetic diversity, remains to pass on genes to future generations of offspring through sexual reproduction. Genetic diversity remains lower, only slowly increasing with time as random mutations occur. In consequence of such population size reductions and the loss of genetic variation, the robustness of the population is reduced and its ability to survive selecting environmental changes, like climate change or a shift in available resources, is reduced.

https://en.wikipedia.org/wiki/Population_bottleneck

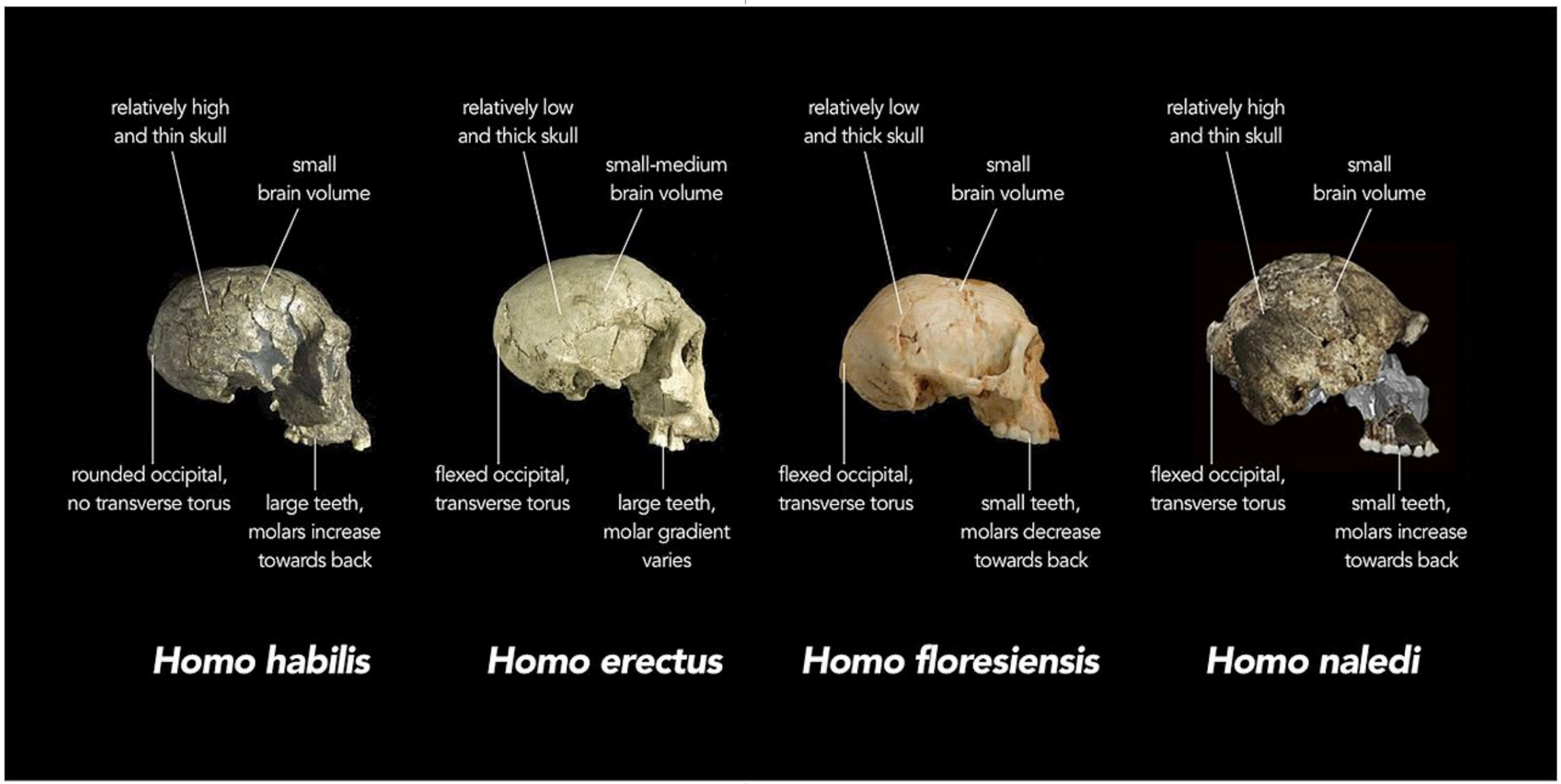
Bottlenecking is often invoked to explain changes in hominid development either from environmental reasons (Stringer 2011, 121) genetics (Stringer 2011, 219) population (Stringer 2011, 302) or a combination of these factors. In chaotic dynamics 'bottlenecks' can occur simply as a consequence of the mathematics.

Of course the 'old guard' will stubbornly support the their position.

"Given that interbreeding seemingly did happen between modern and archaic humans, both in and out of Africa, does this mean that we should now abandon the different species names and lump all the fossils of the last million years or more as Homo sapiens, as some suggest? I think that if the hybridization events prove to have been widespread in time and space, we may well have to do that, but I don't think we are at that point yet. There are still good scientific reasons to give populations that had long and (relatively) separate evolutionary histories different names – species or otherwise." (Stringer 2011, 324).

But the new evidence about neanderthal DNA and the Dmanisi material concerning a much earlier period, strongly suggests a 'chaotic' approach to human evolution would be preferable to sticking to the now discredited linear approach.

One of the latest discoveries is of the proposed Homo Naledi. The discovers claim these specimens represent a 'missing link' between australopithecines and



cating Homo. There are no dates of these finds, either of the fossils or from the deposits they came from. Their claim of c. 3million years ago is based solely on the genus Homo. This contention is based entirely on assessing various features as being australopithecine, like the small brain, with advanced features, such as the hands and feet and certain aspects of the jaw indi-

the identification of the mixture of features so the specimens must be before Homo Erectus. Other researchers have suggested that Homo Naledi should be

identified as Homo Erectus, a position that is rejected by the discoverers.

We have here another case of archaeologists making a discovery that, to enhance their find (and funding), they exaggerate the evidence. Another example of Homo Erectus being found does not have the impact of a new species that they have claimed constitutes a "discovery of the century" in a TV program recently seen on British TV, First Humans: The Cave Discovery.

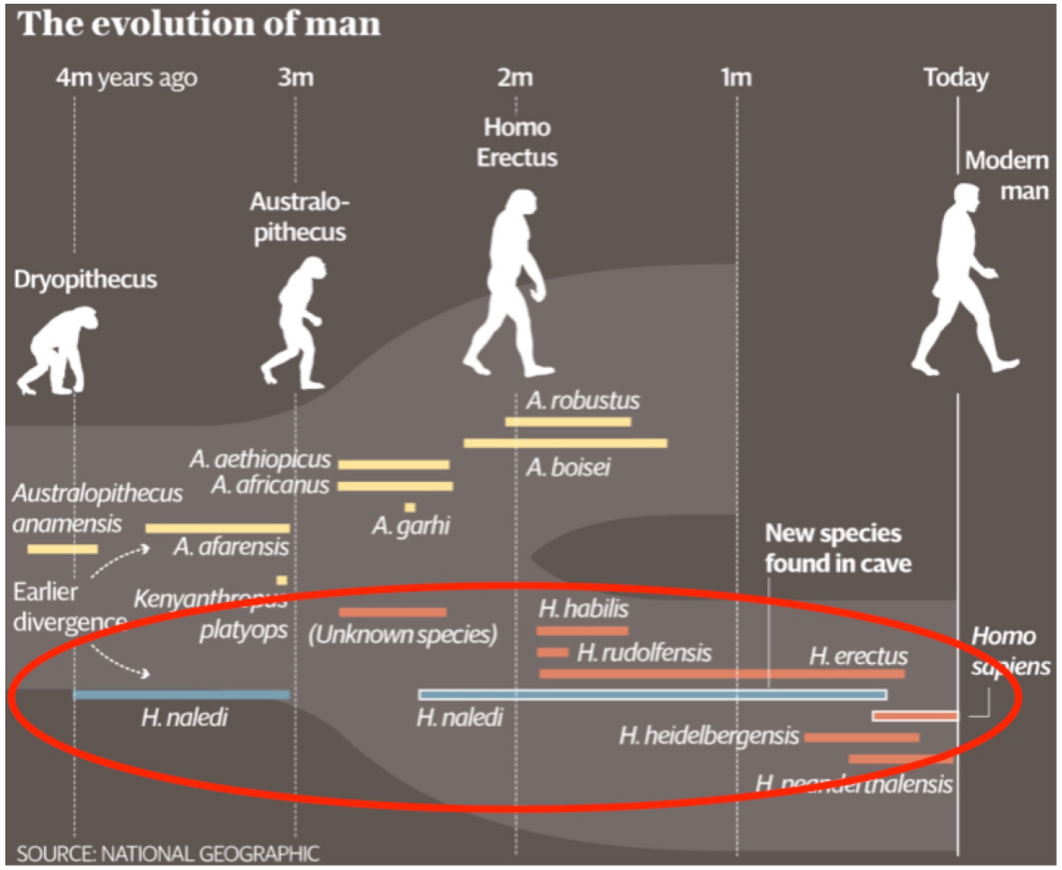
http://www.channel4.com/info/press/programme-information/first-humans-the-cave-discovery

see other internet references

https://en.wikipedia.org/wiki/Homo_naledi

http://www.theguardian.com/science/2015/sep/10/new-species-of-ancient-human-discovered-claim-scientists

http://www.telegraph.co.uk/news/science/science-news/11855405/Homo-naledi-a-new-species-of-human-discovered-in-a-cave-in-South-Africa.html



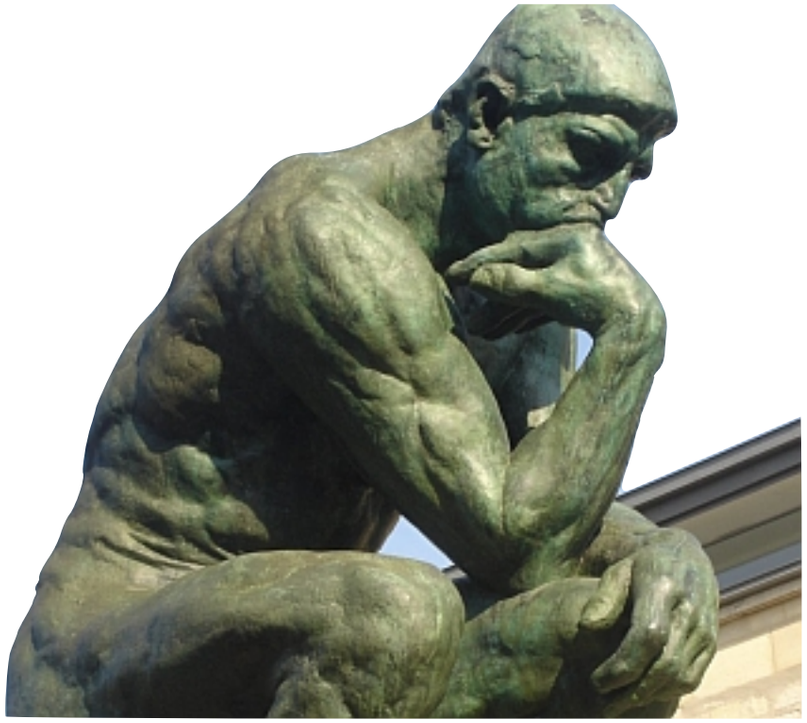
So we have yet another species to fit in to yet another timeline of human evolution.

Perhaps we should go back to the old definition of the species Homo as in the expression 'man the tool-maker'. (Oakley 1949)

The major difference between Homo and earlier forms is the introduction of stone tools with Homo Habilis with Olduvan industries and the continuation of the use of stone tools with Homo Erectus.

Genus Homo begins with stone tools, the rest is 'chaos'

Conclusions



Conclusions

Perhaps we can never fully comprehend the full complexity of the phenomenon that are being studied in Archaeology but that complexity must be accepted rather than ignored simply because it is easier to do so. "...chaotic dynamics raises entirely new, and difficult, problems for the interpretation and analysis of data. But it's better to have a clear problem, however difficult, than to live forever in a fool's paradise." (Stewart 1989, 274).

The details of chaotic dynamics cannot be modeled in prehistory because of their unpredictable nature, but the behaviour that is reflected by the material remains from each site and relationships with sites in similar space-time coordinates can be studied within the concept of chaotic dynamics. No grand unifying theory is necessity. The Complexity concept removes the need for such a theory. We are not trying to explain the data from a pre-conceived theoretical viewpoint but to understand what the data means in terms of anthropological behaviour. Complexity provides the concept within which the apparent anomalies of archaeological evidence can be accommodated. Expert systems provide a heuristic methodology by which that anthropological meaning can be understood, accepting that we are always dealing with probabilities rather than objective facts, as in quantum mechanics.

Probabilities allow for flexibility of interpretations that can change in the light of new evidence rather than 'facts' that are inviolate. Archaeological interpretation itself should be seen as a dynamic system; an open system that does not attempt to reconstruct history as fact, but to understand the process of human development as probabilities that are open to continuous re-interpretation.

Science does not operate in a cultural vacuum. The kind of science we get is a reflection of the society in which it exists. The concept of the cultural independence of objective science is as outmoded as the Newtonian model of the Universe. Perhaps this juxtaposition of science and society is best illustrated by the use of symbols as suggested by Prigogine and Stengers, "Each great period of science has led to a model of nature. For classical science it was the clock; for nineteenth-century science, the period of the Industrial Revolution, it was an engine running down." For contemporary science the symbol they suggest is a sculpture of a dancing Shiva, the Hindu god of creation and destruction, as representing, "...the search for a junction between stillness and motion, time arrested and time passing" (Prigogine and Stengers 1984, 22). This symbol also suggests the assimilation of eastern philosophy into western science that Complexity represents, "Perhaps we will eventually be able to combine the Western tradition, with its emphasis on experimentation and quantitative formulations, with a tradition such as the Chinese one, with its view of a spontaneous, self-organizing world."(ibid, 22). This holistic approach within the Complexity paradigm is also seen as a reaction to what has been perceived as the de-humanization of the social sciences with the concentration on statistics and analytical techniques. Though these procedures have an important role to play, archaeology is essentially concerned with people, within a humanistic tradition.

Dancing Shiva

Complexity is not being offered as a panacea for all our archaeological ills. It certainly offers no simple answers. But the concept of chaotic dynamics can offer a framework within which the complexity of archaeological data need not be ignored. Complexity places the emphasis on the dynamics of human development, which is the origin of change, rather than the stasis of assumed regularities.

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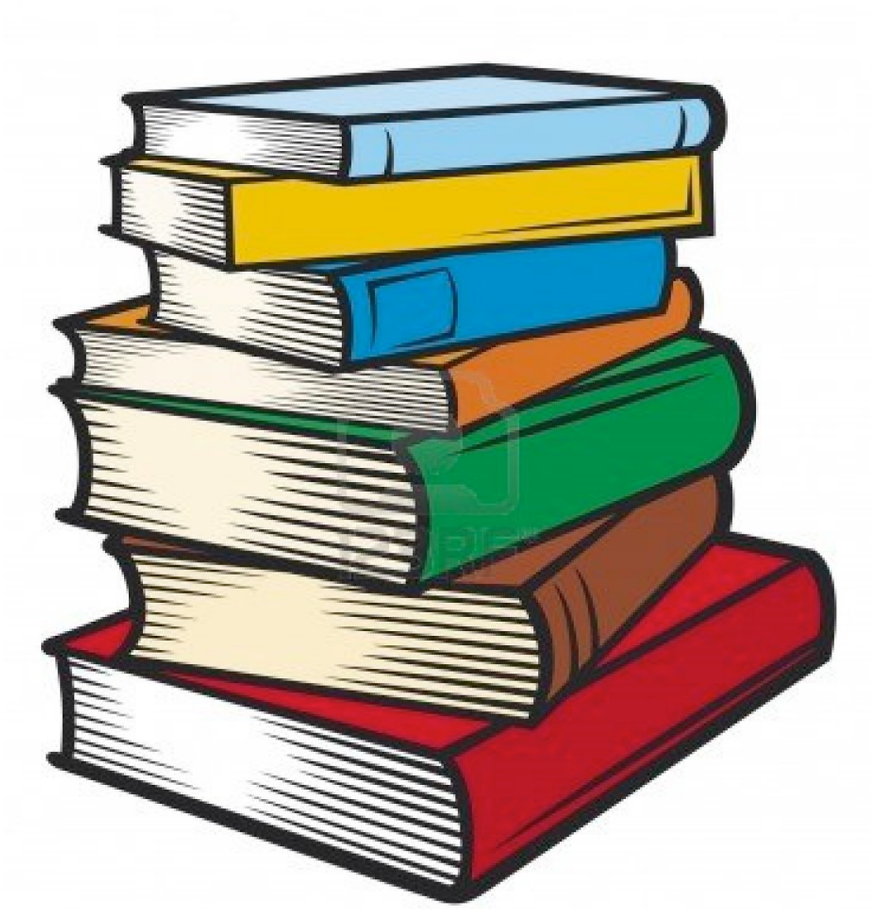

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appendices

Levaillois technique

Levallois is the name archaeologists have given to a distinctive flint knapping technique, which makes up part of the ancient Acheulean and Mousterian artifact assemblages.

The stone tool making technique involves flaking pieces off the edge of a large piece of flint until it is shaped like a turtle shell, and using the core to make tools. The Levallois technique is thought to have been used by Neanderthals in Europe beginning about 250,000 years ago, and then perfected during the Mousterian of 100,000 years ago.

see movie on Levallois

Levallois core

Levallois point

Burins

Burin: A chisel-like implement derived from a flake or blade; the modification of other implements by using the burin technique to remove the edges parallel to their long axis and/or transversely or obliquely. Generally forms a right angle edge on one or both margins. The specialized flake removed as a result of the burin break is called a burin blade or burin spall" (Crabtree 1982, 27).

The negative scar produced by the removal of a burin spall is calleda burin facet. A burin is a tool which can take many forms, but all are made by the burin blow technique. This has been defined as the action of making the ´sides´ or facets of a burin.

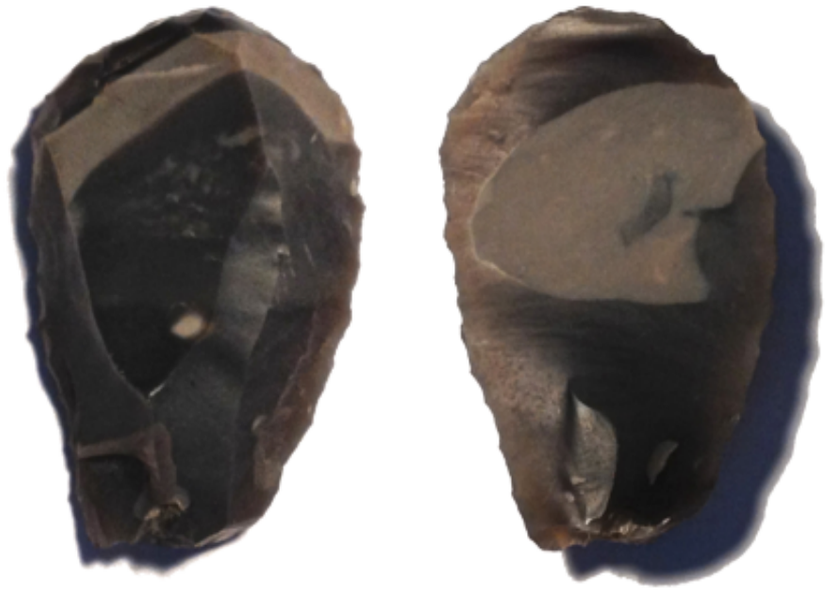
see movie on burin technique

burin

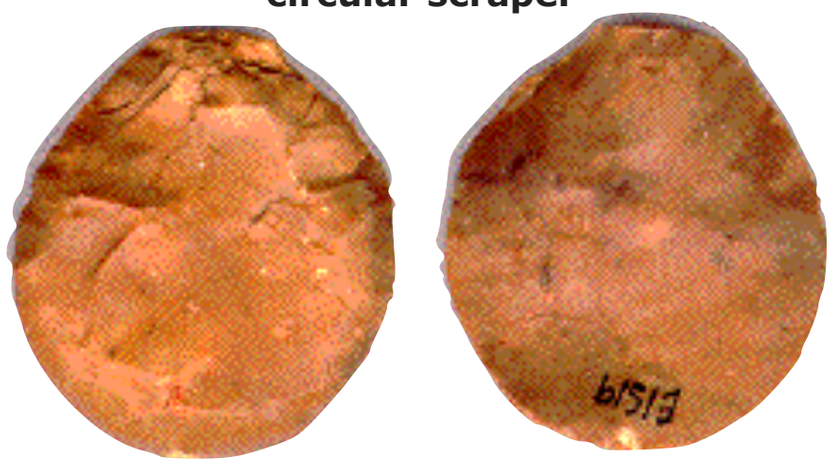
Scrapers

Scrapers are the most common type of tool found from the Middle Palaeolithic onwards. Any tool with scraper retouch on any edge, or combination of edges is a scraper.

convex end scraper



circular scraper



nosed endscraper

side scraper