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Quantifying Palaeolithic Landscapes: Computer Approaches to Terrain Analysis and Visualisation

Christopher Duke

Department of Archaeology,
University of Southampton,
Southampton SO17 1BJ,
England
C.Duke@soton.ac.uk

Abstract. Recent theoretical perspectives in archaeology have emphasized the importance of the physical and social landscape. It is essential at all scales of archaeological analysis to determine how influential terrain variation has been in structuring where, how and why hominins moved. In particular, determining how hominins perceived these landscapes is important for our understanding of what makes us 'human'. This paper provides a brief exploration of these questions in relation to Neanderthal conceptual capabilities. It demonstrates how terrain analysis and visualisation software can be used to explore questions of perception in hominins, and also how such software may be used to assess the conceptual capabilities of hominins in quantifiably different landscapes.

Keywords. Middle Palaeolithic, Neanderthals, Planning, Curation, Mobility, Geology, Topography, Quantifying terrain

1 Introduction

Determining how people perceived and moved through their physical and social environments has become one of the new holy grails of archaeology (e.g. Tilley 1994, Gamble 1998). The reconstruction of past landscapes is an important first step in this process but is notoriously difficult, whatever the scale of the research area. This is particularly so for the study of Pleistocene hominins because of the many changes in climate that took place during their evolution. Because of this an essential step in making archaeologically based interpretations of cognitive capabilities is to examine the role that these environmental differences may have played in adaptation.

As far as the Palaeolithic is concerned archaeologists have traditionally gained insights into perception and cognition by examining the *chaîne opératoire* of stone tool production. While the prevailing landscape is often mentioned in such interpretations it is difficult to make behavioural comparisons between archaeological sites in very different contexts using only subjective descriptions of these landscapes. The aim of this paper is outline some computer based approaches that may be used as first steps in addressing this problem. Using the Middle Palaeolithic as a focus I will examine how hominins – in particular Neanderthals – may have exploited the landscape at a continental scale and how differences in this landscape may have influenced mobility strategies. I begin by giving a brief background to modern research into Neanderthal conceptual capabilities, after which I outline some approaches within the study of Neanderthals which have been used to argue for and against their having rudimentary cognitive capabilities. Finally I outline some examples from my own research to demonstrate some computer based methods which may help answer my own research questions but may also have applications for theoretical and methodological problems in other periods.

2 Planning and Curation

One of the many goals of Palaeolithic research is to determine at what point the modern human capacity to plan beyond the here-and-now evolved. In particular this involves attempting to determine how hominins other than anatomically modern humans used stone tools to cope with the changing environments of the Pleistocene. Such research is most often based upon the relationship between the stage of reduction of the lithic technology found on sites and the distance the material has travelled from the original rock source (e.g. Geneste 1985). We as archaeologists wish to determine what this relationship reveals about how technology was used and how these strategies of use are reflected in assemblage composition. This type of study has been used to judge the relationship between 'planning', 'anticipation' and the organization of technology and is a particularly important part of the archaeological debate surrounding the replacement of Neanderthals by anatomically modern humans (Roebroeks, Kolen, and Rensink 1988).

Many current ideas about Neanderthal planning rely heavily on the idea of curated and expedient technologies, defined by Bamforth (Bamforth 1986) as follows:

> Technologies based on curation comprise tools that are effective for a variety of tasks, are manufactured in anticipation of use, maintained through a number of uses, transported from locality to locality for these uses, and recycled to other tasks when no longer used for their primary purpose. Technologies based on expediency comprise tools that are manufactured, used and discarded according to the needs of the moment.

The supposed lack of evidence for curated technology in the Lower and Middle Palaeolithic has been used to suggest that pre-modern hominins lacked 'planning depth' (Binford 1989). A high degree of planning depth, the ability to anticipate future needs on a long term basis, is something that Binford has argued is essentially lacking prior to the Upper Palaeolithic. Binford has based his argument on evidence from the Lower and Middle Palaeolithic which to him suggests that the organization of adaptations, particularly in the Lower Palaeolithic, are unlike those in both Upper Palaeolithic and modern hunter-gatherer populations (Binford 1989). In simple terms Binford believes that the more homogenous, expedient nature of Lower and Middle Palaeolithic technologies suggests that, prior to the Upper Palaeolithic, adaptive strategies were tool assisted rather than tools being the driving force for adaptation. Coupled with this Binford (Binford 1979) has argued that raw materials for stone tool production are almost always collected in pursuit of basic subsistence strategies. He believes that this pattern of embedded procurement is only rarely replaced by the direct acquisition of raw materials. Consequently, if we were to find any evidence for the direct procurement of raw materials by Neanderthals, particularly over long distances, we could regard it as evidence for the ability to forward plan in times of scarcity.

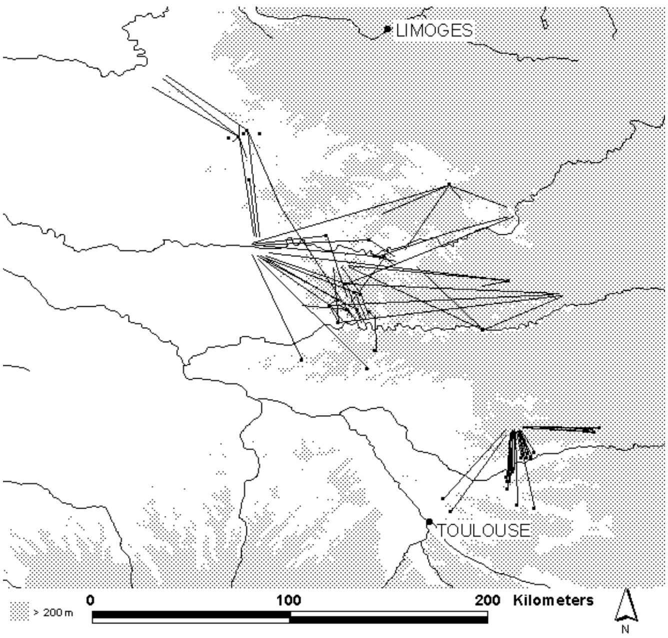

Fig. 1. Raw material transfer patterns for late Middle Palaeolithic sites in South West France (after Féblot-Augustins, 1997a, Fig. 39).

More recently Féblot-Augustins has reviewed the evidence for Middle Palaeolithic raw material transfers and how they compare with transfers in the Upper Palaeolithic (Féblot-Augustins 1993, Féblot-Augustins 1997a, Féblot-Augustins 1997b). Using these transfers as a proxy for the size of home ranges she has suggested that there are significant differences in subsistence patterns and group mobility between the Middle and Upper Palaeolithic. Along with this she notes a difference between the extent of transfers in Western and Central Europe, with those in the latter being greater through all periods of the Palaeolithic (see Figures 1 & 2). Gamble has used this as evidence to suggest that the greater distances in the Upper Palaeolithic are indicative of the extensive social networks characteristic of modern human hunter-gatherer societies (Gamble 1998, Gamble 1999). The implication from this is that, because Neanderthals did not have the capacity to plan ahead to the same extent as anatomically modern humans, they did not have extensive social networks that would facilitate trade and exchange in times of hardship. However, there are problems with many of these suggestions, some of which are outlined below.

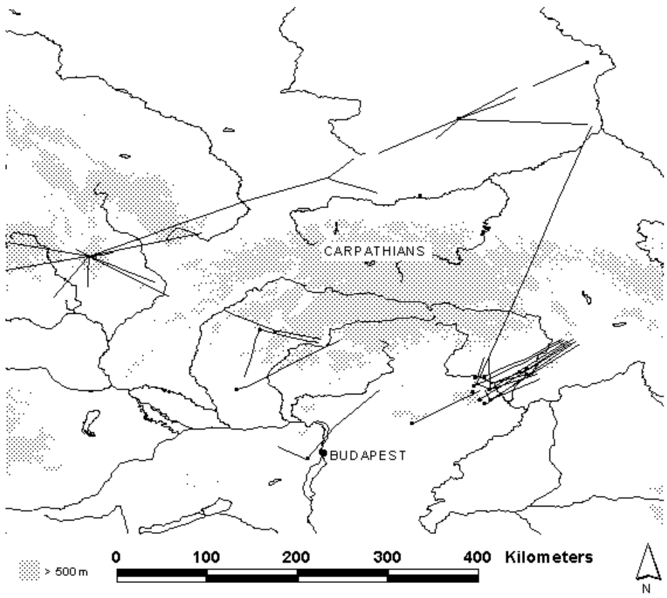

Fig. 2. Raw material transfer patterns for late Middle Palaeolithic sites in Central Europe (after Féblot-Augustins, 1997a, Fig. 56).

3 Problems with Current Approaches

Féblot-Augustins has explained the constant contrast between Western and Central European raw material transfers as being a result of different ecological zones. She suggests that the systemic organization of society in the two areas differs as a result of increased seasonality in Central Europe (Féblot-Augustins 1993). This stems from Binford's work on collecting and foraging in hunter-gatherer communities and the idea that technology is shaped by the systemic organization of society (Binford 1980). The systemic organization of society is in turn linked to the distribution of edible resources, so that foragers will have a certain technology based on their food getting habits while collectors have another. This is a view which has since been criticised for not acknowledging that the distribution of raw material for stone tool manufacture will also condition how these resources can be exploited (Bamforth 1986).

Féblot-Augustins' 'crow's flight' estimations of range size are only valid when assuming, as she does, that raw material procurement is always embedded in subsistence activities (Binford 1979). This implies that underlying geology and topography have no independent influence over where people move. However, a brief re-examination of Binford's work on procurement tactics would suggest that the embedded procurement assumption may not necessarily hold in all situations and does depend upon underlying geology. Based upon his studies of the Nunamiut of the Brooks Central Range in Alaska, Binford concluded that going directly to sources to obtain raw materials was very rare among hunter-gatherers. This was because obtaining these materials while undertaking subsistence activities would result in few or no direct costs. What Binford appears not to have taken into account is how the distribution of raw materials may have influenced the procurement strategies of the Nunamiut.

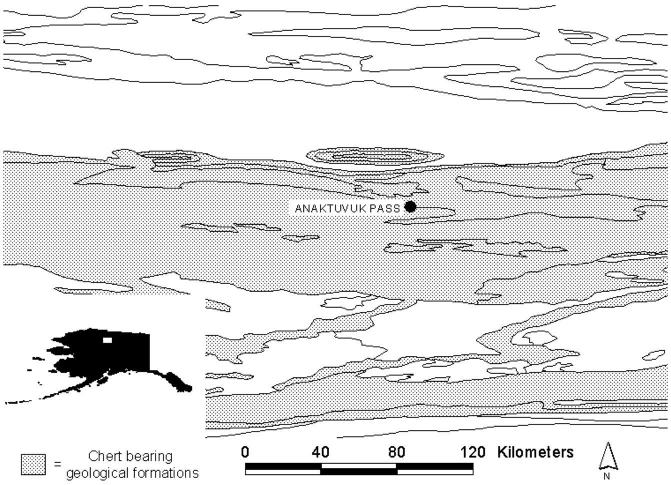

Fig. 3. Distribution of chert bearing geological formations in the Brooks Central Range, Alaska. The Nunamiut were interviewed by Binford while residing in the Anaktuvuk Pass.

An examination of the geology of the area in which the Nunamiut were living when interviewed by Binford reveals an abundance of chert sources (Mull 1995, Bever 1998, see Figure 3). This abundance of sources would appear to have facilitated an embedded strategy, allowing the Nunamiut to continue with other activities in the knowledge that a chert source was never far away if new tools were required.

The idea that procurement tactics are influenced by underlying geology would fit well with the arguments of McBrearty & Brooks (McBrearty and Brooks 2000) who believe that if greater transport distances in central and eastern Europe are ecologically determined then the African Middle Stone Age should be characterised by smaller territories and transport distances. This is not the case and they suggest that the contrast between the two areas may be more to do with gross differences in the geology and topography of the two areas.

4 Potential Solutions

To examine the influence that ecology may have had on these strategies it was decided that modern data would provide a good way to estimate major environmental differences across Europe, on the assumption that the relative differences from west to east would remain stable over time. This assumption was also necessary due to the lack of environmental evidence from the period in question. By assessing differences in effective temperature and seasonal temperature data it should be possible to contrast the two areas focussed on by Féblot-Augustins.

Effective temperature (ET) provides a simplistic proxy for seasonality, with a lower ET indicating a more seasonal environment. It was originally used by Binford (Binford 1980) in order to demonstrate how different strategies for resource procurement were related to the productivity of the environment. Using mean monthly temperature data derived from the period between 1961 and 1970[1] a Europe wide map of ET was generated using ERDAS Imagine. The following equation (from Kelly 1995: 66) was used:

$$ET = (18\,W - 10C) \div ((W - C) + 8). \qquad (1)$$

Where W and C are the mean temperatures (ºC) of the warmest and coldest months.

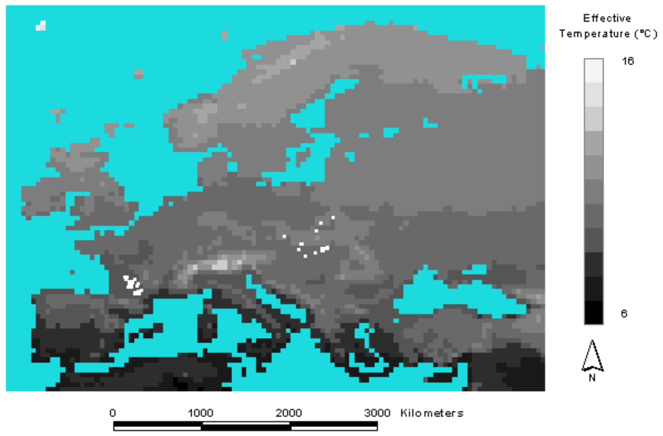

Fig. 4. Modern day effective temperature (°C). Lower values indicate a more seasonal climate.

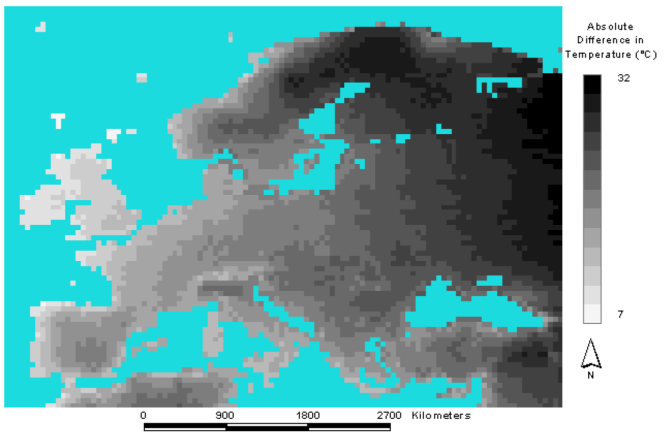

Fig. 5. Absolute difference between mean January and July temperatures (°C).

In this analysis the warmest and coldest months were assumed to be July and January, respectively. The results can be seen in Figure 4. The late Middle Palaeolithic sites used in Féblot-Augustins' study (Féblot-Augustins 1993) have been plotted to give some idea of the relative differences. From this map it can be seen that there is indeed a difference in modern day effective temperature and thus seasonality. This difference is between 1 and 2 degrees depending upon where sites are located. Sites in areas with a 2 degree difference appear to be clustered around the mountains of Central Europe such as the Carpathians. While a north-south gradient is evident across Europe the east-west contrast appears not to be as great. Looking at the mean monthly maps for January and July gives a much greater indication of an increase in continentality in the more eastern parts of Europe. This is further accentuated in Figure 5 which shows the absolute difference between July and January temperatures. It is interesting to note that in terms of Binford's forager-collector continuum (Binford 1980) this difference in ET would suggest that there would only be a

[1] Downloaded from the University of East Anglia Climatic Research Institute: http://www.cru.uea.ac.uk (accessed on 31/07/02).

minimal difference between modern hunter-gatherer subsistence strategies in these two areas.

From this modern day data it can be seen that there is a difference in seasonality between the two regions in question. However, on the basis of ET, I would argue that it is not one which would result in radically different mobility strategies. So, if seasonality cannot fully explain the differences in transfer distances as McBrearty & Brooks (McBrearty and Brooks 2000) suggested, then it is likely that differences in geology and topography might.

5 Examining Geology and Topography

To explore the relationship between geology, topography and the contrast between Western and Central European transfers, two sub-regions of Europe were selected: south-western France and an area around the Carpathians. These areas were chosen for the high number of late Middle Palaeolithic sites located within them. They can be seen in Figures 1 & 2.

5.1 Geology

To contrast the geology of the two regions a combination of small scale geological maps and the geology literature was used. In order to gain some idea of the potential for knappable rocks in each region a general scale of the likelihood of finding silicite bearing formations based on the work of Hein & Parrish (Hein and Parrish 1987) was created. Silicites comprise rocks such as chert (one of the most commonly used rocks in the Palaeolithic) and their production has varied over geological time. We can therefore expect certain formations to contain more knappable rocks than others.

South-Western France. Looking at a map of south-west France (Figure 6) we can see relatively short transfer distances with the sites all lying on Jurassic, Cretaceous and Neogene rocks. These are all systems during which silicite production was high. What is evident from the geological history of the Aquitaine basin are the long periods of carbonate deposition, especially during the Cretaceous and Jurassic periods. This is a result of the many marine transgressions during these periods which facilitated calcite deposition (Ager 1980). The lack of any significant tectonic activity has meant that these extensive deposits of limestone remain to this day. The increase in silica production during these periods can be seen in the distribution of silicite sources in this area. The lack of carbonate sediments in the Massif Central is witnessed by its lack of sources. The younger formations to the south-west of the Cretaceous deposits appear to have a fair amount of sources. All in all, examination of the geological history and maps of this region suggest a high potential for silicite bearing deposits.

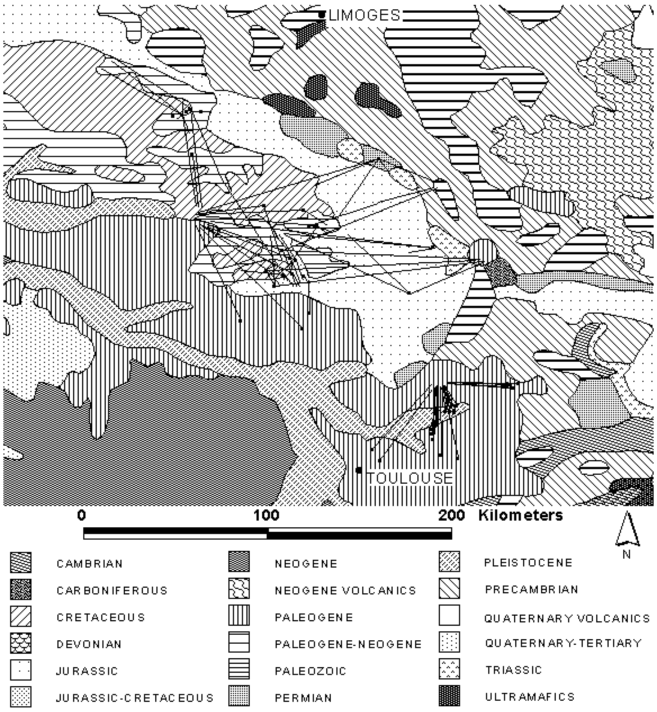

Fig. 6. Geology and raw material transfers in south-western France.

Carpathian Region. The Carpathian region has a very different geological history which is characterised by high tectonism. Silicite bearing carbonate sediments appear to be much fewer and more localised. Figures 7 and 14 demonstrate that sources are spread over a far larger area and appear to be focused in areas of uplift. Triassic carbonates are present in the Bükk and Holy Cross mountains of Hungary.

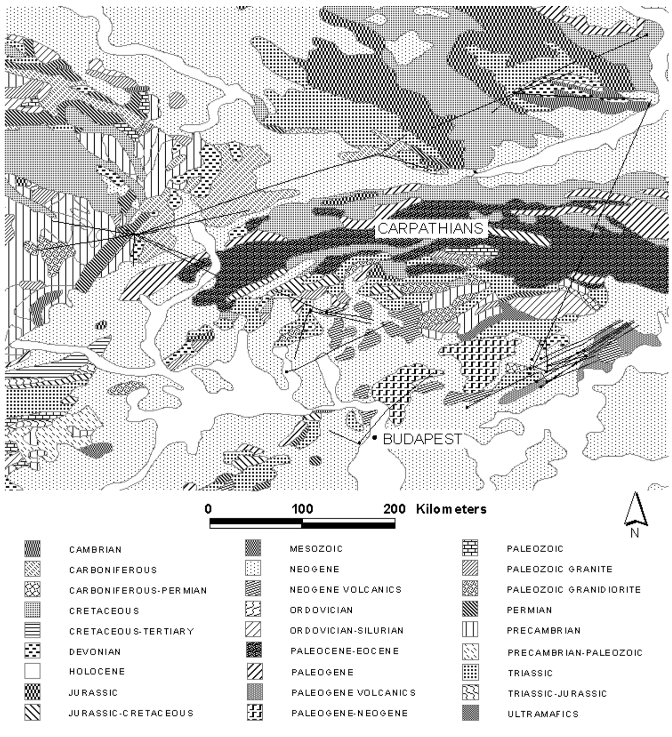

Fig. 7. Geology and raw material transfers in the Carpathian region.

In the Western Carpathians the internal zone contains some Jurassic radiolarites. Looking at Figure 14 it can be see that a large proportion of the region is made up of the Hungarian plains to the south and the Russo-Polish plain to the north. The former is characterised by thick Pliocene and Miocene sediments.

This brief contrast suggests that the two regions are geologically different. Even without knowing anything about geology this is apparent when comparing Figures 6 and 7. Perhaps the best demonstration of the contrast between the regions is to calculate the number of sampled sources per km^2. Working on the basis of the sources listed in Féblot-Augustins (Féblot-Augustins 1997a) there are approximately 74 in south-west France and 78 in the Carpathian region. The size of the region encompassing the French sites and sources is about 36921 km^2, while for the Carpathian region it is about 323142 km^2. This works out as 0.002 sources per km^2 in south-west France and 0.00024 sources per km^2 in the Carpathian region.

5.2 Topography

The exposure of these raw material sources will also be related to the topography of an area, which itself has an important influence over where and how populations move. Traditional GIS methods, such as generating slope data from DEMs, allow for only limited comparison of different topographic regions and so far there has been no way to quantify these differences in the spatial patterning of terrain. Recently however a free software tool has become available that allows the user to quantify terrain fabric. The topographic fabric or 'grain' refers to the strength and orientation of ridges and valleys and provides a measure of the tendency of the landscape to form linear ridges (Guth 1999b). The geological software MICRODEM, developed by Peter Guth of the Oceanography Department, U.S. Naval Academy, allows the topographic grain of an area to be quantified using eigenvector analysis on DEM data of any scale (Guth 1999a, Guth 1999b).

Topographic Grain. Comparison of Figures 8a and b give a good idea of topography with different fabric strengths. To the left in each figure is a statistical slope orientation diagram (SSO) generated using MICRODEM (Guth 2001).[2]

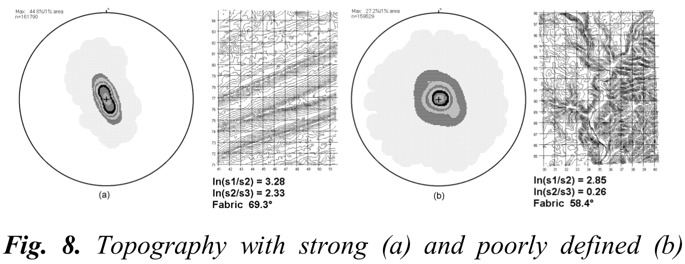

Fig. 8. *Topography with strong (a) and poorly defined (b) fabric (taken from Guth, 1999b).*

SSO diagrams allow the visualisation of the orientation of slopes over a small region. The contour data in Figure 8a can be seen to be highly elongated and regular. The high value for organization ($\ln(s_2/s_3) = 2.33$) indicates strong fabric. In other words, there is a dominant linear fabric to the terrain with a preferred orientation of 69.3°. This contrasts with Figure 8b which, from looking at the contour data and the results of the fabric analysis, has poorly defined fabric. The wider more circular spread of contours in the SSO diagram and the much smaller value for organization ($\ln(s_2/s_3) = 0.26$) indicates a weak preferred orientation of 58.4°. Guth has demonstrated that freely available elevation data can be used to visualise these terrain parameters and make comparisons between different regions and on a number of scales (Guth 1999a).

Contrasting Topography. To examine differences in topography between the two areas in question, nine sites in the Haut-Agenais region of France and nine from the Bükk region of Hungary were selected based on the similarity in their spatial distribution i.e. they are all clustered relatively close together. Using Gamble's scale for the landscape of habit (Gamble 1999), 40km buffers were generated around the sites using ArcView 3.2. The buffers were then used to clip Level 0 (30″ grid spacing) Digital Terrain Elevation Data (DTED),[3] generating a new DEM of only the elevation data within the combined 40km buffers (see Figure 9).[4]

Once in MICRODEM the topographic grain vector overlay command was used to generate an SSO diagram, a vector overlay and a flatness versus organization graph for each of the buffered DEMs. The results can be seen in Figures 9 to 12.

The vector overlays in Figure 9 give an idea of the strength and direction of the topographic grain for both regions. The length of each individual line is proportional to the strength of the terrain, while its orientation indicates the dominant direction of the fabric at that point in DEM. These diagrams suggest a more consistent fabric for the Haut-Agenais. The Bükk region is characterised by some areas that are highly organized (the mountains) and some that are totally flat lying (the Hungarian plains to the south east).

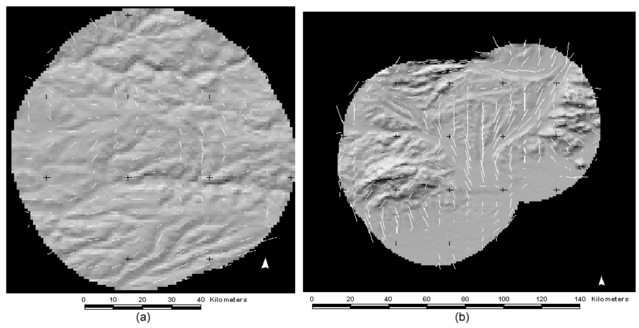

Fig. 9. *Vector overlays showing the strength and orientation of the topographic fabric in the (a) Haut-Agenais and (b) Bükk region.*

The SSO diagrams confirm this. Neither area has a significant directional trend. The larger outer contour in Figure 10b indicates the more focused areas of uplift in the Bükk region which can also be seen in the contour diagram (Figure 11b). Possibly the best indication of the differences between the two areas is given by the flatness versus organization graphs. The

[2] Downloaded from Peter Guth's website: http://www.nadn.navy.mil/Users/oceano/pguth/website/microdemdown.htm (accessed on 31/07/02).

[3] Downloaded from the NIMA Geospatial Engine: http://geoengine.nima.mil (accessed on 31/07/02).

[4] It must be noted that the buffered zone for the Carpathian region is larger because the sites used were spaced out over a larger area.

higher organization in Figure 12b represents the mountainous and uplifted areas of the Bükk region. The higher flatness reflects the most northerly part of the Hungarian plains. The terrain in the Haut-Agenais can be seen to be less variable in both flatness and organization (Figure 12a).

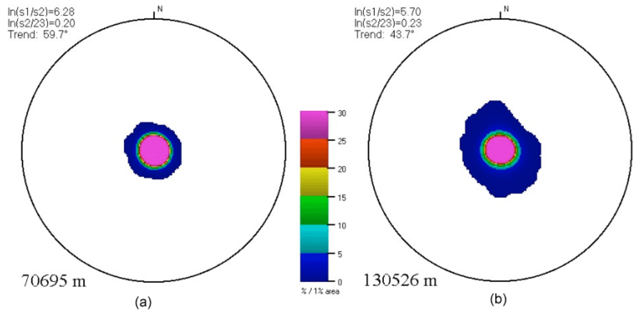

Fig. 10. SSO diagrams for the (a) Haut-Agenais and (b) Bükk regions.

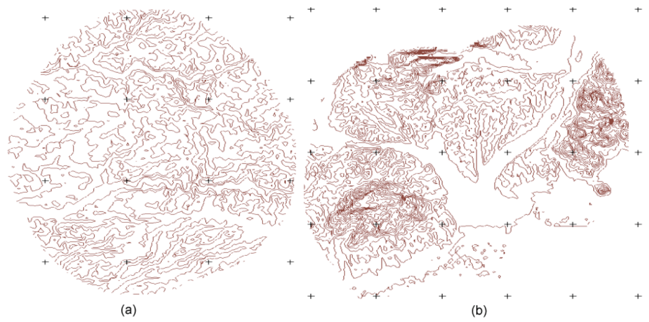

Fig. 11. Contour diagrams for the (a) Haut-Agenais and (b) Bükk regions (50m contour interval).

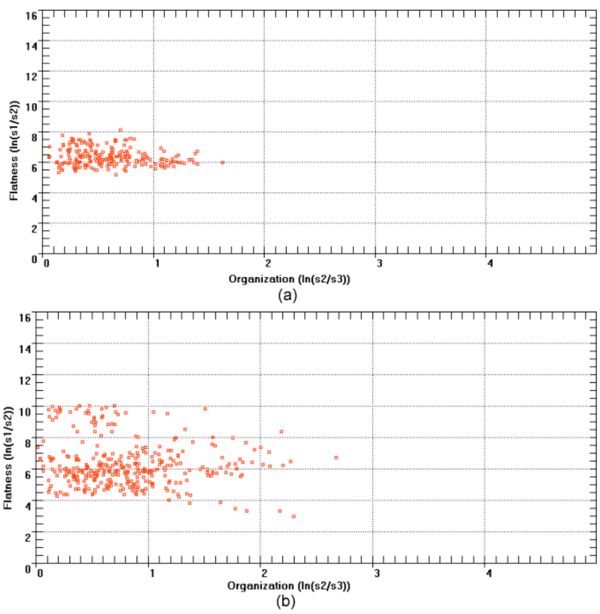

Fig. 12. Flatness vs Organization scatterplots for the (a) Haut-Agenais and (b) Bükk regions.

The relative differences in flatness are also much less than in the terrain of the Bükk area. It must be noted that although Guth's analysis appears insensitive to DEM quality or spacing (Guth 1999a) there are a number of problems inherent in the DEM data which cannot be discussed due to lack of space.

So far this section has emphasized the topographic contrast over a small area. Looking at the regions discussed by Féblot-Augustins as a whole we see this contrast even more clearly. Figures 13 and 14 show DEMs of the two regions. What is noticeable is that the French region is much smaller than that of the Carpathian region. This is to be expected, as the sites and raw material sources in France are much closer together. The French region is less topographically distinct and has a large number of rivers cutting through the bedrock geology. The Carpathian region is characterised by the more sudden uplift of the Carpathians and scattered smaller mountains to the south-west. To the north and south of the Carpathians are the Russo-Polish and Hungarian Plains, respectively.

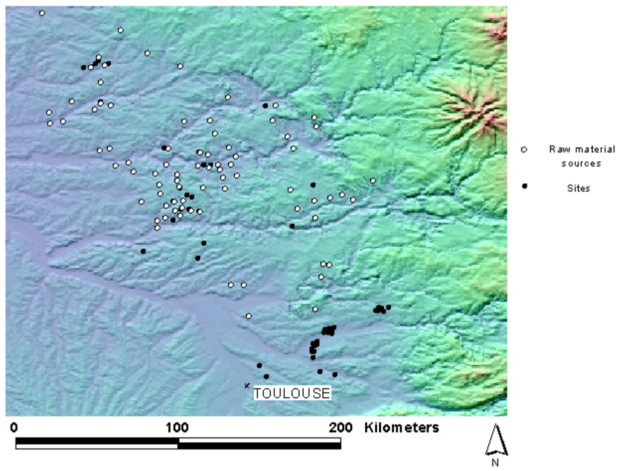

Fig. 13. Raw material sources and late Middle Palaeolithic sites in relation to the topography of south-western France.

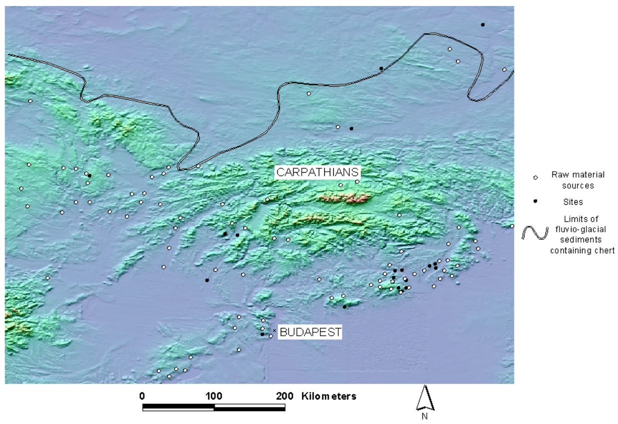

Fig. 14. Raw material sources and late Middle Palaeolithic sites in relation to the topography of the Carpathian region.

The distribution of known outcrops as mapped on Figure 143 demonstrates that sources in the Carpathian region are mostly focused around these areas of uplift. Those in France would appear to be less focused. Their more random nature may be a result of the greater number of plateaus and river valleys in this region, which would facilitate natural exposure.

From the discussion above it is evident that these two regions of Europe are geologically and topographically distinct. For this reason current ideas and approaches to planning, curation and mobility need to be modified in order to account for the influence that geology and topography have had upon Neanderthal mobility at all scales.

5 Conclusions

In this paper I have suggested that current approaches to Neanderthal planning using evidence from raw material transfers have failed to account for the small scale influence of geology and topography. From this work it is clear that a more detailed methodology is needed to look at raw material procurement and how it relates to planning.

In particular the methodology needs to link these continental differences to the more detailed and larger scale on which individuals perceived their environment. In order to achieve this the next part of this research will involve exploring Binford's ideas about embedded procurement with the use of multi-agent simulations. Using case studies in the regions discussed above which incorporate environmental evidence (i.e. geology, topography, ecology etc.), I aim to examine how different procurement tactics may influence the survival of agent populations. The initial examination of the geological distribution of knappable rocks outlined in this paper will also be revised in order to create a predictive model based upon known occurrences and digital geological maps. The results of these simulations will be contrasted with the archaeological evidence in the hope of shedding new light on the thorny issue of Neanderthal planning and perception.

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