Grant-in-Aid of Research, Artistry and Scholarship

Investigating Neanderthal Stone Tool Functions by Residue Analysis using SEM-EDS
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Abstract

The field of Paleolithic archaeology has made great progress in recent years in reconstructing the manufacturing processes of Neanderthals’ stone tools. However, it has not achieved the same degree of success in reconstructing the functions of these stone tools. This problem hampers our understanding of Neanderthal economic, subsistence, and technological activities. The field of microscopic use-wear analysis has used light microscopy to interpret use-wear traces on the edges of stone tools, but has yielded mixed results. Scanning electron microscopy (SEM), however, shows great potential for identifying residues of worked materials on the edges of stone tools. Energy Dispersive Spectroscopy (EDS) coupled with SEM provides the ability to identify the elements present in these residues. The proposed research program will 1) generate an experimental set of stone tools with residues, which will be analyzed using SEM and EDS, and 2) apply this methodology to stone tools made by Neanderthals from a collection located in the Evolutionary Anthropology Labs.
Category Justification

I am an assistant professor in the first year of my appointment in the Department of Anthropology. The Department has generously provided startup funds, which are committed to the purchase of equipment and materials for setting up a lab in which the proposed project will take place. [word count = 47]

Present Status of Knowledge

The behavior of Neanderthals, who existed in Europe and western Asia from approximately 130,000 years ago until 29,000 years ago, has long been a subject of fascination within the field of archaeology, as well as for the general public. Years of research on this extinct cousin of modern humans has revealed much information [1, 2]. We know that they survived in challenging environmental conditions for tens of thousands of years; they hunted large and small game; they buried their dead; and they made stone tools using sophisticated techniques. What we don’t know, however, is what they used these stone tools for. In other words, when we identify a “scraper” or a “backed knife”, we do not know whether those were actually the functions of those tools — the names were attributed to them decades ago based upon ethnographic analogy. As such, there is a lacuna in Middle Paleolithic archaeology — the field which studies the archaeological record coeval with the time period of the Neanderthals and their immediate ancestors, from about 300,000 years ago until 30,000 years ago. Because we do not know the functions of stone tools, our understanding of Neanderthal activities, such as subsistence, is incomplete. We are limited in our ability to reconstruct activity areas within sites, as well as between different types of sites located in different parts of the landscape. Besides hampering our understanding of the technological and economic aspects of Neanderthal behavior, this knowledge gap makes it difficult to study questions regarding social and symbolic behavior.

My own research in Paleolithic archaeology has always focused on Middle Paleolithic stone tools. I have particularly been interested in the interpretation of stone tool shapes, which are extremely varied. In a recent study I explored the chronological patterning of the major tool types used to define the Middle Paleolithic and the period immediately preceding it, the Lower Paleolithic [3]. This research revealed some surprising and heretofore unknown patterns, such as a rise and subsequent drop in the use of Levallois technology, an important technique used by Neanderthals for knapping, or breaking, rock to produce flakes which could be used as is or further modified into other kinds of stone tools. I would like to be able to explain this intriguing pattern; however, without knowing what Levallois flakes were used for, this question can only be answered circumspectly. In another set of recent papers [4, 5], I examined the notion that standardization within a stone tool type reflects higher cognitive abilities on the part of those who made them. This argument has been championed by Mellars
[2], who has suggested that standardization reflects the presence of a mental template that is imposed on the stone. I showed that standardization of shape can result from factors other than the deliberate imposition of form; for example, constant resharpening of tools results in diminished metric and morphological variability. This raises the question of the relationship between tool shape and tool function, and emphasizes the need for developing this key area of research.

In order to address some of these issues, such as the chronological patterning of stone tool types and the meaning of stone tool shapes, my proposed research will study stone tool functions. The traditional way of studying stone tool functions in Paleolithic archaeology is to use the methods developed by the field of microscopic use-wear studies, or simply “microwear.” Microwear analysis has largely relied upon light microscopy to interpret polishes and striations indicative of use-wear on the edges of stone tools, in order to identify the materials that the tools were used on, and the actions performed [6-9], such as hide-scraping, woodworking, and butchery. However, the difficulty of quantifying polishes observed by light microscopy has rendered polish identifications subjective and non-replicable, and blind tests have yielded extremely poor results [10]. This has resulted in a great deal of mistrust of microwear results by the archaeological community [11], and is the reason why so little is known about the functions of Neanderthals’ stone tools.

Fortunately, the related field of residue studies shows great potential. Residues of worked materials accumulate on the edges of stone tools and can be identified microscopically [12-15]. While light microscopy has yielded mixed results [16, 17], Scanning Electron Microscopy (or SEM) has shown that residues of materials such as bone and bamboo can be clearly identified, even after procedures mimicking chemical alteration during burial [18]. SEM analysis has only been used very sporadically in stone tool residue studies, however, due to three main issues: 1) size of the SEM specimen chamber; 2) the need to create a vacuum in the specimen chamber, and 3) the cost and technical expertise needed to operate the SEM. Fortunately, due to technological and software advances, many of these problems are now overcome. The JEOL 6500 Field Emission Gun Scanning Electron Microscope located at the Characterization Facility at the University of Minnesota has a specimen chamber that can accommodate specimens up to 7 cm. in diameter; this is large enough for most stone tools. Second, the JEOL 6500 vacuum pumps can create the vacuum necessary in a reasonable amount of time, from 2 minutes to 20 minutes, depending on the size of the sample. Finally, the JEOL 6500 is easy to use. I was trained to use it in September, 2008, and carried out pilot studies which demonstrated that I can successfully obtain high-quality images of the surfaces of flint tools.
Images of residues alone are often not sufficient for positive identification. Characterization of the elements present in the residues can provide information essential to their identification. This can be done using energy dispersive spectroscopy (EDS), which uses instruments attached to the SEM. [word count = 1,040]

Plan of Work

The goal of my proposed research is to initiate a program geared towards the identification of residues of worked materials on the edges of prehistoric stone tools, in particular those used by Neanderthals. There will be two components to my work. The first will be to develop the methodology. This will require, first of all, generating a set of experimental stone tools used for a variety of tasks that would have been common in the Paleolithic, such as woodworking and butchery. Stone tool manufacturing experiments are common practice in Paleolithic archaeology, and the techniques for replicating stone tools such as those used by Neanderthals are well established [19]. Furthermore, the experimental use of stone tools is also common practice and has in fact been applied to microwear studies [9]. A series of 75-100 stone tools will be made using known Middle Paleolithic flintknapping techniques. They will then be used for tasks that we know Neanderthals carried out, such as defleshing animal carcasses (we know this from the patterning of stone-tool cutmarks on animal bones in many sites), whittling yew wood to make sharpened spears, processing tubers and nuts, and so forth. Every effort will be undertaken to ensure that the actions and materials used in the experiment are as similar as possible to those Neanderthals used. Finally, the experimental stone tools will be analyzed using the SEM in order to generate a database of residue images and elemental compositions. The second component of my research will be to apply the methodology to stone tools from Le Moustier, a site in France dated to about 60,000 years ago and associated with Neanderthal remains. Le Moustier is the type site of the Mousterian, which is the original name used to define the lithic industry associated with Neanderthals (now we mostly use the term “Middle Paleolithic”), and is still considered one of the most classic Neanderthal sites. A collection of approximately 150 stone tools from Le Moustier is located in the Evolutionary Anthropology Labs at the University of Minnesota. If successful, this initial study will enable me to expand the work to other Neanderthal sites in the future.

The immediate impact of the proposed research will be the development of a new methodology designed to identify residues on prehistoric stone tool edges. This methodology will be applicable to lithics from other time periods and geographic locales than the European and western Asian Middle Paleolithic. In addition, this research will hopefully yield some information about the functions of stone tools from Le Moustier. The long-term impact of the study will be to provide new information regarding the materials that stone tools were used on,
thereby helping us decipher their functions. This, in turn, will allow us to begin to address issues concerning the relationship between tool form and function, and will enable us to better understand the meaning of certain chronological patterns in stone tool types. It will enable us to assess Neanderthal cognition with respect to stone tool manufacture. Finally, it will enable us to begin to improve our understanding of such basic social, technological, and economic issues as inter- and intra-site activity patterning, degree of dependence upon food sources other than meat, and importance of woodworking in Neanderthal societies (since wood artifacts are seldom preserved, but wood residues will be observable using this methodology).

Work on this project will begin in August, 2009 and is expected to be completed by the end of December, 2010. It will generate publications in peer-reviewed journals such as the *Journal of Archaeological Science* and *Paleoanthropology*. It will also provide initial results which will improve the chance of success in grant applications I plan to submit to the National Science Foundation Archaeology program and to the Wenner-Gren Foundation for Anthropological Research, in order to expand the project. [word count = 532]

**Budget Justification**

- **Graduate Student Research Assistant**
  (Duties: helping make and use experimental stone tools; cleaning all experimental stone tools and carbon-coating prior to SEM analysis; doing approximately 60% of SEM imaging and EDS on experimental tools as well as archaeological stone tools)
  
  - 2-semester 50% appointment, salary + fringe $26,410

- **Graduate Student Training on SEM at the Characterization Facility**
  
  - SEM $180
  - EDS $124

- **Hourly Fees, JEOL 6500 Scanning Electron Microscope**
  
  - 375 hours total (Analysis of the experimental stone tools will take approximately 3 hours for each tool, X 75 tools = 225 hours; Analysis of 50 artifacts from Le Moustier will take approximately 150 hours)
    - 175 hours daytime use (175 x $41.40/hour) = $7,245
    - 200 hours evenings/weekends (200 x $13.80/hour) = $2,760

- **Carbon-coating fees for carbon-coating artifacts before placing in SEM = $400**

**Total Budget = $37,119**
Need Justification
The startup funds allotted to me by the Department of Anthropology will be used to outfit a research lab which will be used to run this project. Equipment to be purchased with these funds includes:

- flint for making the experimental stone tools
- materials to be worked for residue deposition (elk and reindeer antler, bison and horse bone, hides, plant materials, etc.)
- materials and equipment for cleaning the stone tools before SEM analysis, such as solvents and glassware
- a videocamera, computer, and software, for recording the stone tool motions during use (e.g., the angle between stone tool and material)
- furniture (a table) and hardware (vises, etc.) for carrying out the experiments

I have not applied to outside granting agencies for funding, because this is a relatively new area of research for me. Although I have studied Middle Paleolithic stone tools and published on them for almost a decade, I have only become engaged in the field of residue analysis within the last year and a half (I conducted pilot studies on SEM imaging and EDS of residues on stone tools during the Fall, 2008). I believe that the experiment outlined above has great potential for providing results. If I can obtain “seed money” from a GIA to carry it out, I will have greater success in obtaining funding from outside agencies in the future.

References Cited