Reconstructing Human-Landscape Interactions

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Edited by

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PREFACE

The first ever Developing International Geoarchaeology conference (DIG 2005) was held in Saint John, New Brunswick, Canada, in October 2005. It aimed to bring together those involved in geoarchaeology: students, university researchers, government and cultural resource management people, whether they identify themselves as geologists, archaeologists, geophysicists, geographers, or of course as geoarchaeologists. The enthusiastic response to our first call for expressions of interest was very encouraging, and was indicative of things to come: the conference was a great success. We received approximately 50 abstract submissions for oral and poster presentations, from authors in a dozen countries. The submissions themselves provided the conference themes: 1. Coastal and Underwater Geoarchaeology, 2. Geophysical Survey and Geoarchaeology, 3. Landscape Evolution (including sessions on Settlement and on Formation Processes), and 4. Artifact Provenance Studies. About 70 people actually attended, traveling from as far away as Kuwait to do so, and enjoyed a day and a half of presentations and a full day field trip through southern New Brunswick. The presentations and posters were of up-to-date, original work, of impressive quality. The conference sessions were intense and highly productive, with many excellent discussions during the question and answer periods, and during the coffee breaks. At the same time, the single session plan of the conference, so that everyone heard everyone else's paper, probably contributed to the very informal, good-natured ambience, which extended through the Saturday evening banquet and even survived the day-long driving rain during Sunday's field trip.

This volume of papers from the conference exemplifies the quality of the work presented, just as its title, *Reconstructing Human-Landscape Interactions*, describes the over-riding theme of this discipline. People have long used the landscape in many ways: as a place to live, as a place to grow crops, as a source of natural resources. Those activities leave their traces. The characteristics of the landscape constrain which activities are possible, just as social and cultural habits condition people's connection with the environment. Geoarchaeology is about finding the traces of these interactions, and using them to reconstruct how people in the past behaved in their environmental context.

All participants in the conference were invited to submit papers to the proceedings volume. Those submitted were reviewed both by the editors and by anonymous referees, and the authors were then asked to revise their papers based on those comments. The papers in this volume are not organised into the sections used for the conference, but rather as one flowing whole: starting with the oldest and largest subjects, they then move to more specific themes and from the land to the coast and back onto land to examine particular techniques. The prologue by Rip Rapp gives us some of the historical context of the field. Chris Hill then shows us how geoarchaeological techniques can be applied to different areas (Egypt and the United States) and time periods while still addressing similar questions about the environmental context of human life. Papers on the geomorphology of arid landscapes (Gillmore et al.), post-glacial landscapes (Evans et al.) and fluvial environments (Adelsberger and Kidder) move us out to the east coast of North America, where we learn about human traces around the lakes and shorelines of New Brunswick and Maine (Dickinson and Broster, Pelletier and Hall, Leach and Belknap). We then look at the effects of sea-level changes and land use on human settlements in coastal Italy (Lorusso) and France (Sivan et al., who also provide a fascinating look at the regulatory context of salvage geoarchaeology). Goodman et al. show how non-destructive GPR imaging can find and elucidate the features of settlements, using examples from various parts of the world, without the need for excavation. As Dean said during his presentation, perhaps the next conference should be called “Don’t DIG!” Owen et al. then demonstrate how the geochemistry of glass samples can show whether local silica resources were used or not, thus helping to reconstruct human-landscape interactions in a very specific way. Wilson uses the provenance of stone tool raw materials to trace human interactions with the landscape context. Finally, Charly French takes us beyond prehistory. Since geoarchaeological work shows us how people used to use the land, and what the consequences of that use were (soil depletion versus sustainability, for instance), we have a responsibility to contribute to the debate about whether present-day land use practices are sustainable or not: a fitting challenge to take us into the future. We are confident that future DIG conferences will continue to chart this development of international geoarchaeology.

Lucy Wilson, Pam Dickinson, and Jason Jeandron

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The conference and this book have also benefited from the hard work and enthusiasm of a large number and variety of individuals, and we thank them very much for their efforts: Patricia Allen, Chris Baker, Sue Blair, Lydia Calhoun, Craig Evans, Don Fillmore, Charly French, Patrick Gamblin, Dean Goodman, Elizabeth Gorman, Chris Hill, Katie MacLeod, Alison McAslan, Jim McDonald, George “Rip” Rapp, Eduard Reinhardt, David Sanger, Jane Simmons, and Emma Toner. We apologise if we have inadvertently missed any names.

CHAPTER ONE

PROLOGUE: THE ORGANISATION, DEVELOPMENT AND FUTURE OF GEOARCHAEOLOGY

GEORGE (RIP) RAPP

When I accepted the position of Associate Director of the Minnesota Messenia Expedition (Greece) in late 1966, in charge of all archaeological science but especially geoarchaeology, it was approximately 100 years since Charles Lyell had published his Geological Evidences for the Antiquity of Man. That volume launched the field of geoarchaeology. For convenience, in this paper archaeological geology will be considered as incorporated in geoarchaeology.

In North America during the last half of the 19th century and the early part of the 20th century various earth scientists focused on determining the antiquity of humans in the New World – the possibility of an American Palaeolithic. Leading figures in North American geology found the geological aspects of the early-man controversy compelling and made significant contributions to the resolution of questions about the glacial context of human and artifactual remains. Prominent among them is the first state geologist of Minnesota, N. H. Winchell. While working out the glacial geology of Minnesota, Winchell became interested in the remains of the indigenous Native American tribes. Winchell's interest culminated in a large volume, *The Aborigines of Minnesota*, published in 1911. In addition, he summarised many of the questions about the geological context of early humans in North America in his presidential address to the Geological Society of America on 20 December 1902.

During the middle half of the 20th century a number of geologists worked individually on archaeological excavations to answer stratigraphic, geomorphic, and sedimentary questions. Among the most notable of these were Elias Sellards, Ernst Antevs, and Kirk Bryan. Yet there is no evidence that these individuals considered that they belonged to a subdiscipline – archaeological geology.

In 1971 I was on the Joint Technical Program Committee for the Annual Meeting of the Geological Society of America (GSA). An abstract for a paper for this meeting was submitted on what was essentially a geoarchaeological topic. It was rejected because none of the sessions, each tightly focused on a given subdiscipline of earth science, would take it. The paper did not fit within the perceived boundaries of any of the subdisciplines (e.g. geomorphology, sedimentology, or stratigraphy). Not only did geoarchaeology not fit into the organisational structure, geoarchaeology did not appear to qualify as a subdiscipline. It had no formal organisation, no journal, no annual meetings, no university degree programs or even university courses. I decided things had to change.

For the 1972 GSA meeting, as Technical Program Chair I organised a session on geoarchaeology. The committee assigning rooms put the session in one of the smallest rooms. Before the first paper was well underway the audience had expanded into the hallway. I quickly put on my other hat as Co-General Chair of the GSA meetings and moved us to a large room. For 1973 I was again on the Technical Program Committee so I saw to it that geoarchaeology again got its foot in the door. I learned that to be guaranteed a technical session the session organisers had to represent an associated society, e.g. the Mineralogical Society of America, or a division or section of the GSA.

I noticed that some subdisciplinary groups each year organised something less than a technical session but were given a room for half a day and recognised in the formal program as a "Friends of…" meeting, e.g. Friends of the Brachiopods. So for three or four years I requested a "Friends of Geoarchaeology" meeting and we were underway. At these meetings 15 or 20 people would attend and I attempted to gauge the interest in forming a division of the GSA, a separate society altogether (as we had done for the Society for Archaeological Sciences), or affiliation with the Society for American Archaeology. I contacted the SAA but they were not [then] interested. The GSA was interested so I wrote some bylaws, asked a few members for their active support, and made a formal proposal to the GSA Council for an Archaeological Geology Division. I chose archaeological geology rather than geoarchaeology because GSA was an association of geologists. The proposal was successful. I was surprised when over 400 GSA members joined the new Archaeological Geology Division.

About the same time I wrote a brief piece entitled "*Geoarchaeology Anyone?*" for the GSA's newsletter [then called Geology I believe] and I conned Claude Albritton and Reuben Bullard into signing on as co-authors. For a few years I wrote and distributed an informal newsletter to interested geologists and archaeologists. Once a year the American Geological Institute, in its magazine GEOTIMES, devoted an issue to recent research in each of the various subdisciplines of earth science. The editors quickly accepted my offer to add archaeological geology to this annual review.

The geoarchaeology literature at that time was sparse indeed. Much of it was in the grey literature as appendices to archaeological reports. So some of us set about getting a journal started. After some false starts the journal *Geoarchaeology* emerged. That still left the problem of university-level programs. At the University of Minnesota, first at the Twin Cities campus and later also at Duluth, I offered M.S. and Ph.D. degrees in geoarchaeology under the aegis of an interdisciplinary graduate program. This program was first called Ancient Studies and later morphed into Interdisciplinary Archaeological Studies. John Gifford and Julie Stein were the first two graduate students.

Others got courses and programs started at additional universities so I soon had to put out a *Guide to Graduate Programs in Archaeological Geology and Geoarchaeology*, updated every couple of years. The Guide is now published jointly by the Archaeological Geology Division of the GSA and the Geoarchaeology Interest Group of the SAA. It can be accessed through the GSA's website. Go to www.geosociety.org then to the Archaeological Geology Division. The 2005 Guide lists 23 departments in the United States and Canada. One can consult the Guide to see the current plethora of opportunities for graduate education in geoarchaeology. Many colleges and universities in North America now offer courses that are broadly geoarchaeology, most often in anthropology, geography, or archaeology departments, sometimes in geology departments or in interdisciplinary studies programs.

In addition to the GSA and the SAA, geoarchaeology has a home in the American Quaternary Association. AMQUA is organised into broad disciplinary groups. One is archaeology and anthropology; this essentially is geoarchaeology.

A mere 30 years or so after its organisational birth in North America geoarchaeology is flourishing. DIG 2005 was just one of the geoarchaeology meetings in 2005 and theses and dissertations are numerous. A dozen national and international journals publish papers in geoarchaeology. New books in this field appear yearly. Career opportunities are increasing. Importantly, the old guard is retiring and broadly-educated younger people are now defining the future.

Is geoarchaeology on a satisfactory trajectory for the future? Geoarchaeology is constrained to work within the shifting framework of archaeology. Archaeology is far more than excavating and using a background in anthropology or classics to tell a plausible story about the human past. To get the fullest possible understanding of ancient peoples and events, it is necessary to study the context of everything humans interacted with: plants, animals, rocks and minerals, the landscape, and so forth. This is beyond the capacity of individual scholars and researchers. Hence most modern projects in archaeology are team efforts.

Only a small portion of any ancient human environment exists today for study. However, geoarchaeology has the luxury of working with rock products, which are exceptionally stable, and with landscapes, that while undergoing slow change, leave recognisable evidence of their evolution. Cultures have been largely defined by their range of material products, mostly geological in nature, and by their environmental context. This makes geoarchaeology a vital component of almost every archaeological research effort.

There remains the question of the education of geoarchaeologists. Academic geoarchaeology in the United States is in a period of transition. Most of the first wave of post-1950 geoarchaeologists were trained in and subsequently taught in geology or geography departments. Now in the U.S. most are taught in and teach in anthropology departments. This has led to an ongoing discussion about whether archaeology is anthropology and, particularly in the last two decades, whether archaeology should be housed in academic anthropology departments or be a free-standing academic department.

In Britain there are archaeology and archaeological science departments and in Canada there are archaeology departments. When archaeology is a free-standing department geoarchaeologists, archaeometrists, archaeometallurgists, and other archaeological scientists are a basic component of the teaching and research program. It is more difficult to integrate these “hard sciences” in anthropology departments. In the United States the vast majority of archaeology and geoarchaeology courses and programs are now in anthropology departments. My view is simply that not all of archaeology is anthropology so archaeology should be organised and taught as the broad-based discipline that it surely is today.

Why should archaeologists study geoarchaeology? The answer is simply because human social frameworks and their natural environments have co-evolved through time. A thorough understanding of culture and culture change is not possible without an appreciation of the environmental context. Humans wandered and worked across, and made an impact on, a continuous landscape. It is with the continuous space-time landscape that geoarchaeologists must and archaeologists should deal.

Geologists and geoarchaeologists focus on larger areas than sites and site-catchment areas and therefore employ different strategies and methodologies from archaeologists. Somewhat the same thing can be said for their contrasting approach to stratigraphy. Archaeologists have always focused on the specific strata in archaeological sediments that contain artifacts and features. They usually consider the time interval between the deposition of these strata as dead time and the deposits as ‘sterile’, largely out of bounds for archaeological work. Geoarchaeologists need to see time, as well as space, as a continuum. Life went on whether the deposits recorded examples of it or not. Landscape changes, the climate, gross impacts of human activities, soil development, changes in vegetative cover, all are time-continuous features in our earth's surface environment. So, can there be broad archaeological conclusions without geoarchaeology?

Now we turn to the near future. With excavation being both exceedingly costly and destructive of sites, survey will play an increasingly more prominent role. In North America, archaeologists began systematic archaeological surveys (mapping the locations of the sites) in the 1930’s to supplement excavation data. By the 1960’s there was extensive discussion about how to sample large areas for surveying where intensive and complete coverage was impractical. Reconnaissance survey gave only a limited view of the regional picture and could not be used in a statistical sense. It required an intensive and carefully controlled archaeological survey to provide an inventory of the nature and distribution of sites. But I believe even intensive surveys lack two features: (1) they are two-dimensional, with archaeologists walking over the surface of the land; the vertical dimension is not systematically addressed, and (2) they recover only certain types of strictly archaeological information, with only limited attention paid to ecological and geomorphic components.

In large alluvial plains archaeological sites have been buried 15 m below the present land surface. Some ancient harbours are now more than 10 km from the sea. Locating sites and reconstructing the associated landscape evolution requires intensive core drilling with detailed geological and ecological analyses of the cores. Coring is used far too little in archaeological surveys. The nature and origin of the sediment/soil matrix are critically important in understanding the formation of an archaeological site in its landscape context. In some cases ground-based geophysical exploration methods (electrical resistivity, magnetometry, or ground-penetrating radar) also might be useful. Geochemical prospecting to locate sites, as distinct from burials, is inefficient but useful in determining horizontal and vertical boundaries of known sites and features within sites. All of these methods are components of geoarchaeology and all should expand in importance as this new century advances.

Archaeological site preservation is largely a post-World War II phenomenon. Unfortunately, few follow-up studies have been undertaken to determine the effectiveness of site-preservation methodologies. Hence, site preservation should be a fertile field for future research by geoarchaeologists. Short-term protection of a resource, though often expedient, does little to ensure long-term preservation. Until we evaluate long-term effectiveness, we cannot begin the appropriate cultural resource management planning. With their broad training in archaeological science, geoarchaeologists should play a major role in the preservation, monitoring, and evaluation of our past.

CHAPTER TWO

SURFICIAL PROCESSES AND PLEISTOCENE ARCHAEOLOGY: CONTEXT, LANDSCAPE EVOLUTION AND CLIMATE CHANGE

CHRISTOPHER L. HILL

Abstract

Surficial processes inferred from Pleistocene sedimentary sequences can provide a record of events leading to archaeological site formation as well as landscape evolution. In northeastern Africa, Palaeolithic artifacts are found within sedimentary deposits that seem to reflect surficial processes linked to changing climate and environmental settings. These include Acheulian, Middle Palaeolithic, and Late Palaeolithic occurrences in the Western Desert and Nile Valley of Egypt, and their site-specific sedimentary contexts. In the western interior region of North America, records of landscape evolution dating to the last glacial-interglacial transition and the Pleistocene-Holocene boundary can be related to settings contemporaneous with late Pleistocene human populations. Stratigraphic sequences provide evidence that can be utilised to examine the relationships between human adaptations, surficial processes, and landscape evolution.

Introduction

Sedimentary deposits containing Palaeolithic artifacts offer information connected with Pleistocene surficial processes on at least two scales: 1) discrete events that provide information on landscapes and site formational contexts, and 2) landscape evolution that can be correlated with climate and environmental change. Sedimentary sequences can be used to infer surficial processes that reflect specific depositional events and local palaeoenvironments. Variations in stratigraphic sequences also have the potential of being related to climate change. Thus, the examination of stratigraphic successions provides information pertinent to interpreting the human past in terms of formation processes on a site-specific scale, as well as human adaptation and landscape evolution on broader regional-to-continental scales that may ultimately be related to global climate change (Hill 2005). In this paper, sedimentologic, stratigraphic, landform, and geochronologic data are used to evaluate Middle and Late Pleistocene contexts associated with the presence of human populations in northeast Africa (the Sahara and the Nile Valley) and the western interior of North America (the Upper Missouri Basin and Southern High Plains) (Figure 2-1).

Applications of geoarchaeological concepts and methodologies to examine aspects of Quaternary landscape change rely on the use of landform mapping, sedimentology and stratigraphy, and geochronology (Brown et al. 2003; Butzer 1982; Gregory 2000; Karlstrom 2005; Mayer 2005; Miall 1996, 2000; Posamentier and Allen 1999; Rapp and Hill 2006; Selly 2000; Waters 2000). At a minimum these involve the documentation and description in the field of sedimentary deposits and their vertical and lateral variations, along with their relationships to archaeological occurrences. Additionally, it sometimes proves very useful to obtain textural and compositional information from laboratory studies. These methods provide a way to use sediments, erosional surfaces, and soils found in stratigraphic successions to infer surficial processes of erosion, deposition and landscape stability. Although changes in lithostratigraphic facies reflect variations in surficial processes that can be used to examine site formation and spatial distributions or longer-term landscape evolution, connecting these variations to global climate change requires correlation. Correlation of discrete sedimentological events or broader-scale patterns of landscape evolution can be undertaken by using geochronological methods such as uranium-series and radiocarbon dating of the deposits and relating them to independently developed measures of global climate change, such as marine and ice stable isotope curves. The basis of this kind of geoarchaeological study is the examination, analysis, and interpretation of stratigraphic sequences.

Middle and Late Landscape Evolution in the Eastern Sahara and Nile Valley

Introduction

Southern Egypt contains a record of landscape evolution within stratigraphic sequences that reflect local changes in environments. In some instances these appear to be related to patterns of continental- and global-scale climate. An understanding of the conditions under which stratigraphic sequences have been produced provides information pertinent to evaluating site-specific formational events, local and regional landscapes, and temporal correlation on a variety of scales.

From the perspective of hominid behavioural and biological evolution, the Middle and Late Pleistocene are connected with the patterns of artifactual change within the Palaeolithic and the fossil evidence for changes from archaic forms of the genus *Homo* (e.g. late forms of *Homo erectus*/*ergaster* or *H. heidelbergensis*) to anatomically modern *Homo sapiens* (Wendorf et al. 1994; Tryon and McBrearty 2002; White et al. 2003). Biologically modern *Homo sapiens* forms appear to have emerged during the Middle Pleistocene (McDougall et al. 2005).

Artifacts dating to the Middle Pleistocene (from about 800 000-130 000 years ago) represent two taxonomic sets: Lower Palaeolithic Acheulian assemblages (characterised by the presence of hand axes, or bifaces), and Middle Palaeolithic or Middle Stone Age assemblages. The Late Pleistocene (the last glacial cycle, from about 130 000 to 10 000 years ago) in northeast Africa contains Middle Palaeolithic and Late Palaeolithic artifact assemblages that are both likely connected with *Homo sapiens*. Here, stratigraphic successions that can be related to Palaeolithic archaeological assemblages in southern Egypt are considered from the perspective of landscape evolution by examining the implications of two aspects of Pleistocene surficial processes: 1) sedimentary events, and 2) potential correlations with climate fluctuations.

Sedimentary sequences in southern Egypt at Bir Tarfawi and Wadi Kubbaniya contain Palaeolithic artifacts (Figure 2-2). The Bir Tarfawi region, within the Western Desert in south-central Egypt, contains deposits that can be directly linked to Acheulian and Middle Palaeolithic artifact occurrences (Wendorf and Schild 1980; Hill and Wendorf 1991; Wendorf et al. 1993; Hill 1993a, 2001c, 2002b). At Wadi Kubbaniya, a tributary of the Nile River located northwest of Aswan, the sedimentary sequence can be linked to some Middle Palaeolithic occurrences and a significant set of Late Palaeolithic assemblages (Hill and Schild 1986; Wendorf et al. 1989; Hill 1989). Together, Bir Tarfawi and Wadi Kubbaniya provide evidence of Pleistocene surficial processes and adaptive responses of hominids associated with Acheulian, Middle Palaeolithic and Late Palaeolithic artifacts that can be examined in terms of the site-specific depositional contexts and long-term Pleistocene climate change.

Surficial Processes and Sedimentary Sequences in the Egyptian Western Desert

Sedimentary deposits related to Acheulian and Middle Palaeolithic (or “Mousterian”) occurrences from the eastern Sahara provide information that can be used to evaluate landscape settings, site formation (taphonomic) processes, and palaeoclimate chronologies associated with Middle and Late Pleistocene hominids

(Hill 1993a, 1993b, 2001a). The sedimentologic and stratigraphic evidence appears to show changing landscape conditions in the Sahara since the Middle Pleistocene that can be linked to the presence of hominids that used Palaeolithic artifacts. In terms of landscape evolution, the evidence for wetter, pluvial conditions is in the form of sheet wash, paludal, and lacustrine deposits, while intervals when more arid conditions prevailed are represented by aeolian sediments and erosional boundaries within the stratigraphic sequences.

Middle Pleistocene strata associated with Acheulian artifacts consist mostly of carbonates and coarse siliciclastics (mostly sands). The carbonates (micrites and limestones) are interpreted to indicate the presence of wet climates that resulted in higher ground water levels, spring mounds and lakes. Deposits dominated by clastics are interpreted to reflect shore, beach, or basin-margin facies. The clastics have been protected from erosion by the deposition of younger carbonates as a consequence of ground water rise or transgression events in basins.

Some of the sediment remnants associated with Acheulian artifacts show signs of erosion by wind; deflational processes have affected both the sedimentary matrix and the artifactual record. Where a sedimentary sequence has been preserved, the patterns of deposition and erosion primarily reflect a single pluvial event and subsequent erosional activity that can be linked to arid conditions. Changes in the Acheulian landscape, therefore, seem to have been largely driven by climate fluctuations that have contributed to the preservation, transformation, and destruction of the Middle Pleistocene artifactual record.

Sedimentologic contexts containing Acheulian hand axes provide information pertaining to the physical landscapes available to the Middle Pleistocene hominids in this region. The deposits suggest the episodic presence of ponds or small lakes during wet ("pluvial") climate intervals. These Acheulian contexts can be used to suggest some of the geological processes that could have formed the surviving, observable record. From the geoarchaeological perspectives of taphonomy and site integrity, some Acheulian sites appear to have not been significantly affected by post-depositional processes (Hill 2001c). At other sites, however, there appear to have been modifications of the patterns originally produced by hominid activity. For instance, vertical displacement of artifacts may be implied by the trace fossil horizons indicative of bioturbation.

Modifications to the original Acheulian artifact assemblages at some sites are indicated by evidence for wind erosion. At one locality (designated site BS-14) estimated to date from about 600 000-500 000 years ago, wind erosion appears to have removed the surrounding sedimentary matrix, resulting in dense concentrations of artifacts. Deflation also seems to have led to the destruction of smaller artifacts (such as debitage), changing the original character of the assemblage. The artifact assemblages recovered from deposits not affected by deflation contain a much higher percentage of smaller artifacts relative to larger Acheulian artifacts (hand axes) when compared to the surface collection affected by deflation. The wind removed the sandy matrix and left the larger artifacts in lag position mantling the remnant of a fossil groundwater pond.

The deposits with Acheulian artifacts are overlain by carbonates deposited in a groundwater-fed pond. The carbonate reflects a change in local surficial processes that can be linked to a wetter climate. The carbonate protected the underlying sediments from erosion, whereas along the margins of the basin, where there was no protective carbonate, wind could easily erode the sandy deposits. The surficial processes that occurred after the deposition of the artifacts affect the interpretation of Palaeolithic hominid behaviour; the presence of higher proportions of smaller artifacts in the undeflated deposits implies that hand axes were being used and resharpened at the site and also suggests that these Acheulian artifacts are in primary context.

The sedimentary sequences associated with the Middle Palaeolithic at Bir Tarfawi contain evidence for multiple pluvial-arid cycles, as well as in situ artifact assemblages. They provide information relevant to understanding changing landscape conditions, as well as the surficial processes that have influenced the pattern of the Middle Palaeolithic artifactual record. These deposits are the products of discrete events (for instance site or intra-site spatial distributions of artifacts or depositional episodes), as well as broader-scale temporal patterns (such as diachronic variation in artifactual assemblages or climatic fluctuations).

The spatial and size fraction analyses of artifacts and associated sediments provide data useful in evaluating site formation events associated with both hominid behaviour and surficial processes that contribute to the archaeological record. For instance, understanding the surficial processes that have affected a Typical Mousterian site at Bir Tarfawi, designated as E-87-3, is critical for interpreting the landscape context and the spatial patterning of artifacts (Hill 1993c, 2001d). Figure 2-3 shows the lithostratigraphy of the site. The Mousterian artifacts were recovered in clastic-dominated strata on a surface composed of sandy mudstone plates, underlying sandy muds. The landscape at the time hominids deposited the artifacts appears to have been the surface of a pan or seasonally-dry lake. Limestones below the artifact-bearing clastic deposits have uranium-series ages of around 172 000-118 000 years ago (Table 2-1). The carbonates imply that the basin contained a larger more permanent lake before the hominids were present. As with the Acheulian localities, the stratigraphy and geochronology of this Mousterian (Middle Palaeolithic) site indicates the presence of pluvial conditions in the Sahara during the Pleistocene. Because of the large standard deviation associated with the ages of the deposits (Table 2-1), it is difficult to directly relate the patterns of landscape evolution reflected by this sequence with global stable isotope climate records.

Besides information on the landscape, the surficial processes thought to have been active at the site provide two alternative interpretations of the events leading to the spatial distribution of the Mousterian artifacts (Figure 2-4). The spatial patterning could be the result solely of the original hominid behaviour, or the combined result of human activity and geological site-formational processes. Evidence supporting these alternatives includes the arrangement and size of the artifacts and the sedimentologic context. Statistical analyses by Hietala and Applegate (1993) led to the conclusion that the artifact distribution was not altered by post-depositional events. However, the size fractions of the sediments (medium and fine sands and muds) indicate a medium-to-low energy environment for transportation and deposition that could be connected with local rainfall or fluctuating groundwater levels. Some clustering of the artifacts may have been caused by a short, intense episode of flooding at the end of a dry season leading to the movement and redeposition of smaller artifacts (Figure 2-4). In this instance it may not be possible to determine whether the spatial distribution of artifacts reflects both human activity, as well as post-depositional movement, but only that the geological context suggests the possibility of re-arrangement of the original pattern formed by hominid behaviour.

The examination of surficial processes at a nearby Middle Palaeolithic site, designated as E-87-2, also provides information on both landscape evolution and the interpretation of spatial patterning of artifacts. The site contained an artifact assemblage composed of over 50 000 stone artifacts (mostly debitage), within sandy deposits (Hill 1993b). Uranium series ages range from 302 000-195 000 years ago, with the sample with the smallest standard deviation having an age of about 220 000 years ago (Table 2-1).

The surficial processes active at this site can be inferred from the spatial patterning of artifacts and the character of the sediments. The artifact assemblage was recovered from within sands that are interpreted to reflect the beach and shore facies of a shallow lake (Figure 2-5). The spatial patterns of different artifact size-sets can be interpreted by relating them to potential surficial processes connected to transport and depositional facies within the basin (Morton 2004). The distribution of artifacts appeared to indicate some size-sorting (Figure 2-6). The larger, heavier artifacts do not seem to have been moved very far from their point of initial deposition, while the smaller, lighter artifacts appear to have been eroded and redeposited in a position slightly closer to the centre of the basin. The spatial patterning of artifacts could be the result of the original hominid behaviour along the edge of a lake combined with shore processes that preferentially moved the smaller artifacts (Figure 2-6).

The lithostratigraphy of sedimentary sequences containing Middle Palaeolithic artifacts also provides information pertaining to broader-scale processes linked to landscape evolution in northeast Africa. A stratigraphic sequence associated with Middle Palaeolithic assemblages from the north area of Bir Tarfawi provides an example (Figure 2-7). Uranium-series ages on ostrich eggshell ranging from 137 000-122 000 years ago suggest that the sequence at least partially reflects pluvial climate conditions that can be correlated with the transition to or the early part of the Last Interglacial in the global isotope records (Table 2-1).

The variation in lateral sedimentary facies provides information related to depositional environments at the time of the Middle Palaeolithic presence. For example, it is possible to correlate beach and shore margin deposits dominated by coarse clastics (sands) at one stratigraphic section with deeper water deposits characterised by high amounts of carbonate (marls) and muds (silts and clays) at another section (Figure 2-7). Vertical variations in lithology, in contrast, provide information on changing depositional conditions and thus variation in surficial processes over time at a specific locality. For instance, a lithostratigraphic sequence consisting of coarse clastics overlain by carbonates and muds suggests a transgressive lake event, associated with rising groundwater or increased local effective moisture. A change from strata containing high amounts of carbonates and muds to overlying deposits chiefly composed of coarser clastics could imply a regression event, connected with reduced moisture levels and increased local aridity. Thus lithofacies changes within sedimentary successions can provide synchronic information on environmental settings as well as diachronic information relevant to landscape evolution.

Surficial Processes and Sedimentary Sequences in the Nile Valley

A framework for evaluating landscape evolution in part of the Nile Valley can be developed by examining the record of Late Pleistocene surficial processes at Wadi Kubbaniya. The stratigraphic succession consists mainly of Late Pleistocene sediments containing Middle and Late Palaeolithic artifact assemblages. In the case of Wadi Kubbaniya, Pleistocene landscape evolution appears to be the result of sedimentological events instigated by local environmental conditions (wadi and aeolian activity and pedogenesis) and processes connected to the Nile River (fluvial deposition resulting from climatic conditions in the upper sections of the Nile basin) (Figure 2-2) (Hill 1989).

The petrographic properties of sediments, along with vertical and lateral stratigraphic variation, from Wadi Kubbaniya were used to document and compare sediments associated with Acheulian, Middle Palaeolithic, and Late Palaeolithic artifacts in the Nile Valley (Hill and Schild 1986; Hill 1989). The presence of Acheulian and Middle Palaeolithic artifacts in the Nile Valley deposits is used to infer that these deposits date to the Middle or early Late Pleistocene. Sedimentary deposits with Middle Palaeolithic artifacts are older than about 40 000 BP, while younger Pleistocene deposits are associated with Late Palaeolithic artifacts (Bluszcz and Pazdur 1989; Haas 1989). Detailed petrographic studies of the Wadi Kubbaniya sediments illustrate two of the most useful applications of geoarchaeological methods: the description of lithostratigraphic units, and the interpretation of surficial processes and palaeoenvironmental contexts associated with prehistoric humans.

The textural and compositional characteristics used to study the Nile Valley sediments included particle size, clay mineralogy, organic content and carbonate content (Hill and Schild 1986; Hill 1989). Based on sediment particle size analyses, there are two groups of deposits at Wadi Kubbaniya. One group is characterised by the presence of larger-sized sedimentary particles. It likely reflects surficial processes assocated with wadi wash, sand sheet, and sand dunes. Another group, dominated by silts and clays, seems to be the result of Nilotic river and lake depositional environments. Clay mineralogy also provided clues to environmental change. For instance, vertisols at Wadi Kubbaniya contain higher amounts of secondary chlorite. The relative amounts of organics and carbonates were also used to interpret environmental conditions associated with the Palaeolithic in the Nile Valley. Sediments associated with floodplain environments, for example, can have higher carbonate values, as can pond and lacustrine deposits. Sand-dominated units generally do not have high organic or carbonate values, unless affected by post-depositional soil-forming processes. The Late Pleistocene stratigraphic sequences at Wadi Kubbaniya are the product of various types of depositional contexts that reflect the development of the local landscape and the role it sometimes played in influencing Middle and Late Palaeolithic prehistoric humans. In this instance, artifact assemblages typically are associated with aeolian sands that interfinger with Nilotic silts, apparently demonstrating that Palaeolithic humans were actively utilising landscapes that were episodically flooded by fluvial processes.

Late Pleistocene Contexts from North America

Introduction

The Pleistocene landforms and stratigraphy of North America, like the landscapes of the Sahara and Nile Valley, are the products of episodic changes in local and regional environmental conditions. Some of these changes can be linked to global-scale glacial/interglacial climates. In North America, an interdisciplinary approach has also been used to address a diverse array of archaeological issues such as developing geoarchaeological models used to predict the location of Pleistocene archaeological sites, documenting landscape evolution and past physical environments, and evaluating site formation and taphonomic contexts. In the western interior region of the Rocky Mountains and Great Plains the last climate cycle from non-glacial to full glacial and back to non-glacial conditions resulted in dramatic changes in landscapes and biotic habitats.

The oldest clearly defined artifact types in North America are Clovis and Folsom fluted points (Holliday 2000). Human populations using Clovis artifacts existed as part of a Rancholabrean biota that included mammoth (*Mammuthus*), while Folsom artifacts have been recovered with extinct forms of bison (*Bison antiquus*). Plano-type (non-fluted) point forms are generally assigned to latest Glacial and post-Glacial palaeoenvironmental contexts. Age relationships between regional geological events and artifact assemblages have been determined using radiocarbon measurements and/or stratigraphic relationships. For example, the averages from Great Plains Clovis sites range from about 11 600-10 800 BP (all ages in this paper are uncalibrated). Based on this age range, Clovis can therefore be partly correlated with the last part of the late Glacial Interstadial and the beginning of the Younger Dryas reflected in the global isotope record. Sedimentary sequences for the southern margin of the Laurentide ice sheet in the Upper Missouri basin and on the Southern High Plains provide data relevant to understanding the environmental conditions from before the Last Glacial Maximum (the Middle Wisconsinan non-glacial) to the end of the Pleistocene (the Younger Dryas-Preboreal boundary).

Surficial Processes and Sedimentary Sequences on the Great Plains and Rocky Mountains

The character of the Late Pleistocene Laurentide southwestern margin is considered here in relation to the eastern margin of the Cordilleran ice sheet and the availability of landscapes along the eastern front of the Rocky Mountains and on the Great Plains for migration and habitation. An examination of landscape dynamics along the eastern front of the Rocky Mountains and Late Pleistocene environmental conditions on the Great Plains can be undertaken by developing a time-space framework based on stratigraphic sequences and related landforms (Hill 2006).

Some evidence suggests that the southern position for the Laurentide continental ice was at the Lethbridge moraine in southwest Alberta, within the Saskatchewan River drainage, while other evidence indicates a more southerly limit along the Missouri River in northern Montana (Fullerton et al. 2004a, 2004b). The difference is significant in terms of the presence of available land for biotic communities and the timing of glaciation. A more southerly ice margin advance to about the present-day location of the Missouri River appears to be supported by Late Wisconsin luminescence ages on lake deposits above and below Laurentide till within the Missouri drainage near Great Falls, Montana (Hill and Feathers

2002). The advance and melting of the Laurentide glacier resulted in changes in the Saskatchewan and Missouri River drainages; proglacial (ice-marginal) lakes that developed along the margin help to constrain the deglaciation chronology of the region.

The Missouri River drainage contains evidence of interaction between mountain and continental glaciers and other areas where the space between them was always ice-free. In Montana, lakes formed between the mountain valley glaciers and the Laurentide continental ice margin. The pattern of ice retreat along the southwest margin of the Laurentide Ice Sheet is useful for understanding the availability of inhabitable post-glacial landscapes. Glacial Lake Great Falls was formed when the Laurentide Ice Sheet blocked the drainage of the Missouri River (Montagne 1972; Hill and Valppu 1997; Hill 2000; Hill and Feathers 2002; Feathers and Hill 2003; Reynolds and Brandt 2005). Lacustrine silts and overlying sands adjacent to Holter Lake indicate the youngest stage of Glacial Lake Great Falls has an age of around 17 000-13 000 OSL BP indicating that the ice extended to and blocked the Missouri River during the last part of the Pleistocene (Figure 2-8) (Hill and Feathers 2002; Feathers and Hill 2003).

Vertebrate remains provide information on Middle and Late Wisconsin landscapes close to the glacial margins (Hill 2001a, 2001b, 2006) (Figure 2-8). The stratigraphy along Indian Creek in the Elkhorn Mountains contains both the late Pleistocene Glacier Peak and middle Holocene Mount Mazama tephras, along with faunal remains and a series of artifact assemblages (Albanese and Frison 1995). The nearby MacHaffie site contains a Folsom artifact component associated with a bone collagen age on bison of 10 390 BP (Table 2-1) (Davis et al. 2002). The uppermost deposits at Blacktail Cave contained large mammal remains dated from 11 240-10 270 BP (Hill 2001a). In the Sun River area near Augusta, along the eastern front of the Rocky Mountains, mammoth fossils were found embedded in organic-rich (swamp and paludal) deposits dated to about 11 500 BP (Marsters et al. 1969). The sediments containing the mammoth fossils were deposited after the melting of the Sun River lobe alpine-valley glacier and are buried by alluvial deposits that contain the Mazama tephra. In the Marias River Valley the late Quaternary stratigraphic record includes two tephras correlated with the Glacier Peak and Mazama, at the Elwell section. Deposits between the two tephras contain palaeosols. A fragment of mammal bone with an age of 11 170 BP recovered near the oldest tephra and above Laurentide till helps to constrain erosional and depositional processes connected with the Late Pleistocene landscape evolution of this region (Hill 2002a, 2006).

Physiographic features and stratigraphic sequences in the lower Yellowstone River basin also provide information on late Pleistocene surficial processes and landscape evolution. Surficial processes include intervals of aeolian deposition and periods of increased landscape stability resulting in the development of soils. Some pedogenic (soil-forming) features consist of secondary carbonates (possibly associated with arid climates), while other palaeosols are characterised by well-developed A horizons (potentially the result of wetter or cooler climates). Two late Quaternary stratigraphic sequences illustrate this pattern.

The South Fork of Deer Creek flows into the Yellowstone Valley from the north. Upland silts overlie bedrock and contain buried A horizons and secondary carbonates. The silts contain the remains of a mammoth (*Mammuthus columbi*). Radiocarbon ages from this mammoth indicate the silts were deposited around 12 330 to 11 500 BP, followed by the soil-forming episodes (Table 2-1) (Hill and Davis 1998; Hill 2003, 2006). The deposits provide information relating to landscapes that were contemporary with human groups using Clovis. Fossil pollen recovered from the silts demonstrates the presence of both arboreal and nonarboreal vegetation (Huber and Hill 2003). The pollen assemblage contains *Pinus*, *Betula*, and *Salix* and open-ground herbaceous plants. This may mean that the mammoth habitat in this region at about the time when Clovis artifacts were used was an open coniferous/deciduous parkland. This landscape could have been a northern variant of gallery woodland and parkland or savannah landscapes that have been proposed to have been present in the Southern High Plains during the Late Pleistocene (Hill and Wendorf 1998), or it may reflect landscape contexts similar to the Southern Rocky Mountains at about 10 200 BP where conifer stands may have been separated by steppe (Mayer et al. 2005).

The sequence can be interpreted in terms of prevailing surficial processes and the dynamics of landscape evolution. The mammoth-bearing silts seem to be aeolian deposits; these can be correlated with the Aggie Brown Member of the Oahe Formation (Hill 2003). The overlying palaeosols reflect intervals of landscape stability. Elsewhere, these have been related to moist-cool late Pleistocene and early Holocene climates, and increasingly arid middle Holocene (“Altithermal”) conditions (Karlstrom 2005; Mayer et al. 2005; Rawling et al. 2003; Waters 2000). Palaeosols that formed under moist-cool climates may be the local equivalent of the regional Leonard Palaeosol and Brady buried soil (Albanese and Frison 1995). These are stratigraphic contexts that preserve the landscapes associated with a Late Pleistocene human presence.

Stratigraphic sequences south of the Yellowstone River also contain aeolian silts and palaeosols (Figures 2-8 and 2-9). Buried A horizons developed within aeolian silts at OTL (Oscar T. Lewis) Ridge, south of Glendive, Montana, and have radiocarbon ages of 11 415 to 9 330 BP (Table 2-1) (Hill 2003, 2006). The stratigraphic sequence indicates intervals of aeolian deposition interrupted by episodic intervals of increased pedogenesis linked to landscape stability (e.g. Waters 2000). The radiocarbon ages from materials within the palaeosols are approximately contemporaneous with data suggesting climate conditions wetter than present elsewhere in the western interior of North America (e.g. Karlstrom 2005). The OTL upland lithostratigraphic sequences can also be correlated with the Aggie Brown Member of the Oahe Formation and other regional late Pleistocene-early Holocene deposits that are contemporary with Clovis and Folsom artifacts.

In contrast to the Yellowstone basin sections which reflect Late Pleistocene upland contexts, surficial processes have been examined in valley fill stratigraphic sequences in the Southern High Plains. This region has been extensively studied using geoarchaeological approaches (Haynes 1975; Holliday 1995). At Blackwater Draw and Mustang Draw (Figure 2-10), for example, stratigraphic sequences reflect landscape conditions contemporaneous with Clovis and Folsom archaeological occurrences and can be correlated with broader-scale climate change (Hill and Meltzer 1986, 1987; Hill and Wendorf 1998). At Blackwater Draw, between Portales and Clovis, New Mexico, stratigraphic sequences contain Clovis and Folsom artifacts and fossils of extinct Rancholabrean fauna. One locality, the Barrow Pit section, contains a late Quaternary sequence (Haynes 1975). Two radiocarbon ages indicate the oldest deposits date to the late Pleistocene (Table 2-1). Mudstones (silts and clays) dated to about 15 770 BP seem to reflect the presence of episodic transgressions and regressions in a lacustrine environment. These conditions appear to have prevailed after the Last Glacial Maximum during a wet climate interval designated as the Tahokia pluvial. The mudstones are overlain by calcareous sandy silts dated to about 10 600 BP (Table 2-1). These silts may correlate locally with diatomites associated with Folsom artifacts. They may reflect regional landscape contexts that can be correlated with the Younger Dryas. Pollen data from the Barrow Pit section have been interpreted as indicating a mosaic vegetative landscape with spruce-pine parkland and grassland savannas (Hill and Wendorf 1998). A somewhat similar landscape consisting of steppe separated by conifer stands has been dated to the end of the Younger Dryas (10 200 BP) in the Southern Rocky Mountains (Mayer et al. 2005).

Mustang Draw, north of Midland, Texas, also contains a late Quaternary stratigraphic record that provides information on the types of surficial processes and landscapes on the Great Plains (Hill and Meltzer 1986, 1987). The lowest deposits at one locality consist of calcareous sandy gravels (zone 1) (Figures 2-10 to 2-12). A silty sand (zone 2) overlies the gravel. These sediments may represent surficial processes associated with spring and fluvial activity within the draw. Lacustrine deposits (zones 3 a-g), dating from about 10 130 to younger than 8 260 BP (Table 2-1), seem to indicate a shift associated with the end of the Younger Dryas and the early part of the Holocene. There is substantial facies variation within this set of lacustrine deposits. There are sediments dominated by clastics (silts and clays), as well as cienaga and diatomaceous sediments. Thus valley fill in Mustang Draw suggests surficial processes shifted from fluvial activity to lacustrine deposition close to the end of the Pleistocene.

Conclusion

Studies of stratigraphic sequences provide a means to examine surficial processes linked to archaeological site formation and local environmental contexts and also provide information relevant to landscape evolution and climate change. In Egyptian northeast Africa, the adaptive patterns of hominids that made and used Palaeolithic artifacts can be more fully understood through the study of erosional and depositional surficial processes. This same type of approach is also crucial in attempts to expand and test our understanding of the connections between physical and biological environments in western North America during the Late Pleistocene. Evaluation of the stratigraphic record provides a means of understanding site context and formation processes, as well as the connections between landscape evolution and climate on the human time-scale.

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