This chapter explores how the stratigraphic and sedimentary context of archaeological debris affects the practice of landscape archaeology. Only a fraction of the archaeological record consists of material remains that accumulated on (or close to) the surface of the modern landscape. Material remains from the remote past are preserved only because they were covered over by sediments, and those sediments usually represent fragments of ancient landscapes that bear little or no relationship to the topographic features or habitats that can be observed in an area today. For this reason, documenting and interpreting the geological context of material remains are fundamental to the practice of landscape archaeology, whatever interpretive approaches are employed to explicate the distribution, density, and characteristics of those remains.

Stratigraphy, or the order and arrangement of strata, provides the basic framework for identifying sets of material remains and sediments that were deposited during the same time intervals. Geochronology provides the age determinations for individual beds within a stratigraphic sequence (see Roberts and Jacobs, this volume); thus, it is the springboard for estimating not only the age of the remains being studied but also how much time it took for those material remains and their encasing sediments to accumulate. Facies analysis, which involves the identification and interpretation of distinctive bodies of sediment within a particular stratigraphic interval, is the basis on which the ancient landscape itself is described. Some idea of the habitats supported by that palaeolandscape may be gleaned from the geochemistry of the sediments themselves, as well as from the array of micro- and macro-fossils they contain (see Denham, this volume; Dolby, this volume; Porch, this volume; Rowe and Kershaw, this volume).

Over the past three decades, archaeologists have been coming to grips with the interpretative consequences of recognizing that the palaeolandsapes they study are a complex interplay between the physical features of a landscape and people’s perceptions of them. Not so widely acknowledged are the interpretative consequences of recognizing that the distribution of activity traces results from a complex interplay between the processes of net sediment accumulation and the activities that generated durable material remains (see also Heilen et al., this volume). Material remains and their encasing sediments accumulated through the operation of different processes, and they did not necessarily accumulate at the same rate or over the same time intervals. The interplay between the two exerts a strong influence on the empirical structure of the data being studied and the categories of behavioral information that may be generated from a regional
archaeological record (see Head, this volume for a discussion of such issues in relation to investigative scale). For this reason, understanding the way in which archaeological debris and sediments accumulated and the way in which palaeolandscape features are reconstructed is fundamental to the practice of landscape archaeology.

This chapter illustrates the role stratigraphic relationships and sedimentary context play in reconstructing palaeolandscapes at two contrasting scales, drawing on examples from the Shungura, Nachukui, and Koobi Fora Formations, Plio-Pleistocene geological formations that outcrop along the northern, western, and eastern shores of modern Lake Turkana in southern Ethiopia and northern Kenya (Figure 36.1). These formations are well known to archaeologists because of the extraordinary abundance of early hominin remains and activity traces they preserve. Together, they represent more than 700 meters of mostly fluvial and lacustrine sediments laid down between > 4.3 and 0.74 million years ago by different components of the same depositional regime, in a single, large depression formed through uplift of the Kenyan and Ethiopian domes. Archaeological remains appear in the record from about 2.4–2.3 million years ago and occur in varying abundance in different parts of the basin at different times (Howell, Haesaerts, and de Heinzelin 1987; Isaac 1997; Kibunjia et al. 1992). The two case studies presented here illustrate some of the critical interpretative issues involved in palaeolandscape reconstruction. More detailed information about how to describe and interpret stratigraphic sequences and the landforms they represent can be gleaned from both geology and geoarchaeology texts (e.g., Goldberg and McPhail 2006; Miall 2000; Reading 1996).

### Which Strata? What Scale the Palaeolandscape?

How the boundaries of a palaeolandscape study are delineated depends on the questions driving the research and the characteristics of the sedimentary sequence under investigation. Obviously, palaeolandscapes can be reconstructed at different scales of spatial and temporal resolution, but there is an inverse relationship between the two. Broader stratigraphic intervals sample larger portions of an ancient landscape, but they also represent longer time spans. Vertically discrete stratigraphic horizons may represent relatively fine time lines, but only rarely can they be traced any distance and consequently they sample only a part the spatial and temporal discontinuities in net sediment accumulation, the more marked the trade-off between the spatial and temporal dimensions of the palaeolandscape.

There is also an inverse relationship between the quantities of archaeological debris that accumulated on a landscape and the amount of time represented by the sediments encasing the archaeological debris. Beds that accumulated rapidly (such as air-fall or water-lain ashes) rarely formed the surface for long enough to accumulate any quantity of archaeological debris (e.g., Isaac 1997: 33–41). Soil horizons representing prolonged periods of landscape stability may accrue more debris but often represent a single landform. Stratigraphic intervals representing gradual and/or intermittent sediment accumulation across a larger area will preserve greater quantities of mater...
Figure 36.2 Map showing the distribution of four members of the Koobi Fora Formation, where two different palaeolandscape studies have been undertaken (the distribution of geological units is modified from Isaac 1997: fig. 15). The FxJj20-37 palaeolandscape is based on a 2.2-km section of outcrops representing a variety of channel systems and abutting, but unrelated, bank and floodplain settings. The minimum archaeological stratigraphic interval that could be traced out across this distance is up to 9 m thick and represents a time span of approximately 70,000 years (Stern 1993). The outcrops making up FxJj43 can be traced out for only 500 meters, but they represent a related set of palaeotopographic features (a channel, its southern bank, levee, and adjacent floodplain) and archaeology-bearing strata that
settings. However, those archaeological traces are derived from a three-dimensional wedge of sediments that may have built up over thousands or tens of thousands of years (e.g., Stern 1993).

Although it is possible to identify discrete archaeological occurrences that arguably represent single events—such as the knapping of water-worn cobble(s)—the contemporaneity of any two such occurrences can be determined only by the amount of time it took to accumulate the sediments within which they are sandwiched (Stern 1993, 1994). Thus, to sample the debris that accumulated on a palaeolandscape, the material traces of many different activities and events must be aggregated, and in most Pleistocene sequences there is no way of establishing the precise temporal relationships of any two, geographically separated occurrences.

In response to the initial characterization of palaeolandscape, samples as agglomerations of debris accumulated over thousands or tens of thousands of years (e.g., Stern 1993), some researchers sought out those rare archaeology-bearing strata that represent fine time lines. It was believed that a shorter time span of accumulation would result in less overprinting of debris from different activities and thus would be more amenable to interpretation using ethnographic or ecological models (e.g., Conard 1994). However, further consideration of the way in which archaeological debris accumulates on palaeolandscapes suggests that fine time lines actually provide quite inscrutable records, because the probability that they will have captured debris resulting from less frequently occurring activities is low. Although it is obvious that some time had to pass in order to accumulate sufficient quantities of debris on a landscape surface to create an observable archaeological record, it is not clear how much time is required to generate patterns that archaeologists can identify, document, and interpret, and undoubtedly this time span varies from one context to another. However, it is evident that in many circumstances the patterned distributions that become the subject of archaeological investigation would not have been evident to the individuals whose activity traces are being studied.

Ideally, the choice of stratigraphic interval for investigation would involve considered assessment of the likelihood of generating from those sediments the information needed to answer specific research questions. However, because archaeologists are still grappling to identify the categories of behavioral information that can be generated from patterned distributions of debris generated of palaeolandscape samples, in practice these assessments are part of the analytical and interpretative process. As a result, the boundaries of palaeolandscape studies are delineated most often by identifying a stratigraphic interval bounded by distinctive marker horizons that can be traced out across the study area and that contains sufficient quantities of archaeological debris to allow the use of statistical techniques to identify patterned associations. If the marker horizons are datable isochronous units, then it is possible to establish the total time span represented by the stratigraphic interval under investigation. The time span represented by the palaeolandscape provides the basis for developing an interpretative framework commensurable with the resolution of the archaeological data under investigation.

**Basinwide Reconstructions of Regional Palaeogeography**

Basinwide reconstructions of the palaeolandscape involve the application of familiar stratigraphic principles at scales ranging from kilometers to tens or hundreds of kilometers. In the Turkana depression, geographically scattered outcrops accumulated varying thicknesses of sediment over varying time intervals. These scattered sequences have been correlated using widespread volcanic ashes that were ejected during single eruptive events and therefore have distinct geochemical signatures. These ashes have also been used to divide each formation into a series of members and to provide a time frame for each sequence (Brown and Feibel 1986; Harris et al. 1988; de Heinzelin 1983). Only 11 of the 130 chemically distinct ashes that have been identified are found in all three formations (Figure 36.3), although each formation also contains 30–35 ashes that are found in one of the other formations (Brown and McDougall 1993). These correlations identify where sediment was accumulating during specific time intervals, so once the depositional environments represented by those sediments have been established (e.g., Feibel 1988), it is possible to reconstruct the landscape features that existed during that time span (Brown and Feibel 1988; Feibel and Brown 1993). There is, of course, an inherent bias to this landscape sample, which is restricted to low-lying areas that experienced stable, net sediment accumulation during the time period under investigation. This bias is common to most early Pleistocene landscape studies, since only in rare circumstances (such as the blanketing of an entire landscape by air-fall ash) were the more elevated, eroding portions of a landscape
Once the palaeogeographic features that made up the preserved portions of the landscape during specific time intervals have been established, it is then possible to investigate the distribution of archaeological sites in relation to those features. However, two issues need to be considered in such analyses. The first is the scale at which the palaeogeographic features were changing versus the time span of the stratigraphic interval under investigation (e.g., Feibel and Brown 1993: 37). It can be difficult to establish the landscape setting of sites that formed on dynamic landscapes that were changing on a faster time scale than the time span of the stratigraphic interval under investigation. This is because later erosion removes the deposits laid down by preexisting depositional systems, resulting in preservation of unconnected channel bodies may not relate to the bank and floodplain deposits they abut. The second consideration is how the palaeotopographic settings of individual sites can be related to regional palaeogeographic features. Analysis of facies at a scale intermediate between the basinwide studies that are usually the purview of geologists, and the detailed palaeotopographic settings of sites that are usually the purview of archaeologists, may be required.

Rogers, Harris, and Feibel (1994) examined the distribution of activity traces across the Turkana depression for three successive time intervals (2.3 million years ago; 1.9–1.8 mya; 1.6–1.5 mya; Figure 36.4) and observed that debris was discarded more widely, in a greater variety of topographic settings and in greater quantities after 1.6–1.5 million years ago.
Figure 36.4  The distribution of archaeological traces in relation to palaeogeographic features for 3 successive time intervals, based on Brown and Feibel's palaeogeographic reconstructions for the Turkana basin (modified from Rogers et al. 1994: figs. 4–7).
Homo ergaster (ca. 1.9 million years ago), the first truly committed terrestrial biped that also exhibits a number of adaptations for engaging in high activity levels in hot, arid environments (Walker and Leakey 1993) and for endurance running (Bramble and Lieberman 2004). However, there is a much tighter correlation between the more widespread distribution of activity traces and the appearance of the earliest Acheulian artifact assemblages (ca. 1.65 million years ago), suggesting that it would be worth investigating whether the technological change is related to concomitant shifts in foraging strategies and mobility patterns that were part of an adaptive shift.

**Palaeolandscape Reconstruction of Smaller Stratigraphic Intervals.** To acquire the information needed to investigate such problems archaeologists focus on the distribution, density, and characteristics of individual artifacts and fossils found in vertically discrete, laterally continuous sedimentary horizons found in one part of a longer stratigraphic sequence and in one part of a larger sedimentary basin (e.g., Isaac 1981). Because net sediment accumulation in terrestrial depositional
Part V: Characterizing Landscapes

systems tends to be intermittent and localized, and because facies are time-transgressive phenomena, palaeolandscapes are represented most often in the geological record by a three-dimensional wedge of sediments, rather than a single surface or a single sedimentary layer. The "minimum-archaeological-stratigraphic unit" that can be used to reconstruct the palaeolandscape is defined by the two most closely spaced marker horizons that can be identified in the stratigraphic sections scattered across the study area (Stern 1993). Reconstruction of landscape features is facilitated if one or both of those marker horizons is an isochronous depositional unit that cuts across facies boundaries and identifies the location of specific topographic features at a particular moment in time. This is the situation at FxJj43, an Early Stone Age locality in the Okote Member of the Koobi Fora Formation (Figure 36.5) that preserves a well-defined set of palaeotopographic features that accumulated archaeological debris over a relatively short span of time (Stern 2004; Stern et al. 2002).

The Stratigraphic Sequence. FxJj43 is a collection of outcrops bounded by two distinctive and widespread marker horizons that can be traced around the edge of the modern erosion shelf for almost half a kilometer (Figure 36.6). Both are relatively more resistant to erosion than the underlying or overlying sediments, so the wedge of sediments sandwiched between them forms a prominent topographic feature on the modern landscape and provides an obvious boundary for a palaeolandscape study. Up to 8 meters of sands, silts, mud, and ashes representing a number of fluvial depositional settings are sandwiched between the lower marker horizon is a thick bed of volcanic ash whose chemical composition identifies it as one of a series of ashes of similar (though not identical) chemical composition erupted over a 50,000-year time interval from a single source in the Ethiopian highlands. It was deposited originally as an air-fall ash in the Ethiopian highlands and was washed into the Turkana depression by the river systems draining those highlands, where it was redeposited by overbank floods. The upper marker horizon is a thin but laterally extensive bed of calcareous sandstone representing a widespread sand sheet deposited by shallow, shifting braided channel systems. It is not an isochronous unit, but it represents the establishment of a different, depositional regime, and it is readily traced throughout the study area.

The Landscape Features Preserved. Landscape reconstruction began with a series of stratigraphic sections measured at intervals along the outcrops to establish the sequence of beds sandwiched between the marker horizons and to identify a series of distinctive beds that can be used to correlate those sections (Figure 36.7). It also helped to identify sets of beds representing different depositional environments that make up mappable units (Figure 36.6). The three-dimensional geometries of these mappable units, together with their textural characteristics and bedding features, provided the information needed to identify the palaeotopographic settings they represent. Geological trenches were dug to establish those three-dimensional relationships where they were not visible in the exposed outcrops or in existing gully sections. The sequence and three-dimensional
course, a crucial source of information about the depositional history of the outcrops. But additional information about how the deposits were built up can be gleaned from detailed descriptions of the sections exposed in both the geological trenches and the excavations.

The oldest sediments at FxJj43 can be seen in outcrop at either end of the site but in between are visible only in the geological trenches (Figure 36.7). At the eastern edge of the site these are unconsolidated channel sands whose bedding features indicate that they were laid down by a west-erly flowing river, whereas at the western end of the site they are fine-grained floodplain deposits. Both are overlain by a thick bed of ash (up to 2.5 meters thick), known as the “blue” tuff. Detailed sections through the blue tuff show that beds of pure ash preserving distinctive bedding features are intercalated with numerous lenses of sand and silt dumped by successive flood peaks. Like other widespread ashes in the Turkana depression the “blue” tuff is believed to represent a rare, high-magnitude flood event. It would have destroyed

Figure 36.7 Correlated sections for the outcrops at FxJj43, showing the stratigraphic relationships of the main mappable units and the location of the archaeology-bearing horizon, immediately above the blue tuff.

ous pieces of evidence (discussed below) to indicate that an episode of bank erosion followed its deposition.

The blue tuff has a gradational contact with the overlying tuffaceous sandy mudstone, which grades up-section to a calcareous sandy mudstone. Together, these beds record the gradual resumption of normal terrigenous sedimentation, as the channel that had carried the blue tuff gradually cleared itself of the viscous slurry of ash and water and a stable, vegetated floodplain was reestablished. Intermittent overbank floods laid down another 1.7 meter of floodplain sediments before a second episode of volcaniclastic deposition took place, represented by the “grey” tuff (Figure 36.7). It is also overlain by a tuffaceous sandy mudstone that fines up-section as its terrigenous component also increases; again, these beds represent distal floodplain sedimentation. These are overlain by a thin and laterally extensive bed of calcareous sandstone that caps the sequence. It contains lenses of poorly sorted, gravelly, or conglomeratic sands and represents
braid channels that shifted frequently across a low-relief landscape.

This stratigraphic sequence has the advantage of containing an isochronous unit that can be used to establish the relationships that existed between facies at the time of the massive flood event that deposited it (Figure 36.8). Geological trenches dug across the northern edge of the outcrops show that the surface of the blue tuff dips down steeply to the north, indicating that the tuff has draped over a palaeobank. Tuffaceous channel-fill sands are banked up against the steeply sloping surface of the blue tuff palaeobank. Both overlie interfingered, unconsolidated channel sands and consolidated, medium to coarse sands representing the underlying channel-bank. Detailed sections recorded in the geological trenches that cut through the palaeobank and channel-fill deposits reveal numerous episodes of deposition and erosion (Figure 36.9).

The blue tuff palaeobank can be traced along the northern edge of the FxJ143 outcrops and in places actually has a topographic expression on the modern landscape (Figure 36.10). Outcrops, that the blue tuff is thickest at the palaeobank and that it lenses out to the south, where it is sandwiched between calcareous mudstones that are characteristic of vegetated, distal floodplain settings. In these locations, the pumices found in the upper levels of the tuff are significantly smaller than they are in outcrops adjacent to the palaeobank, reflecting lower-energy flow on the distal floodplain (Figure 36.8). The most southerly exposures of the blue tuff approximate the far reach of the floodwaters that deposited it.

In between the northerly and southerly limits of the blue tuff there are few exposures of it, so, where necessary, its position was determined by auger holes. These revealed that approximately 8–12 meters from the edge of the channel the blue tuff forms a levee that is about 7–8 meters wide.

A number of palaeogullies cut across the blue tuff palaeobank (Figures 36.6 and 36.10). They are marked by a sharp boundary between the pure ash layers making up the palaeobank and the brown tuffaceous sands filling the ancient gullies. The palaeogullies vary in width and depth, and some
The northern bank of the sandy channel that was draped by the blue tuff has long since been eroded away; however, some estimate of the width of that channel can be gauged from an isolated outcrop of blue tuff (at the northeastern edge of the site) that has been interpreted as a mid-channel bar. It is elliptical in plan view and is overlain and abutted by a thin bed of calcareous sand, which, in turn, overlies a low bank of well-sorted, unconsolidated medium sands. It lies about 10–15 meters from the southern bank of the palaeo-channel (Figure 36.8).

The Palaeolandscape Context of the Archaeological Debris. The blue tuff provides a wonderful insight into the topographic features that existed at FxJj43 when it was deposited, but its relationship to the archaeological material that accumulated there also has to be established. Excavations and in situ finds in the gully sections and measured geological sections all indicate that the archaeological material is derived from three distinct beds representing different palaeotopographic settings in the same stratigraphic interval. There is a narrow horizon blue tuff; it straddles the tuffaceous sandy mudstone and the lower levels of the overlying calcareous sandy mudstones. The tuffaceous sandy mudstone was deposited as the river gradually cleared itself of ash, while the overlying calcareous sandy mudstone records the resumption of normal terrigenous sedimentation and the eventual establishment of a vegetated floodplain and the mobilization of carbonates through soil-forming processes. The stratigraphic distribution of the archaeological debris indicates that it accumulated only while normal terrigenous sedimentation was being reestablished. Impregnation of the archaeological horizon by carbonates (which helped to preserve the bones) took place after hominins had abandoned the area.

Immediately after the blue tuff draped the landscape, an episode of bank erosion ensued. Evidence for this includes the nick-points on the blue tuff palaeobank (Figure 36.9), the scoured surface of the blue tuff (visible in the excavation floors), the formation of the palaeogullies, and the presence of eroded clods of blue tuff at the interface between the underlying channel sands...
clods of blue tuff are found throughout the channel-fill sequence, indicating that the erosion of the blue tuff palaeolandscape and the infilling of the channel were coeval. Traces of hominin activities are scattered through both the palaeogully- and channel-fill deposits but are not found in any of the overlying floodplain deposits. So, hominins were in the area only while water continued to flow down this channel segment, albeit intermittently.

This suggests that the features of the blue tuff palaeolandscape probably still existed during the period in which the archaeological material accumulated. However, spectacular confirmation of this comes from an excavation that sampled the abundant archaeological debris that accumulated in the sediments overlying the blue tuff palaeobank and levee. The northern edge of the artifact and bone scatter has been truncated through erosion, but its southern edge was buried and remains intact. This scatter of archaeological debris has an abrupt boundary that coincides with the edge of the underlying blue tuff levee (Figure 36.11).

The Age and Time Span of the Archaeological Debris. The age of the blue tuff palaeolandscape has been established from Argon-Argon age determinations (see Roberts and Jacobs, this volume) on this comes from an excavation that sampled the abundant archaeological debris that accumulated in the sediments overlying the blue tuff palaeobank and levee. The northern edge of the artifact and bone scatter has been truncated through erosion, but its southern edge was buried and remains intact. This scatter of archaeological debris has an abrupt boundary that coincides with the edge of the underlying blue tuff levee (Figure 36.11).

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from the top of the ash, 1.468 ± 0.016 mya (Stern et al. 2002). There is no way of actually measuring the time it took for the archaeology-bearing sediments to accumulate, but contemporaneous observations of the time it takes for river systems to resume normal terrigenous sedimentation after a major ash-fall suggest that it may have been decades, whereas stratigraphic scaling sets an upper limit of < 2,000 years. FxJj43 provides archaeologists with a window into a 1.5 million-year-old palaeolandscape and an opportunity to document the activity traces that accumulated on a small portion of the landscape over a limited period of time.

The Implications of Palaeolandscape Context for Site Formation Processes. Not surprisingly, archaeological debris accumulated in different ways and at different rates in different parts of this palaeolandscape (Stern 2004). Small, discrete clusters of debris representing the knapping of a single block of material have been found on the distal floodplain. Isolated artifacts and/or bones are found in both the gully-fill and channel-fill deposits, but although some of those from the channel-fill exhibit surface abrasion and/or have rounded edges, there are also artifacts that show no signs of abrasion and that retain sharp edges. Clearly, some artifacts and bones were transported downstream during periodic channel flow, whereas others were lost or discarded more or less where they were found.

Artifacts and bones from the gully fills are neither abraded nor rounded suggesting that they were not transported any great distance. These isolated finds are most likely to have originated on the adjacent levee, which preserves the most abundant and varied set of activity traces at FxJj43. These include low-density scatters of debris, small, discrete clusters of artifacts and/or bones, and larger, denser agglomerations of both artifacts and bones. The bones recovered so far from one small discrete cluster, and from one larger, denser agglomeration, exhibit a range of weathering stages, suggesting that neither occurrence represents a single event. However, the larger, denser agglomeration does contain both a wider range of artifacts and a wider range of taxa and body parts than the small discrete cluster, which may reflect a longer time span of accumulation.

Thus, an understanding of the depositional contexts of the archaeological debris at FxJj43 provides scope for investigating not only differences in the debris-generating activities undertaken in different parts of the blue tuff palaeolandscape but also differential rates of accumulation and the impact the resulting archaeological assemblages. Together these provide a basis for considered assessment of the behavioral information that can be generated from the different types of assemblages preserved in different settings.

Conclusions

The stratigraphic and depositional context of a related set of archaeological occurrences establishes the landscape settings in which traces of past activities accumulated. However, the geological context of archaeological materials is not simply a neutral backdrop for investigating the context and characteristics of those activity traces. The way in which, and the time span over which, strata and activity traces accumulated structures the scale and resolution of the palaeolandscape sample. Establishing the time span represented by the sediments making up the palaeolandscape is fundamental to any attempt to study the activity traces accumulated on that landscape. In particular, it provides the basis for identifying the categories of behavioral information that can be generated from the archaeological debris preserved in the palaeolandscape under investigation. This, in turn, helps to identify the analytical and interpretative frameworks considered most appropriate to the empirical structure of the record under investigation.

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