Hidden in the sands of time:
geoarchaeology of sandstone landscapes in the Keep River region, Northern Territory, Australia

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Chapter Seven – Connecting the Local and Regional Records

CHAPTER SEVEN

Connecting the Local and Regional Sedimentary and Archaeological Records

The success of geoarchaeological investigation and indeed of archaeological research in general, depends ultimately on open and mutual exchange of information across the artificial boundaries of various disciplines.

-Hassan, 1978: 211.

7.1 Introduction

This chapter brings the geochronological and sedimentary investigations of the escarpments and sand sheets into the context of the local and regional archaeological records. Some of the issues outlined in Chapter Two are revisited, including issues of quantifying, identifying and interpreting change in the archaeological records. Archaeological information for the Keep River region is sourced from published and unpublished research in the areas of archaeobotany, rock-art studies, and archaeological excavation and analysis. The occupation record for the Keep River region is then evaluated in the more regional context of the Kimberley and adjacent Arnhem Land regions. General thesis conclusions and suggestions for further research are presented in Chapter Eight.

7.2 Quantifying Change - Comparison of Chronological Records

Stratigraphic resolution is determined by the temporal spacing between preserved depositional events, and defined within the resolving power of each dating technique. The following section compares the chronological records obtained from in situ cosmogenic dating, luminescence dating and radiocarbon dating in the Keep River region; contributing to a more general discussion of the local and regional geochronology in section 7.6.
Chapter Seven – Connecting the Local and Regional Records

7.2.1 Comparison of in situ Cosmogenic and Luminescence Dating Results

The results from in situ cosmogenic dating, luminescence dating and sediment characterisation can be used to provide an indication of sedimentary processes across the sand sheets from the erosional sources to sediment sinks. The slow denudation (5 mm.ka\(^{-1}\)) of the sandstone escarpments provides the main source of sediment to the adjacent sand sheets, which periodically accrete over a previously exposed palaeosurface. The accumulation of sand over this palaeosurface is temporally and spatially discontiguous with greater accommodation space for sediment accumulation away from the escarpment. Accordingly the age of the sediments near the escarpments and within rock shelters is younger than that further from escarpments. The rate of sediment accumulation is slowest near the low-energy escarpments (< 100 mm.ka\(^{-1}\)) and greater near the high-energy creeks and rivers (> 200 mm.ka\(^{-1}\)) where there are a greater number of sediment sources.

Between the escarpments and the creeks, the sand sheets are in-transit zones for sediment storage. The minimum accumulation rates of the sand sheets are 133 mm.ka\(^{-1}\) at JG1 (based on TL age at 210 cm) and 7 – 10 mm.ka\(^{-1}\) at JG2 (based on TL ages at 390 and 560 cm), which are 5 – 20 times greater than the cosmogenic rate of 5 – 20 mm.ka\(^{-1}\) for the same profiles. Turnover rates by termites in similar sandy terrain has been estimated to be in the order of 20 - 50 mm.ka\(^{-1}\) (Williams, 1968; Holt et al., 1980; Colin et al., 2001), which may amount to 20 – 50 % of apparent accumulation rates. Such mixing will induce significant scatter in both the cosmogenic (refer 4.4.2) and OSL data (refer 6.5.2.1) and will make OSL ages appear too young and the apparent sedimentation rate higher than the actual net rate. Thus some of the inconsistency between the estimated sediment accumulation rate of the sand sheets from luminescence dating and in situ cosmogenic dating may be due to mixing. It is reasonable to expect that the scale of such mixing will be greater over longer-term timescales.

The differences also reflect the chronometric sensitivity of each technique - in situ cosmogenic dating which measures over timescales of 100 ka to 2 Ma is much less sensitive to more disparate
episodes of erosion, transport, deposition and preservation of sediment horizons than luminescence
dating which measures over timescales of 10 ka to 200 ka. However, there is some overlap. If the
regional age-depth curve of luminescence ages (from Fig. 6.23) is extended over longer timescales
using a logarithmic axis (Fig. 7.1), the trend is towards lower accumulation rates. Based on this
figure, Holocene accumulation rates range from 100 - 250 mm.ka\(^{-1}\), for the LGM to Holocene
period, 50 – 100 mm.ka\(^{-1}\), and since the last interglacial (Stage 5), 20 – 50 mm.ka\(^{-1}\). Estimates from
cosmogenic isotope dating are consistent with these trends.

Over human timescales, sedimentation on the sand sheets is likely to be out of equilibrium with
both these longer term estimates. In the Selima sand sheets, Egypt, stratigraphic, archaeological
and radiometric dating of materials indicated a dynamic equilibrium over timescales of only tens of
years, with sediment supply matched by transport across the sand sheet, contrasting with slow
vertical accretion over timescales of hundreds to thousands of years (Maxwell and Haynes, 2001).
It is clear that in the Keep River region there must also be some disequilibrium of longer and shorter
term dynamics otherwise the bedrock would eventually be buried by the faster accumulating sand.
sheets (refer 4.6). Essentially in situ cosmogenic dating is used to provide a geomorphological story. The remainder of this chapter considers the archaeological record from timescales provided only by luminescence and radiocarbon dating.

7.2.2 Comparison of Radiocarbon and Luminescence Dating Results

Direct comparison of age estimates from radiocarbon dating with those from TL and OSL dating (Table 7.1) indicate a correspondence between 6 of the 12 samples. With the exception of Spit 17 in the Karl-3 excavation (Table 7.1), there is a good correspondence between radiocarbon ages and luminescence ages in the first metre of both the Goorurarmum and Karlinga sand sheet deposits. The correspondence between radiocarbon and luminescence ages to this depth in these sand sheets attests to the minimal disturbance and general homogeneity of the organic and inorganic material being dated. The major discrepancies occur between luminescence and carbon samples from the Karlinga rock shelter (Karl-1) and from the Karlinga sand sheet (Karl-3). The results for OZG337 and OZG338 derive from NaOH soluble extracts of charcoal, and should be reliable (Head, pers. comm., 2003). Some inconsistency is not unexpected for the two radiocarbon results OZG339 and OZG240 (Table 7.1), which derive from fine grained organic material and may be more mobile in the sediment profile (Head, pers. comm., 2003). Nor is it unexpected for there to be a poor correlation between OSL and radiocarbon ages in either of the rock-shelters, where the OSL age is extrapolated from only a single OSL estimate (particularly for Karl-1 where the OSL is considered to be unreliable). The only inexplicable radiocarbon age is that from Spit 17 in the Karl-3 excavation ($^{14}$C 0.7 ± 0.09 ka c.f. OSL 2.5 ± 0.12 ka), which may simply reflect local contamination by young charcoal.
Table 7.1 Comparison of radiocarbon dating results with measured and extrapolated luminescence age estimates for equivalent depths in the rock shelter and adjacent sand sheets at Goorurarmum and Karlinga. Extrapolated luminescence ages are essentially estimated from a line drawn through dated samples of known depth in the same sequence back to the origin. Samples with a ‘Wk.’ lab code comprise < 125 µm material, whereas samples with an ‘OZ’ lab code comprise finer grained or degraded carbon material.

<table>
<thead>
<tr>
<th>Sample Name</th>
<th>Depth (cm)</th>
<th>Laboratory Code</th>
<th>δ¹³C</th>
<th>Age (Cal BP)</th>
<th>Measured OSL Age (BP)</th>
<th>Extrapolated TL/OSL Age (BP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goor 1 – Spit 4</td>
<td>16</td>
<td>Wk 10779</td>
<td>-25.5 ± 0.2</td>
<td>Modern</td>
<td>-</td>
<td>200 ± 10</td>
</tr>
<tr>
<td>Goor 1 – Spit 21</td>
<td>100</td>
<td>Wk 10780</td>
<td>-25.8 ± 0.2</td>
<td>2536 ± 105</td>
<td>2530 ± 70</td>
<td>-</td>
</tr>
<tr>
<td>Goor 1 – Spit 21</td>
<td>100</td>
<td>OZG337</td>
<td>2780 ± 40</td>
<td>2530 ± 70</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Goor 1 – Spit 35</td>
<td>175</td>
<td>OZG339</td>
<td>3680 ± 50</td>
<td>5200 ± 80</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Goor 2 – Spit 3</td>
<td>7</td>
<td>Wk 10781</td>
<td>-25.6 ± 0.2</td>
<td>Modern</td>
<td>-</td>
<td>185 ± 10</td>
</tr>
<tr>
<td>Goor 2 – Spit 11</td>
<td>27</td>
<td>Wk 10782</td>
<td>-23.4 ± 0.2</td>
<td>286 ± 71</td>
<td>-</td>
<td>720 ± 40</td>
</tr>
<tr>
<td>Karl 1 – Spit 3</td>
<td>6</td>
<td>Wk 10783</td>
<td>-26.3 ± 0.2</td>
<td>484 ± 45</td>
<td>-</td>
<td>5600 ± 300</td>
</tr>
<tr>
<td>Karl 1 – Spit 12</td>
<td>39</td>
<td>Wk 10784</td>
<td>-25.8 ± 0.2</td>
<td>917 ± 76</td>
<td>-</td>
<td>36 300 ± 1800</td>
</tr>
<tr>
<td>Karl 1 – Spit 12</td>
<td>39</td>
<td>OZG338</td>
<td>4080 ± 40</td>
<td>-</td>
<td>-</td>
<td>36 300 ± 1800</td>
</tr>
<tr>
<td>Karl 3 – Spit 17</td>
<td>85</td>
<td>Wk 10788</td>
<td>-24.4 ± 0.2</td>
<td>708 ± 57</td>
<td>2500 ± 120</td>
<td>-</td>
</tr>
<tr>
<td>Karl 3 – Spit 20</td>
<td>100</td>
<td>Wk 10789</td>
<td>-24.7 ± 0.2</td>
<td>3619 ± 122</td>
<td>-</td>
<td>3600 ± 180</td>
</tr>
<tr>
<td>Karl 3 – Spit 31</td>
<td>155</td>
<td>OZG340</td>
<td>2810 ± 40</td>
<td>11 400 ± 170</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

The results of all past and present radiocarbon data and luminescence data for occupation deposits over the past 20 ka are shown in Fig. 7.2. It is apparent that, whether calculated from radiocarbon or luminescence dating, most occupation deposits preserved in the Keep River region are Holocene in age. Radiocarbon ages are generally younger for the same depth than luminescence ages, which
may in part reflect the different age range of multiple sediment populations as measured by multiple and single-aliquot luminescence dating.

![Figure 7.2 Comparison of luminescence ages and radiocarbon ages (including Atchison, 2000; Roberts et al., 1998) for archaeological sites in the Keep River region over the past 20 ka. Note, radiocarbon ages do not extend beyond 150 cm.](image)

No radiocarbon ages have been obtained at depths greater than 150 cm (Fig. 7.2) and this most likely reflects \textit{in situ} weathering processes beyond these depths, such as water table changes, rather than any sampling bias (J. Head, pers. comm., 2002). At Nauwalabila, for example, Fifield et al. (2001) observed that beyond this depth radiometric $^{14}$C ages were unreliable, coincident with the appearance of pisoliths, which themselves indicate a previous fluctuating water table. Similarly, in the Jinmium rock-shelter excavation, fruit seeds were noticeably weathered and declined in number with depth indicating that this record was influenced more by preservation factors rather than cultural processes (Atchison et al., in prep.). The implication is that some of the deeper radiocarbon ages in the Keep River region may be less reliable and should be assessed in the context of the
material dated and the sedimentary environment. This does not imply that all radiocarbon ages beyond 150 cm are meaningless, and less so if careful extraction procedures (e.g. Bird et al., 1999; Fifield et al., 2001) are used. However, in occupation sequences deeper than 150 cm where radiocarbon dates appear unreliable or unobtainable, other dating techniques may be required.

7.3 Identifying Change

In contrast to the stratigraphic resolution determined from the duration between preserved depositional events, depositional resolution is determined by the temporal span of physical records preserved within the sediment horizons (Kowalewski and Bambach, 2001). In effect, depositional resolution represents the archaeological record (e.g. artefacts, seeds). The typical temporal range of both types of resolution is comparable over hundreds to thousands of years, but whereas stratigraphic resolution is controlled more by geomorphic and climatic factors and depositional resolution is controlled primarily by temporal mixing though bioturbation and taphonomic processes (Kowalewski and Bambach, 2001). The following is a step towards quantify depositional resolution in the Keep River sand sheets.

7.3.1 Depositional Resolution

The appearance of undisturbed sediments is no guarantee of stratigraphic integrity (Richardson, 1992). The movement of stone artefacts in seemingly cohesive sandy deposits has been estimated to be in the order of 50 - 80 mm in Nauwalabila I (Jones and Johnson, 1985) and up to 30 cm in Kenniff Cave (Richardson, 1992). Hughes and Lampert (1977: 136) indicate that a zone of 20 cm or so that has been affected by deliberate occupational disturbance (e.g. trampling) could easily cover hundreds or thousands of years. Given that well over half the dated archaeological sites in the Kimberley including the Keep River region relate to sandy deposits of a metre or less, these
estimates translate to at least 20 – 30 % of the entire deposit or timespan measured. For Kenniff Cave, this amounted to a temporal resolution no better than 2.5 ka (Richardson, 1992). For deeper sites such as the Karlinga sand sheets, the resolution is probably shorter than 1 ka years, but for shallow sites such as the Karlinga rock shelter, the entire artefact chronology may be questionable. Temporal mixing of hundreds or thousands of years is probably the rule rather than the exception (Kowalewski et al., 1998).

The extent of bioturbation is an important factor on archaeological and chronological interpretations (refer 2.4.2). The introduction of points around 3 ky BP in the Keep River region (Fullagar et al., 1996: 764; Atchison, 2000; Boer-Mah, 2002: 38) represents a useful chronological marker, which if it differs significantly from the chronology (e.g. from radiocarbon or luminescence dating) may indicate the extent of disturbance in the sediment profile. There is no reason to assume that points would appear at exactly the same time at all sites – the temporal differences may well include dating and taphonomic error, but may also include real regional variability. Nevertheless, excepting the Karlinga rock-shelter where there is some doubt the OSL age estimates, the date of introduction of points in the occupation sequences of the sand sheets (Fig. 6.24) and rock-shelters (Fig. 6.28) averaged from luminescence and radiocarbon dating of the sediments is 3.3 ± 0.15 ka. The correspondence between the point and sediment chronology indicates that the degree of disturbance is within the ~ 10 % error of temporal resolution provided by these two measures. For Holocene sedimentation rates around 200 mm.ka⁻¹ this translates to a disturbance rate of about 20 mm.ka⁻¹, which is equivalent to previous estimates of termites reworking (Holt et al., 1980; Colin et al., 2001).

As such, the estimated rate of bioturbation is less than the estimated rate of sand sheet accumulation of 100 – 200 mm.ka⁻¹ from luminescence dating, and is supported by the largely sequential radiocarbon and luminescence chronology shown in the occupation profiles (Chapter Six). Preservation of stratified organic layers in at least one of the creeks studied indicates that
bioturbation may also be reduced in more wet or stagnant environments (5.4.3.2). However, bioturbation may be more significant over horizontal surfaces rather than vertically (e.g. Fanning and Holdaway, 2002), and the possibility that bioturbation does influence some aspects of the archaeological record cannot be discounted.

Other secondary mixing processes may influence the archaeological record. For example, in the Goor-1 sand sheet there is an indication of grain-size sorting through illuviation such that the modal grain size will decrease as finer material is concentrated in deeper horizons (Fig. 7.3). The similar pattern of mean grain size and artefact numbers (2 – 4 mm fraction) with depth in the Goor-1 profile (Fig. 7.3) also indicates that the possibility of some preferential sorting of the archaeological record through secondary mixing processes cannot be entirely overlooked.

Figure 7.3 Profile of mean grain size and artefact (2 – 4 mm) numbers with depth in the Goorurarmum (Goor-1) sand sheet. Both these trends may reflect natural processes.

A more accurate measure of the integrity of the artefact record and the scales over which disturbance processes overlap with it may be better defined from micro- and meso-scale
sedimentary features. Preliminary petrographic and microscopic observations of sedimentary quartz from this study showed more evidence of diagenetic alteration than post-depositional transport (refer Fig. 5.15). Assuming any of the crypto-crystalline quartz grains in the occupational sequences represent cultural material from flaked stones, the presence of iron-rich clay coatings indicates that they have undergone the same diagenetic processes and have probably been buried for the same period as the surrounding grains. The identification of microdebitage in sandy archaeological sites, including the Keep River region, is the subject and expertise of present doctoral research by Susino (in prep.).

7.4 Interpreting Change

7.4.1 Cultural versus Natural Processes - The Stone Tool Record

A major quandary in using abundance estimates of artefact material as evidence of apparent discard rates or of site use, is deciding what unit of measurement to use. From a broad methodological perspective, the production of a few large stone tools may have left little (albeit relatively weighty) debris whereas the adoption of microlithic technology and unifacial and bifacial point manufacture may have increased the number, but not necessarily the weight, of flaked stone pieces. Other percussion techniques, such as quartz bipolar flaking, may produce more flake debitage than point production, depending on the raw materials used (Fullagar, pers. comm., 2003). In addition to these cultural processes, stone artefacts may be broken, burnt and weathered by natural processes that will affect interpretations of assemblage size and composition (Hiscock, 2002). A more careful consideration may be to correlate, where possible, changes in stone artefacts with other artefact material such as ochre, charcoal, bone, and shell, and/or with the total number of occupation sites in an area (e.g. Fullagar et al., 1996). Alternatively, data may be normalised to remove changes in, for example, sediment accumulation (Ward and Larcombe, 2003). Variations in sedimentation rate,
whether due to cultural or natural processes, are an important consideration when evaluating the intensity of site use as a function of the density of artefacts or fauna (Farrand, 2001: 547).

Figure 7.4 shows the rate of artefact accumulation in the Goorurarmum sand sheet excavation (Goor-1), measured both by number and weight, as a function of sedimentation rate. The onset of occupation or artefact accumulation is not specifically defined, and for calculation purposes, the uppermost spit is given a nominal age of 10 years.

![Figure 7.4](image-url)
At 2.5 ky BP the artefact weight indicates a much smaller increase in the rate of artefact accumulation with increasing sedimentation than the artefact numbers (Fig. 7.4). The general increase in both the rate of artefact accumulation and sedimentation may simply reflect high preservation with rapid rates of burial and visa-versa for low rates of burial. Data from the Karlinga sand sheet excavation (Fig. 7.5) shows a similar general correspondence in the rate of artefact accumulation and rate of sedimentation.

Figure 7.5  As for Figure 7.4, for the archaeological excavation site of Karl-3. Note, for clarity, the rate of sedimentation is plotted on a log scale. Numbers refer to the lowest age (ky BP) of each sediment interval. The circled points indicate the large differences where there are low artefact numbers but a high artefact density (e.g. a single core stone).

The onset of occupation or artefact accumulation again is not specifically defined, and the uppermost spit is given a nominal age of 100 years. The rate of change at 2.5 ky BP is calculated from 0.1 ky BP rather than 3.8 ky BP as the latter gives a negative value for both sediment accumulation and artefact accumulation. For the deepest part of the sequence, only the OSL ages of
18 ky BP and 19.4 ky BP are used. The results show a peak in the rate of sedimentation and artefact accumulation around 11.1 ky BP (Fig. 7.5), with weight indicating a significantly higher rate of artefact accumulation than the artefact concentrations. After 11.1 ky BP, the sedimentation and artefact rates fluctuate (Fig. 7.5).

The implication from both excavation records is that high sedimentation rate and high artefact numbers do not necessarily indicate greater discard per unit time, but rather greater preservation per unit time (refer also Farrand, 2001). In other words there is no reason to invoke a cultural explanation for any increase or decrease in the rate of artefact accumulation, because these can be explained readily from sedimentary processes. As pointed out by Hiscock (1984: 133-135), when offering explanations for variability in the archaeological record, post-depositional factors and taphonomic processes, must be considered first before explanations of human behaviour can be considered.

Comparison between these and other sites may begin to reveal patterns in the archaeological and sedimentary record that are indicative of wider landscape processes. For example, in both records the artefact and sediment accumulation rates around 2.5 ka, when the climate is drier, are significantly greater than those earlier around 9 and 6 ka, when wetter monsoonal conditions prevailed (refer 3.5). The low artefact and sediment accumulation rates around 18 ka in the Karlinga sand sheet may be associated with the more arid conditions during the LGM. Local environmental and/or cultural factors may also be important as the correlation of artefact and sediment accumulation rates with climatic conditions is far from absolute.
7.4.2 Rock Shelters - The Rock Art Record

Basal OSL ages for the Goorurarumum rock shelter and adjacent sand sheet excavation are 0.3 ± 0.07 ka and 14.3 ± 0.4 ka respectively. The near-basal OSL ages for the Karlinga rock shelter and more distant sand sheet excavation are 18.4 ± 5.4 ka and 18.0 ± 0.6 ka respectively. An 18 ka age for the Karlinga sediments would imply a considerable hiatus period for these shallow sediments. Hiatuses are not easily recognised in rock shelter and cave sediments and these can give a false impression of continuity (Farrand, 2001). However, the more conservative radiocarbon age of 4.1 ± 0.04 ka (Table 7.1) is favoured for the Karlinga rock shelter as this corresponds better with the presence of stone points just above the radiocarbon sample depth (Fig. 6.28).

From these ages it is apparent the sand sheets preserve a much older record (or time span) than the rock shelters in the Keep River region, demarcating the rock shelters as temporary storage systems for sediments and archaeological material (c.f. Lourandos and David, 1998). In effect ancient sedimentary material is constantly overwhelmed by younger material through natural and cultural processes, and the inefficiency of the rock shelter as a sediment trap (c.f. Fullagar et al., 1996). Often the evolution of stratigraphic sequences is either bedrock controlled or is strongly dependent on the morphology of the floor created by the earliest phase of roof fall (O’Connor et al., 1999). The evolution of stratigraphic sequences on the sand sheets may be similarly controlled by bedrock morphology (refer 4.5.2 and 6.6.2.1).

As a consequence of this differential preservation, younger rock shelter sediments may theoretically be linked with younger rock art, whilst the older sand sheet sediments may be linked with more ancient rock art. Figure 7.6 illustrates possible depositional relationships between the rock art and adjacent sediments, in which previously buried bedrock surfaces, and older surfaces may have been re-exposed by erosion of all or part of any overlying sediments. In Scenario A, the exposed rock art...
may relate to the contemporary sediment horizon (Period 1), or to an unrepresented (eroded) horizon (Periods 2 and 3). In Scenario B, the rock relates to an exposed contemporary horizon (Period 1) or subsequently to a buried horizon (Period 2). Re-exposure of the buried horizon (Period 3) would modify the luminescence age, although representative radiocarbon estimates or artefact material may still provide an accurate age of the rock art.

![Figure 7.6 Possible scenarios for sedimentation and rock-art dating. Horizon ‘w’ represents a sterile surface, over which is deposited an archaeological horizon ‘x’ that is contemporaneous with the rock art surface (x). In scenario A, the archaeological horizon ‘x’ is eroded, re-exposing horizon ‘w’ which is older than the rock art surface. Horizon ‘z’ is subsequently deposited over horizon ‘w’, and is younger than the art surface. Neither surface relates to the age of the rock art. In scenario B, the younger horizon ‘z’ is deposited immediately over horizon ‘x’. Subsequent erosion of horizon ‘z’ would re-expose horizon ‘x’. Luminescence dating of the modified surface (x’) would underestimate the age of the rock art.](image-url)
From AMS $^{14}$C radiocarbon of associated oxalate crusts, the minimum age of the cupules in the Keep River region is mid-Holocene and possibly older than 5.8 ky BP (Watchman et al., 2000). Thus, the cupules were made at or prior to the onset of sand deposition in the rock shelter (Spooner, 1998; Roberts et al., 1998a; 1999; Atchison, 2000). Watchman et al. (2000: 8) speculated that late Pleistocene-early Holocene sediments dating to the time of cupule formation may have been eroded as they have in other parts of the Kimberley (refer 7.4.3 below). However, this hiatus period is not noted in the Keep River region so the cupules could have been made at any time. Thus in the absence of longer sedimentary records in the rock shelters, and until a more accurate age of the rock art is provided, the association of rock art and shelter sediments will remain hypothetical. Samples of rock crusts have been taken from several sites with Bradshaw-style paintings, such as that depicted in Fig. 1.7(a), for such analyses. Given the preservation of occupation sequences of up to 18 ka in the adjacent sand sheets, it is possible that equivalent age sediments to the rock art do exist in the Keep River region. More detailed archaeological studies of the rock shelters in the Keep River are provided by Atchison (2000) and a comparison of rock shelters and open occupation sites is provided by Boer-Mah (2002).

7.4.3 Open Sites – The Climatic Record

The dynamics of the landscape may provide an important palaeoenvironment context for the archaeological record (refer 2.5.3). From geomorphic evidence around Lake Gregory (Fig. 7.9), Wyrwoll and Miller (2001) established that the summer monsoon was not operational from the period of the LGM until about 14 ky BP. If true, it might be expected that sites in the Keep River region older than 14 ky BP should show a corresponding facies change in the sediments (John Head, pers. comm., 2002). However, they do not. Most of the sandy sediments in the Keep River region are petrographically, mineralogically and geochemically uniform (refer Chapter Five) and do not show evidence of palaeoclimatic or palaeoenvironmental changes. This is not so improbable
given the consistent transport processes (runoff, mass transport, sheet flow), low source variability (mostly quartz sandstones), and extreme weathering regime (which preserves only resistant inorganic minerals) of at least the past 100 ka. In addition, secondary mixing processes may obliterate any stratigraphic differentiation which might have been present (Ward and Larcombe, 2003). Vegetation may destroy stratigraphic integrity, and indeed the presence of vegetation is thought to contribute to the sheet-like nature of sand deposits that would otherwise form dunes (Woodroffe et al., 1992).

The geomorphic and chronological evidence from Sandy Creek Gorge indicates that there was a decline in a forest community (e.g. *Melaleuca*, rainforest or vine thicket) around 13 ky BP (OSL age). The degraded indurated horizon at Sandy Creek Gorge may represent a past equivalent of the contemporary association of isolated monsoon rainforest patches with dolomite outcrops (Atchison, 2000) (refer 5.4.3.2). Pollen records from the nearby Flying Fox Springs site, in the Keep River National Park, also indicate the persistence of a vine-thicket community along the surrounding floodplains dominated by *Guettarda* sp. until a few hundred or one thousand years ago, after which *Melaleuca* sp. became dominant (J. Luly, pers. comm., 2000). The Flying Fox swamp itself also indicates a change in vegetation at about 12 ky BP, from fire-infested grassland to pandanas and sedges (J. Luly, pers. comm., 2000). Further west in north Queensland, charcoal collections indicate expansion of Eucalyptus woodlands between 13 and 8 ky BP, with reinvasion of rainforest during the Holocene (Hopkins et al., 1993). These vegetation changes may all be part of more regional trends across northern Australia, which are associated with rising sea-levels (refer Fig. 3.12) and major climatic changes (Torgersen, et al., 1988).

Other major palaeoclimatic and palaeoenvironmental phases in northern Australia include the post-glacial marine transgression from 18 – 6 ky BP, and the concomitant increase in estuarine conditions, including the ‘big swamp’ phase around 8 - 7 ky BP (Woodroffe, 1993), the gradual

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return of the summer monsoon around 7 ky BP (Shulmeister, 1999), and the pluvial maximum and increased freshwater conditions around 4 ky BP (Schulmeister, 1999). It is improbable that there should be a sedimentary expression of all these events in all sites throughout the Keep River region. The facies changes at Sandy Creek Gorge, for example, are not reflected in the sand sheet sediments of the same age anywhere else in the Keep River region probably because the finer grained nature of the Sandy Creek Gorge sediments allow better expression or preservation of the mottled palaeosols (refer 6.4.3.2). For many sandy sites in northern Australia, finding the event ‘signature’ is perhaps more of a forensic exercise.

7.5 Continuity and Discontinuity in the Keep River Region

No site yet excavated in the Kimberley shows a clear continuity of occupation between Pleistocene and Holocene levels (Walsh, 2000: 36). Then again, there is no depositional context in which sedimentation is continuous both through time and across space (Sadler, 1981). Temporal continuity is essentially defined within the stratigraphic and depositional resolution of the sedimentary record (Kowalewski and Bambach, 2001). Whilst in situ cosmogenic dating indicates sedimentation is cumulative over timescales of many hundreds of thousands of years (refer 7.2), luminescence dating indicates continuity over many tens to hundreds of years but from combined rather than individual site records (refer 6.5.5).

It might be argued that the Karl-3 sand sheet excavation does combine Pleistocene and Holocene time periods, but more detailed sampling may reveal more episodic and discontinuous depositional events. The closest sampling interval in this study was 20 cm in the Karl-3 excavation. Given a progressive change in the rate of sedimentation from ~100 mm.ka\(^{-1}\) during the Pleistocene to ~200 mm.ka\(^{-1}\) during the Holocene, the maximum chronological resolution provided from this sampling interval is 1 – 2 ka. Unfortunately when considered over shorter periods, such as only the past 10
ka, the greater scatter in the data means that the chronological resolution is even less definitive. Thus the (analytical) precision of radiometric dating is often unnecessary because time-averaging blurs many short-term events, processes or discontinuities. The shorter term dynamics that exist in the natural and cultural records may only be discerned from high-resolution dating (e.g. Kowalewski, et al., 1998; Otte et al., 2002), but this ideal is generally limited by financial constraints.

The higher frequency sampling and analysis of cultural records potentially provides a more comprehensive indication of short-term and site specific changes, provided the influence of taphonomic processes is acknowledged. For example, in many of the excavation sequences stone artefacts are present to the base of the profile (refer site profiles in Chapter Five), but time-averaged assemblages of these records indicates that sedimentation is intermittent and localised (refer 7.4). Where there are discontinuities in the cultural record, such as the break in seed deposition evident in the Granilpi and Punipunil rock-shelter sequences (Atchison, 2000: 184), these may be bridged from adjacent excavations. Once the temporal and spatial discontinuities within the sedimentary and archaeological evidence can be quantified (and they may not be equivalent), the formation history of the archaeological landscape may then be defined. Atchison (2000) argued that although the archaeobotanical record in the Keep River region is spatially and temporally variable at both a regional and site-specific scale, the landscape retains elements of both continuity and change.

In order to better understand the changes in human use of the landscape it is first necessary to undertake studies aimed at deciphering the diverse formation processes within the context of the depositional environment. If human activity and land-use was concentrated within or at the boundary of any particular facies environment then the record of that land-use may conceivably be temporally continuous, but would be spatially variable. If land-use remains geographically constant regardless of facies change, then the cultural record may be both temporally and spatially
continuous. The former scenario may be typical of riverine or other open environments such as the Keep River region, whereas the latter may be more typical of inland rock-shelter environments. In this context, Barton et al. (2002) argue for a middle-ground approach, which focuses beyond the site but within the geographic range of many human activities. Barton et al. (2002) suggested that a more nomadic existence would be better observed over larger spatial and longer temporal scales, whereas a more sedentary existence would be better observed over local spatial and shorter timescales.

7.6 Placing the Keep River Record into a Regional Perspective

It is evident (assuming the more widely accepted age determinations are valid) that the earliest evidence for occupation is in Arnhem Land (~ 60 ky BP), then in the western Kimberley region (~ 40 ky BP), and finally in the eastern Kimberley region, including the Keep River area. From the period 7 – 6 ky BP, the cultures of Arnhem Land and the Kimberley started to become distinct (Lewis, 1988). In these regions, this period is considered to be one of increasing cultural innovation and ecological change, but the nature and timing of changes in the Kimberley remains unknown (Lewis, 1988). The following attempts to place the occupation record of the Keep River into a more regional context with Arnhem Land and the Kimberley.

7.6.1 Age-depth Curves for the Kimberley and Arnhem Land region

Before interpretations concerning prehistoric human behaviour between regions can be properly addressed, it is important to know whether the archaeological time period being studied is equally preserved within these regions (Waters and Khuen, 1996). In terms of regional representation, there is no clear correlation between age and depth (Fig. 7.7). In parts of western Kimberley (O’Connor, 1995, 1996), occupation sequences are generally older for the same depth than those in Arnhem
Land (Roberts et al., 1990, 1998b), indicating a much slower sediment accumulation rate. In contrast, the higher sediment accumulation rates of the Keep River sand sheets (100 – 200 mm.ka\(^{-1}\)) have generally preserved relatively young and shallow occupation deposits. These regional differences may be an effect of the proximal distance of the coastline, with older (Pleistocene) sequences better preserved inland and at higher topographic levels, and better resolution of recent (Holocene) sedimentation in more lowland coastal sequences.

![Age-depth data for archaeological sites (rock-shelters and sand sheets) in the Kimberley and Arnhem Land regions (data from Atchison, 2000; Balme, 2000; Dortch and Roberts, 1996; Harrison and Frink, 2000; Morwood and Hobbs, 1995; McConnell and O’Connor, 1997; O’Connor, 1996).]

**Figure 7.7**
7.6.2 The Holocene Record and Intensification

Figure 7.8 plots the chronological record for the Keep River against the available ages for other archaeological sites in the Kimberley and nearby Arnhem Land region. The chronological evidence for the Keep River region, including nearby Miruwin (Dortch and Roberts, 1996), indicates probable occupation from the LGM but a significantly greater preservation of Holocene sites. Most archaeological sites excavated in the Keep River and surrounding region have been rock shelter sites, and of these rock-shelter sites, most are Holocene in age with occupation beginning about 4 - 3.5 ka (Fig. 7.8). The chronological results from this study support archaeobotanical evidence of fruit seed processing in the Goorurarmum - Jinmium catchment area from at least 3.5 ky BP (Atchison, 2000), introduction of stone points in the Keep River region around 3 ky BP (Fullagar et al., 1996: 764; Atchison, 2000; Boer-Mah, 2002: 38), and an increase in preserved rock art at from about 4 ky BP (Watchman et al., 2000; Ouzman et al., 2002). In the nearby Wardaman country, there is also an apparent increase in the amount of rock art at about 4 ky BP (Watchman, 2001).

Regionally, this period from 4 - 3.5 ka is generally regarded as one of increased cultural change with alterations in stone artefacts (new types), use of processed plants, regional art styles, and increased occupation of older sites (Hiscock, 1984). Whilst qualitative changes can be observed in the processing of plants (e.g. Atchison, 2000; Atchison et al., in prep.) and reduction of stone tools (Fullagar et al., 1996; Boer-Mah, 2002), it is questionable whether the quantitative changes in the number of archaeological deposits actually indicates increased numbers and more intensive use of sites (Lourandos, 1996), or reflects the preferential preservation of archaeological deposits dated to this period (refer 7.4.1).
Figure 7.8 Dated archaeological sites in the Kimberley and Arnhem Land region (data from Atchison, 2000; Balme, 2000; Dortch and Roberts, 1996; Harrison and Frink, 2000; Morwood and Hobbs, 1995; McConnell and O’Connor, 1997; O’Connor, 1996 and Walsh, 2000 and references therein). All ages are calibrated 14C ages, or are marked by subscript as luminescence age (TL or OSL). Chronological gaps (stippled line) are defined as a cultural hiatus according to the authors, or as a question mark if unknown. The yellow band marks the period (~ 17 to 12 ky BP) where no ages have apparently been registered for northwest Australia (Veth, 1995: 744). The dated introduction of stone points (P) and adzes (A) are marked.
The sediment chronology throughout the Keep River region indicates that open sites are much older than the adjacent rock shelters. However, the apparent ‘intensification’ of late Holocene sites in the Keep River region may be a product of both research and preservation, rather than of cultural change. In terms of research the total number of excavated rock shelter sites (~ 8) is significantly greater than the number of open sites (~ 3), which translates as a greater emphasis on Holocene geomorphic environments. Poor preservation in semi-arid monsoonal climates will also result in a biased record in favour of younger sites, particularly where older records are located within a fluctuating water table zone (refer 7.2.2). Progressively increasing sedimentation rates will also favour preservation of Holocene records (refer 7.4.1). A similar problem exists in North America, with problems in the poor preservation and dating of pre-Clovis sites (Marshall, 2001) and justification of ‘intensification’ of Clovis sites around 4.3 – 3 ka (Dent, 1995).

The implication is that rock shelter sites could have been occupied earlier but the associated sedimentary record was either removed or was never present. The removal of sediments may have occurred during wetter monsoonal periods before (e.g. Nott and Price, 1994) and after (e.g. Wyrwoll and Miller, 2001) the LGM. The absence of sediment deposition may indicate that the sand sheets had to build up to the level of the rock shelters before there was any intrusion into the rock shelters, as demonstrated in Sandy Creek rock shelter, North Queensland (Morwood et al., 1995). In any case, before comparing any cultural trends it is just as important to consider whether archaeological time periods are equally preserved within regions as it is between regions (Waters and Khuen, 1996).
7.4.3 The Pleistocene Record and the east Kimberley Refuge

In the other parts of the Kimberley, including Widgingarri I and II, Koolan 2 (O’Connor, 1996), Carpenter’s Gap (O’Connor, 1995), Mimbi Cave (Balme, 2000) and Drysdale (in Walsh, 2000), the period from ~17 to 12 ky BP is regarded as a cultural hiatus (refer 2.6). It is unclear whether each of the major chronological hiatuses evident in these excavations (Fig. 7.8) actually represent a ‘cultural hiatus’ during which time the site was seldom used and little sediment accumulated, or represent a natural hiatus in which any late Pleistocene-early Holocene sediments were removed by geomorphic processes. There is additional interpretive inconsistency at Carpenter’s Gap which apparently provides evidence for a continuous cultural presence for the past 40 ka (McConnell and O’Connor, 1997; Balme, 2000), but at the same time reveals a disconformity above the LGM levels, which may more not represent a cultural or natural hiatus (Wallis, 2001: 105).

In the Keep River region there is an archaeological record which extends back to the LGM, and which includes the cultural hiatus period (Fig. 7.8). The Keep River record may perhaps be compared with that from nearby Miriwun which also extends back to the LGM (Fig. 7.8). It has been postulated that riverine sites in this region were favoured for occupation during the LGM (Veth, 1995; Dortch and Roberts, 1996). Unlike the southwest Kimberley, which likely experienced arid conditions during the LGM and Pleistocene-Holocene transition, the uplands of the Mitchell Plateau (west of the Ord River) and the east Kimberley provided reliable networks of water during the climatic oscillations of the last 40 ka (Veth, 1995). The Keep River system itself may have been one of these reliable networks (Fig. 7.9), which formed part of the alleged east Kimberley ‘refuge’ (Veth, 1989).
Chapter Seven – Connecting the Local and Regional Records

Figure 7.9 Location of the Keep River region in the context of the biogeographic refuge, defined by Veth (1989: 81) as an extensive system of piedmont/montane uplands and riverine gorges which provided reliable networks of water during the climatic oscillations of the last 40 ka.

The Ord, of which the Keep River may have at times been part, is the most likely catchment in the general region to have retained permanent water at this time (Walsh, 2000: 36). Under the arid conditions operating at the LGM, this region of the Kimberley contained seasonal herbaceous vegetation with open forest along stream courses, an attractive and suitable landscape for the migration of early peoples (Van Andel and Veevers, 1967: 108). Indications of perched water and swamp conditions at the LGM at Fox Creek (in what is now the Keep River National Park) (J. Luly, personal communication, 2002) may support the region as a refuge for plants, animals and people.

Thus existing data are consistent with the Keep River region as a refuge area but supporting archaeological evidence is limited by the preservation factor of sedimentation. As in the Polop Alto valley, in eastern Spain, the evidence for human activity and landuse is a cumulative, but
discontiguous palimpsest of the most durable behavioral residues whose distributions have been
affected by diverse natural and cultural formation processes (Barton et al., 2002). If the Keep River
and the Ord River regions provide reliable water but the sedimentary record is discontiguous (refer
6.6.2), then it might be predicted that a continuous occupation record exists but has not yet been
found archaeologically. In this respect, the nature and completeness of the buried archaeological
record parallels that of the sedimentary record (Waters and Khuen, 1996).

7.7 Conclusions

The continuity of the geoarchaeological record in the Keep River region is dependent on the
temporal and spatial resolution within which both the sedimentary and archaeological records are
defined. In situ cosmogenic dating indicates net sedimentation is cumulative at the regional scale
and over many tens of millennia, whereas luminescence and radiocarbon dating indicates more
stochastic sedimentation at the local scale and over centuries to millennia. Superimposed on this
temporal variability is spatially discontiguous sedimentation and geomorphically biased
preservation – whilst more ancient Pleistocene sequences are preserved in the sand sheets, only
Holocene sequences are preserved in the rock shelters.

The archaeological record potentially provides better resolution of shorter term dynamics of
centuries or greater, although analyses and interpretations need to be defined within the context of
the depositional environment. Comparison of stone points and sediment chronology indicates that
although bioturbation may be important, the rate of bioturbation is probably only 20 mm.ka⁻¹ and
less than the rate of sediment accumulation (100 – 200 mm.ka⁻¹). Other taphonomic factors which
may influence the archaeological record include secondary reworking and in situ disintegration.
Some artefact accumulation rates may be explained as a function of sedimentation rates and
differential preservation, with changes in sedimentation reflecting regional climatic conditions. A
Holocene age for the rock art is consistent with a Holocene age of the preserved rock shelter sediments, but links between any existent ancient rock art and adjacent sand sheet sediments need to be geomorphologically defined.

Overall, in order to more clearly define temporal and spatial resolution in sandy deposits, decipher the various processes of site formation and patterns of artefact preservation, substantiate the Keep River region as part of the East Kimberley refuge, and also substantiate late Holocene ‘intensification’, more work is needed to understand past and present relationships between the sediments and the physical and climatic environment, both locally and throughout northern Australia. Although no single site provides the necessary detail of both cultural and natural dynamics, these may be pieced together from representative archaeological and non-archaeological sites.