Cultural versus natural explanations for lacunae in Aboriginal occupation deposits in northern Australia

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Abstract

Regional archaeologies in Europe, Africa and Australia have pointed to significant changes in human occupation patterns corresponding with periods of major climatic change. The construction of such regional sequences and models of changing demography and landscape use rely on the identification of continuities and hiatuses in occupation sequences and the determination of whether gaps in the record are the result of sediment removal due to the operation of geomorphological processes or alternatively record periods of site abandonment. This paper highlights the need for methodological refinement in addressing this issue. © 1999 INQUA/Elsevier Science Ltd. All rights reserved.

1. Introduction

Regional chronological perspectives on late Pleistocene Europe have enabled archaeologists to model changes in demography during the last glacial maximum (Gamble, 1987; Joehm, 1987; Soffer, 1987). Equally, significant changes in climate in Africa, corresponding to the last northern European cold stage maximum, have also been argued to result from major resource restructuring and changes in settlement dynamics and demography (Hubbard, 1989; Parkington, 1987). The construction of such regional sequences and models of changing landscape use rely on the correct identification of continuities and hiatuses in occupation sequences.

A number of Australian regional archaeological chronologies have pointed to the minimal evidence for human occupation, during the last cold stage maximum (oxygen isotope stage 2) and through into the early Holocene. Typically, many northern Australian rockshelters contain cultural units dating from the onset to the height of the last period of glacial aridity which are immediately overlain by mid- to late Holocene units. This pattern of change in Aboriginal occupation patterns has been modelled as a process involving regional abandonment of some parts of the continent — abandonment which persisted for thousands of years (O'Connor et al., 1993; O'Connor and Veth, 1996; Veth, 1993). These regional syntheses have met with a variety of critical responses. While acknowledging the widespread occurrence of this patterning in the temporal sequences of archaeological sites, most critics have highlighted the problems with stratigraphic resolution inherent in many sites and/or suggested that breaks in the sequences may have been caused by natural factors such as erosion or scouring of the deposits.

The demonstration of repeated or continuous occupation of sites in Australia is fraught with methodological and technical problems (cf. Frankel, 1993). Many of these problems stem from poor vertical development of deposits — where tens of thousands of years are often represented in \(<1.5\) m of deposit, the homogeneity of sediments and the lack of reliable materials for dating. These site attributes are generally acknowledged by archaeologists as limiting factors in creating regional archaeological chronologies — as are the problems of sampling deposits at adequate spatial scales to infer presence/absence of a hiatus in the deposit. If we are to say anything meaningful about long-term patterns of regional occupation and associated land use, then understanding periods of 'unrecorded time' is critical. This must involve some assessment of the lateral and vertical stratigraphic completeness of the deposits — in tandem with the application of dating techniques. We
argue in this paper that (i) cultural processes should be invoked as first-order explanations for breaks in the occupation record unless there is positive evidence for geomorphic processes, such as erosional sediment removal by wind or water and (ii) that strategies for identifying hiatus/unconformity in excavated sequences require methodological refinement.

2. Cultural versus non-cultural hypotheses for time hiatus in the Northern Australian regional archaeological record

Non-cultural explanations for incomplete stratigraphic records have been advanced by Smith and Sharp (1993) for sites in northern Australia. They argue that ‘... the terminal Pleistocene/early Holocene was a time when the rate of sediment accumulation in rockshelters was very much lower or when existing deposits were destroyed by erosion’ (1993, p. 55). In support of this view they produced a graph showing the temporal distribution of what they describe as ‘stratigraphic unconformities’ in northern Australian rockshelters (Smith and Sharp, 1993, Fig. 12). The graph is based on the number of rockshelters with incomplete stratigraphic records graphed in 1000 yr intervals. We have reproduced this graph, with no modifications, as Fig. 1.

Their methodology is based on the comparative analysis of 154 site stratigraphic records from the wider Sahul region. Data were integrated by site from all available sources, and then screened for quality. Of the full data set 73% (113) failed to fully meet criteria essential in any site report (Smith and Sharp, 1993, p. 49). In some cases the Pleistocene age component was therefore attributed by extrapolation from radiocarbon age-estimates, or stratigraphic association. Stratigraphic description was generally poor, although rockshelter sites were well reported twice as often as other sites. The data presented (Smith and Sharp, 1993, Table 1) group rockshelters and caves into a single category of depositional context. As is argued below, this is an unfortunate feature of the analysis, given the hypotheses they then posit.

Smith and Sharp (1993, p. 53) regarded the grouped rockshelter and cave data as of highest quality, and argue that it is the grouped rockshelter and caves depositional contexts that have the best potential for showing continuity or discontinuity of site use. A total of 82 sites fall into the rockshelter/cave category for Sahul, of which 33 are marked as having one or more unconformities (Smith and Sharp, 1993, Table 1). Of these sites, approximately 39 sites listed appear to form the group represented in Fig. 1 for northern Australia, within which 22 (73%) have one or more unconformities present, cumulatively totalling 30 unconformities for the northern Australia cave/rockshelter group.

The precise method by which unconformities were ascribed and then attributed to Fig. 1 is unclear. However, it is clear that evidence from both rockshelters and caves are subsumed in a single category, that much of the basis for inferring unconformities is based on inferences drawn from poor-quality stratigraphic data and that both dates on occupation deposits and other breaks in the stratigraphic record (Smith and Sharp, 1993, Table 1 caption) form the basis for plotting unconformities then distributed in 1000 yr time slices in Fig. 1.

Fig. 1. Temporal distribution of stratigraphic unconformities in northern Australian rockshelters (from Smith and Sharp, 1993, Fig. 12). The shaded zone marks the period between 9000 and 6000 BP which, according to Smith and Sharp, is a time of widespread erosion of rockshelters.
They conclude that the shaded zone, between 9000 and 6000 BP, marks a time of widespread sediment erosion from rockshelter deposits in northern Australia with the tail indicating the removal of Pleistocene sediments in some sites and to varying degrees and varying depths in individual sites (Smith and Sharp, 1993, p. 55).

We have a number of major concerns with the methodology used. Firstly, with the lack of clearly stated criteria and methods used to classify sites into 1000 yr time slices labelled as having unconformities present, secondly, the grouping of caves and rockshelters into a single depositional context category and, thirdly, the rationale behind applying a concept of 'a uniform erosional phase' to these sites in northern Australia, based on the data presented.

We believe the term unconformity has been used too loosely and recommend that its use in archaeological contexts requires clarification if we are to begin to differentiate between cultural and natural factors contributing towards periods of stratigraphically unrecorded time. Before considering the use of the term unconformity as used in northern Australian archaeological sequences dating to the late-Quaternary — the problem of resolving time in relation to stratigraphic completeness will be briefly reviewed from a general geological perspective, as this has relevance to developing improved methodological approaches in rockshelter sequences specifically, and regional archaeological chronologies more generally.

3. Terminologies and methodologies for identifying time hiatus in rockshelters

It is well established that in the geologic rock record, the stratigraphic record of time is extremely incomplete (Ager, 1981; Blatt et al., 1991; Boggs, 1995; Sadler and Dingus, 1982; Tipper, 1987), and that sedimentation rates are normally variable and episodic (Byers, 1982; Dott, 1983; Retallack, 1984). Completeness of the sedimentary record is normally a function of the magnitude-frequency characteristics of the sedimentation process, combined with the nature of the depositional basin, or local depocentre, being infilled over time (Gretener, 1967; Keller et al., 1987; McShea and Raup, 1986; Sadler, 1981). Estimates of completeness i.e. the proportion of the total time span being considered represented by sediment accumulated in the sequence, rely heavily on the reliability of dating methods used to define rates of accumulation (Tipper, 1987).

Incompleteness of the stratigraphic record reflects breaks in the continuity of deposition. However, it is important to distinguish deposition rate over time (i.e. the flux of sediment onto a potentially accumulating sediment interface) from the net sediment accumulation rate. Net sediment accumulation rates reflect the ratio of additions and removals of sediment from the sedimentary interface (in the case of rockshelters — invariably an air/sediment interface). It is the net sediment accumulation rate over time which primarily defines the age-depth characteristics of a stratigraphic sequence, although post-depositional processes such as compaction/solution can have significant effects. Increases in deposition rates may or may not result in increases in net sediment accumulation rate, depending on the ratio of depositional inputs to losses from the sediment interface (where losses can result from either erosional processes, or solution, organic breakdown or removal of sediment by biotic and/or cultural activity). It is therefore possible for an increase in loss rates (lr) to result in hiatus while deposition (dr) continues at a steady constant rate (where lr ≥ dr).

There are numerous features in stratigraphic sequences that indicate breaks in continuity of deposition. Among the more common are bedding surfaces, created by minor interruptions in net sediment accumulation. Where diagenesis/pedogenesis occurs on a surface during a period when neither sediment accumulation or erosion is taking place, fissility surfaces may develop. Both bedding surfaces and fissility surfaces can represent mini-unconformities, defined by Bates and Jackson (1987) as diastems — where the interruption in sedimentation is minor, only involving a brief interval of time with little or no erosion, before net sedimentation resumes. Diastems involve less time than paraconformities (Blatt et al., 1991, pp. 82–83) — and therefore represent the type of time hiatus likely to be encountered in late Quaternary rockshelter sequences where 10–20,000 yr are represented in a 1–2 m of deposit, and missing time is of the order 10^2–10^3 yr. Diastems grade upwards in scale into paraconformities — which are discontinuities defined by palaeontological breaks and criteria (Newell, 1967). The application of the term paraconformity to evidence based on human/presence absence is therefore terminologically problematic and inappropriate, in the context of late-Quaternary Australian archaeological sites.

Other evidence for breaks in continuity may take the form of disconformities (where there is lithologic evidence for hiatus in parallel sequences) and condensed sections (Blatt et al., 1991, pp. 79–80; Kidwell, 1989). Condensed sections are relatively thin units representing a considerable length of time, but in apparently uninterrupted stratigraphic successions. They may be produced by winnowing processes, and in the rock stratigraphic record, are often represented as bone beds. A water or wind-winnowed unit in a rockshelter, characterised by clast-rich concentrates (or high artefact frequency), high sorting and thin bedding (e.g. < 20 cm bed thickness) would be an archaeoological example of a condensed section (sensu Kidwell, 1989). Condensed sections can also result from very slow deposition — without winnowing — so artefact-rich layers accumulated during intervals of permanent or intermittent human occupation, but
with minimal sediment matrix deposition during the time interval of occupation, could also represent archaeological examples of condensed sections, when located in rockshelter sites.

The implications for archaeological sequences such as those found in northern Australia rockshelters are threefold.

First, the majority of time hiatuses likely to be encountered will be of diastemic type, and on the evidence available are rarely likely to be time synchronous for geological reasons across wide areas — given the local variable nature of rockshelter geometries as depocentres, bedrock, aspect and altitudinal relationships.

Secondly, where either net sedimentation rates fall to near zero, or, erosional removal of sediment from the accumulating surface takes place, predictable sedimentary outcomes should be expected. These would include i) incipient pedogenesis and enhanced mixing and/or localised hardening of the sediment surface in carbonate-rich environments where net accumulation is very slow ii) winnowing effects producing condensed sequences characterised by higher clast (or lithic artefact) content, higher sorting, coarser grain sizes and higher percentage composition by volume of more resistant mineralogies and iii) higher mass/unit volume ratios in condensed sequences where particle size ranges of available sediment are restricted and drastic inputs low.

Thirdly, where erosional processes are associated with the time hiatus, the hiatus is more likely to have observable lithostratigraphic expression — marked by either bedding planes, or fissility surfaces. Time hiatuses of this type, when identified, should be termed stratigraphic disconformities.

If one compares these geological considerations with the conceptual and methodological approaches routinely applied in archaeological context recording (Barham, 1995) it is common to find minor bedding planes (or interfaces sensu Harris, 1989; Brown and Harris, 1993) viewed paradoxically either as evidence for conformity of deposition, or as time missing in the sequence (see Brown and Harris (1993), Collett (1987) for alternative viewpoints on this issue in relation to cultural deposits).

Moreover, the term unconformity is commonly used less precisely in archaeological publication. For example, as defined by Bahn (1992), the term unconformity describes a surface of non-deposition that appears as a break between two sediment units in a sequence. Unconformities arise from changes in depositional conditions, to conditions of erosion or non-deposition.

4. Models for lithostratigraphic development with time hiatus in rockshelters

Viewed from a wider perspective, some general patterns can be discerned in the reported occurrence of stratigraphic unconformities in caves and rockshelters. In areas marginal to ice and snow accumulation in the late Pleistocene, major erosional unconformities are documented due to activation of groundwater regimes in cave systems. These are visible lithologically as stratigraphic disconformities. Campy and Chaline (1993) report systematic increases in conformability on transects of cave stratigraphies running away from Alpine systems influenced by late Pleistocene meltwater systems, with increasing distance into the Perigord and northern France.

Conversely, cave deposits in southern Albania have recently been used to construct proxy-climate records using the mineral magnetic properties of redeposited allochthonous sedimentary inputs from eroded topsoils as climate indicators — where the method applied relies on unique records of constant sedimentation over a 6 ka time interval (Ellwood et al., 1996, 1997, pp. 570–572, Fig. 2). Similar stratigraphic conformability has permitted reconstruction of a palaeomagnetic record from multiple hearths for the early to mid-Holocene at the Modoc rockshelter in Illinois (Kean et al., 1997). Highly conformable sequences are thus known for both caves and rockshelters, spanning the late Pleistocene and early Holocene.

At Drotsky's Cave in the semi-arid Kalahari, shallow stratigraphies of <1.4 m span the late-Pleistocene and Holocene (Robbins et al., 1996) and exhibit the high faunal preservation of small mammals and reptiles, fine sediment grain size, and irregular sedimentation rates typical of some northern Australian sites. At Drotsky's Cave, low sedimentation characterises the time interval 11.2–5.5 ka b.p. with rates increasing by an order of magnitude during an intense occupation phase at 12.4–11.2 ka b.p., associated with both flaked artefacts and higher organic composition in the sediment. This late Pleistocene occupation is correlated with wetter climatic conditions prior to a transition to more arid conditions.

Generally, rockshelter sequences are less erosively influenced by groundwater hydrology, and yield shallower sedimentary sequences with a large proportion of accumulating sediment derived from local sources (Farrand, 1985, pp. 22–25). Evolution of stratigraphic sequences is often either bedrock controlled or strongly dependent on the initial floor morphology created by roof fall. Massive roof falls frequently set up local depositional pathways for sediment focusing, creating initial fast filling of crevices of bedrock, and steeply dipping concave-upward beds orientated to local sediment traps between fallen boulders. At Red Canyon Rockshelter in Wyoming, both bedrock properties and age-depth relationships illustrate the effects of this local sedimentary response to pronounced relief on the shelter floor following catastrophic roof fall (Abbott, 1997). At Red Canyon Rockshelter initial phases of focused sedimentation into
hollows, eventually give way to sub-horizontal bedding and more even rates of net sediment accumulation across the shelter floor, once floor topography has levelled. The stratigraphic development was clear due to the extensive areal excavation undertaken (Abbott, 1997, pp. 317–322). Had small test-pit sampling been conducted, positioning of test-pits would have inevitably resulted in local diastems being encountered during dating of the sequence (Abbott, 1997, Fig. 4).

Rockshelter sites are also prone to episodic catastrophic failures of roof and walls. This can give rise to rapid sealing of archaeological deposits, as at the Akrotiri Aetokremnas rockshelter (Mandel and Simmons, 1997) — where contexts are preserved with minimal weathering and high contextual reliability, allowing inferences to be drawn on the co-existence of extinct fauna and humans. Rock-falls also stratigraphically separate Holocene from Pleistocene archaeological contexts in Southeast Asia e.g. at Lang Long Rongrien rockshelter in Thailand (Anderson, 1987, 1990, 1997). Such roof fall horizon may have been interpreted as false bases to Holocene sequences at sites excavated previously in Southeast Asia (Anderson, 1997, p. 618), with Holocene archaeology interpreted, incorrectly, as unconformably overlying bedrock, as opposed to lying over roof fall with further Pleistocene archaeology lying at depth beneath the roof fall.

The implications for interpreting the results generated by Smith and Sharp for northern Australia are (i) stratigraphic unconformities will be present in the data they analysed due to the small areal excavations their sample set includes (ii) not all sites included in the survey are necessarily stratigraphies which represent the full depth, or most conformable sequence, potentially available at the sites analysed (iii) the unavoidable practice of skewing the vertical and lateral distribution of age-estimates to contexts rich in archaeological dateable materials, e.g. hearths, means apparent hiatuses will be produced when the full lateral extent of the stratigraphy is not established and sampled and (iv) while regional climatically-coupled erosional effects due to groundwater hydrology are known to impact on cave systems (e.g. Campy and Chaline, 1993) no such regional erosional mechanism is likely for rockshelters which are typically dominated by local, intrinsic depositional pathways (Farrand, 1985).

In view of the data presented by Smith and Sharp (1993), we believe that it is worth giving consideration to the assumptions, models and processes that might give rise to apparent time gaps within rockshelter sequences. Three alternative simple sediment accumulation models for rockshelter stratigraphic accumulation can now be considered — as might be applicable to rockshelter sites included within the database analysed by Smith and Sharp (1993).

A simple lithologic criterion, applicable to rockshelters, by which sites should be included in the general category of hiatus as defined by Bahn (1992) is shown in Fig. 2. Here features, such as a lag deposit, provide stratigraphic evidence for the compression of adjacent dates. Such evidence, as Frankel (1993, p. 28) notes, ‘... has seldom been defined in the field'.

Smith and Sharp (1993, Fig. 12) have proposed a single chronozone typified by erosion for the period 9–6 ka radiocarbon years BP. As our model illustrates, even if their conclusion is justified and accepted (i.e. that a major hiatus is common in rockshelter stratigraphies for this time interval) it does not follow that this implies net sediment erosion. The same phenomena is equally likely to result from inter alia the ratios of weathering losses to accumulation; net changes to input:output fluxes of sediment within a given shelter area, or simply a phase of non-deposition.

If such a major erosional phase has occurred in northern Australia why have so few disconformities been defined in the field using lithologic criteria? While in some cases the combined effects of well sorted sandy matrices, narrow ranges of particle sizes in contributing sediments and stratigraphic reworking in caves may obscure unconformities, there still should be some evidence for increased artefact density and increased roof fall — even if the mechanism is slow erosional winnowing. For example, Smith and Sharp’s graph (1993, Fig. 12) indicates that up to 15,000 yr of net sediment accumulation may have been removed during their hypothesised erosional phase. Unless all cultural materials were effectively removed along with the finer-grained sediments, then
a dense lag horizon of artefacts and roof fall should be a common lithologic feature of all these rockshelter sites. Such horizons are generally absent, or have gone unrecorded, in early to mid-Holocene rockshelters in northern Australia. Such a scenario should be distinguishable from an archaeological ‘living floor’ as it will also incorporate the lag deposit of 15,000 yr worth of roof fall. Indeed the erosion scenario could be expected to result in a dense band of roof fall in all size classes incorporating large numbers of artefacts i.e. a lithologically distinctive form of condensed stratigraphic section.

Time hiatuses of this type should be detectable in the lithology of the stratigraphic sequence — either during excavation, or through subsequent analysis. The hiatuses being sought are disconformities, if of the erosional process origin inferred by Smith and Sharp (1993), and should produce recognisable stratigraphic features.

As noted earlier, other mechanisms than erosion may be responsible for diastems in the local depositional systems of rockshelter floors. Diastems can be particularly difficult to detect when either the particle sizes within the sequence do not favour the development of thin bedding or laminations, or when initial primary stratigraphy is overprinted by secondary mixing processes (Barham, 1995). Some discontinuities need not be readily visible, even in the rock record (Blatt et al., 1991, p. 86). It is therefore worth considering methods which might assist the identification of diastems if the hiatus was of non-erosional origin, and particularly if condensed sequences might result from periods of cultural abandonment.

Technical approaches which might assist would involve recovering and preserving undisturbed samples from representative sections of the stratigraphic sequence — particularly in terms of undisturbed sediment density, sediment fabric and concentration properties. Subtle micro- and mesofabric properties of the sequence can be revealed by e.g. X-radiography of resin impregnated slabs, or micromorphological analysis of impregnated thin-sections (Boschian, 1997, pp. 236–241; Goldberg, 1979; Goldberg and Laville, 1988; Goldberg and Macphail, 1990; Meignen et al., 1989). Also, concentration effects due to subtle winnowing and/or post-depositional compaction could be sought by scanning undisturbed samples using e.g. mineral magnetic susceptibility properties, or chemical concentration markers. Depositional events related to human occupation can be marked by phosphate compounds, detected using colorimetry (Abbott, 1997) or through identification of specific particulates such as calcium oxalate, or apatite, detected by thin-section microscopy or SEM/EDAX (Boschian, 1997; Brochier, 1991; Goldberg, 1979, 30–31; Wattez et al., 1990), even where artefactual evidence is absent. Simple replicated bulk density calculations for 1–2 cm vertical increments through sequences of visually uniform stratigraphy could be valuable. Some of these techniques have been applied to selected cave and rockshelter sites with considerable success (Bull and Goldberg, 1985; Ellwood et al., 1997; Wattez et al., 1990) — but are less frequently applied in tandem with high-resolution dating programs where specific organic fractions are targeted for dating. Such mixed method approaches (Canti, 1995) which address specified research stratigraphic problems across a range of scales, and utilising independent techniques, often have a higher chance of research success. Detection of microstratigraphic fabric and bedding properties at scales of between 100 µm and 10 mm, across 2–20 cm units of stratigraphy known from high-resolution radiocarbon dating to possibly involve hiatus — might be a valuable project at selected rockshelter sites in northern Australia.

Such approaches would also permit investigation of the key alternative hypothesis for explaining hiatus in rockshelter sequences — namely, that site abandonment (or infrequent use) is in some way coupled in the sedimentary systems of northern Australian rockshelter floors to decreased net sediment accumulation rates.

Fig. 3 illustrates a model for sedimentation with a cultural hiatus. In this example sediment accumulates without the deposition of any cultural material. Such an example is found in the site of Serpent’s Glen, located in arid north-west Australia, providing the first firm Pleistocene sequence from the Western Desert (O’Connor et al., in press, see Fig. 4).

Dates of 23,500 and 4700 BP are separated by a unit which is culturally sterile. The sterile deposits provide

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Fig. 3. Schematic representation of a sedimentary profile illustrating continuous sedimentation with a cultural hiatus.
evidence for the passage of time where occupation does not occur. Serpent’s Glen is unusual compared to most shelters in the Australian semi-arid zone as it is located in a low lying position on a sandsheet and has an aeolian sediment source. Sediment analysis suggests that the source is the same from the lower to the upper unit (Magee, pers. commun.).

We agree with Smith and Sharp that most excavated and dated rockshelter sequences from northern Australia have a chronological hiatus where the break is not represented stratigraphically and is only detectable chronologically with late Pleistocene dates overlain by mid to late Holocene units (Fig. 5). There are a number of major problems, however, in viewing these types of sequences as representing proof for ‘... widespread erosion of rockshelter deposits’ (Smith and Sharp, 1993, p. 55).

Firstly, the phenomena is equally explicable in terms of zero net accumulation, or very low accumulation of sediment which as outlined above may have a cultural cause.

Secondly, the break in the sequences is not tightly synchronous on a regional scale, which would be the expected outcome of a widespread erosional phase. For example, at Koolan Island Shelter 2, the Pleistocene Unit shows its last phase of occupation about 23,000 yr ago and it is overlain by a shellmidden unit dated to 10,700 BP corresponding with the arrival of the sea proximal to the shelter entrance (due to the steeply shelving offshore profile in this area). Widgingarri shelter on the Mainland to the NE of Koolan appears to have been occupied from c. 30,000 BP until as late as 18,000 BP. A nearby rockshelter registers the arrival of people in the area again by 7500 BP (O’Connor, 1996).

In a recent review of all available dates for sites in north-west Australia, Veth argued that the only period for which dates are completely absent (per millennia) occurred between 12,000 to 17,500 yr ago and that this was out of phase with the period of erosion posited by Smith and Sharp from 6000 to 9000 yr ago (Veth, 1995). From a total of approximately 200 dates available from north-west Australia, 33 fall in the period from 12,000 yr ago to the end of the proposed phase of erosion 6000 yr ago.

Thirdly, climate data for northern Australia in the early Holocene also lends little support for the notion of a wide spread erosional phase in rockshelters.

The early to mid Holocene, from about 9000 to 6000 yr ago, sees a general warming in northern Australia with increases in temperature and or precipitation, denser vegetation cover and a high degree of environmental stability (Kershaw, 1995, p. 667). The results from the Atherton Tablelands indicate that lake levels began to
rise about 10,000 BP and maximum lake levels were achieved at approximately 8000 BP. While in open site locations, adjacent to river channels, the increase in precipitation may have led to scouring or destruction of archaeological sites, many rockshelter sites situated in valley marginal or ridge locations would have been exempt from this process. Increased vegetation stability and ground cover on surrounding plains and outside the mouths of shelters is likely to have promoted more stable conditions reducing the likelihood of erosion of deposits by either water or wind action.

Following on from this point, we find it highly unlikely that caves and rockshelters spread throughout tropical, woodland and arid northern Australia, regardless of their elevation, aspect, geomorphic setting and type of sediment source, could be effected by some temporally synchronous, uniform, and as yet undescribed, erosional process.

We return to our central theme. Without stratigraphic evidence for erosional events in these sites it is simply not acceptable to automatically invoke geomorphic explanations. Instead, we believe the considerable number of chronological hiatuses which have been identified, for example within semi-arid and arid zone sites, can be more plausibly explained through changes in settlement dynamics and types of occupation in shelters (cf. Veth, 1995). Dynamic changes in human population distributions and regional migration consequent on coastal reconfiguration during late Pleistocene and early Holocene mean sea level rise (Chappell, 1991) may also be a factor, as advocated by Anderson (1997, pp. 621–623) at Lang Rongrien Rockshelter in Thailand.

These alternative hypotheses require testing, and in order to improve the data available for regional comparative studies in northern Australia clear agendas need to be set. As acknowledged two decades ago, the study of cave and rockshelter sequences involves both complex problems of micro and meso-stratigraphic correlation and interpretation (Bordes, 1975; Collcutt, 1979) and, through excavation of a finite limited resource, heavy responsibilities for high resolution recording and analytical procedures (Straus, 1979, pp. 337–338). These issues are now central to the resolution of the debate regarding occupation chronologies in rockshelter sites in northern Australia.

As outlined above, a combination of applying high resolution stratigraphic analysis coupled to strategies of multiple method independent dating of key contexts is now justified at many sites in northern Australia. Protocols for standardised recording and long-term archiving of undisturbed samples of significant stratigraphic units (e.g. through monolith consolidation and impregnation techniques) are now required so that contextual problems identified by dating can be resolved through subsequent laboratory analysis without further excavation. As noted by Collcutt (1979, p. 290) few sedimentologists are willing to discuss the precise procedures involved in the recognition of sedimentary units and a body of theory as to how individual cave and rockshelter sequences can be integrated into a regional framework is urgently required (Collcutt 1979, p. 296). In the northern Australian region the recognition of hiatus and conformability in rockshelters now raise the same issues, for the same reasons.

While problems of intrasite correlation between adjacent pits and excavation sections are difficult to surmount — given the need for cultural resource conservation — simple steps can be taken to to improve data quality. Type sections as recorded visually can also be recorded in the field and laboratory using supplementary techniques such as X-radiography, scanning of density and concentration properties and, for selected parts of sequences, micromorphology. These approaches allow qualitative and quantitative checking of sedimentary interfaces and conformability as recorded in the field (Barham, 1995; Canti, 1995). Many sites are sufficiently significant to justify replicate sampling — with sets of undisturbed samples being committed to long-term archive in State or Federal central depositories. Policy initiatives to fund and manage such procedures would be required. Finally, specific research into mixed method approaches appropriate to identifying diastemic hiatuses and condensed sequences in fine-grain shallow rockshelter sequences is also needed.

5. Conclusions

In the absence of lithological evidence for the erosional mechanism proposed by Smith and Sharp to explain hiatuses dating between 9 ka and 6 ka BP, the pursuit of alternative cultural explanations for unrecorded time can be more profitably pursued in northern Australian rockshelters. At present, we recommend clear separation of rockshelter sequences from cave mouth and cave interior sequences in regional chronological database construction and analysis, as depositional processes are known to vary markedly between these systems. Rockshelter sequences are normally accumulated in pathways heavily skewed to localised intrinsic pathways of deposition, so regional synchronous erosional processes would not be expected. However, a clear requirement emerging from this critique, is the standardisation of stratigraphic recording and improvement in undisturbed sampling procedures at rockshelter sites, coupled to high-resolution stratigraphic analysis and dating.

While regional and continental scale models may be based on limited data sets, they should be, at least, ultimately testable. In order to refine these models, agreed protocols for stratigraphic recording, analysis and archiving data in improved primary formats are now required.
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