Pleistocene Settlement of Deserts from an Australian Perspective

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Introduction: Deserts and Desert Colonization

One of the surprising characteristics of deserts is their environmental diversity. Far from the monolithic uniformity of the popular imagination, deserts typically display variation in topography, hydrology, and resources. Within Australian deserts these differences are displayed at a variety of scales. While some areas have coordinated drainage, others have no coherent and articulated drainage systems; some desert areas are principally rocky outcrops, others largely mantled with sand, and still others are a mixture; some have permanent water sources, while many do not; and so on. Within any single desert area the availability of water, stone, and wood suitable for tool making, as well as the nature and abundance of plants and animals, varies across the landscape. All of these features have varied through time as climatic shifts, geological processes such as erosion and sedimentation, and changes in floral and faunal composition have altered the structure of resources across the landscape. A single landscape may even become or cease being a desert with the passing of time. Variation in the distribution and reliability of resources through time and space is likely to have had a critical influence on the colonization and settlement of these desert landscapes.

Adaptations to deserts by humans are also far from being monolithic. Within Australia images of ethnographic desert dwellers have often dominated discussions of possible lifeways within arid and semi-arid lands. These images of historic Aboriginal desert life often emphasize features like the intensive use of vegetable foods such as seeds, and maintenance of long distance social networks involving reciprocity and rights to territorial access (Gould 1977; Tonkinson 1991: 40). Most importantly, the ethnographic desert dwellers were renowned for their intimate knowledge of the landscapes in which they lived; however, these features are unlikely to have been traits of the colonizers of these desert landscapes! Initial colonization must have been accomplished by foragers who did not know the terrain or the

distribution patterns of resources and therefore the early settlement of the Australian deserts is likely to have been undertaken by people who had economic and subsistence strategies that were different from those of the historic period. Some researchers have suggested that the ethnographic forms of desert economy and subsistence are relatively recent, and have emerged only since the Last Glacial Maximum (LGM) and in the Holocene (e.g., Veth 1989). This chapter tackles two of the key problems in archaeological investigations of early occupation of the Australian deserts: (1) How different was the settlement system of early settlers of the inland from that found in recent times and (2) how did foragers colonize the interior without the adaptive strategies of historic desert peoples? In answer to these questions we advance the propositions that much of the Australian interior was initially colonized during a period of higher rainfall and more abundant surface water and food resources – a period in which a dedicated desert adaptation of the historic kind was not in place – and that elements of this pattern of early subsistence continued until the LGM, hence supporting a model in which some of the key features found in historic desert life have accumulated only since the terminal Pleistocene. We argue that in Australia Pleistocene foragers did not move into deserts fully equipped with a modern desert adaptation, but rather that climate change created deserts in areas where hunter-gatherers already lived and those human groups adapted their existing strategies to the new situations or else abandoned the landscape – a “desert transformation” model. A review of deserts around the world suggests that similar colonization models may have broad applicability.

Note that the following review incorporates age estimates derived from a range of dating techniques. To reconcile these different estimates we have adopted the approach of expressing all ages as solar (calendar) years rounded to the nearest 500 years, including those derived from radiocarbon dates. To achieve this, age estimates based on uncalibrated radiocarbon dates presented in the cited literature have been calibrated using the procedures developed by the University of Cologne in its CalPal software and by the formula of Miller et al. (1997). Although such calibrations are of uncertain accuracy they facilitate the synthesis of different data sources, such as luminescence and radiocarbon assays. Using this approach our review of the Pleistocene occupation of Australian deserts requires consideration of the question as to when humans first arrived in the Australian continent.

Arrival of Humans in Australia

Archaeological evidence demonstrates that humans arrived in Australia 60,000–45,000 years ago (Bowler 1998; Bowler and Magee 2000; Bowler and Price 1998; Gillespie 1998; Gillespie and Roberts 2000; Grün et al. 2000; Pearce and Barbetti 1981; Roberts et al. 1990, 1993, 1994). The precise date of initial arrival of humans in Australia has been the subject of vigorous debate, principally between a group of researchers advocating a likely landfall of approximately 45,000 years ago (e.g., O’Connell and Allen 1998, in press) and those preferring an estimate of approximately 55,000 years ago (e.g., Roberts et al. 1990, 1993, 1994).

We consider these debates of little value given a number of factors. Firstly, they have tended to ignore the uncertainty attached to many age estimates, thereby acting as though the various estimates were more precise than they are. For instance, many of the luminescence, U-series, and ESR dates have uncertainties in the order of 5,000–10,000 years (see O'Connell and Allen, *in press*, for data summaries), often making debates as to whether material at a specific site was 50,000 or 45,000 years old merely a speculative adventure. In another context the consequences of these uncertainties have been discussed by Rindos and Webb (1992), and we concur with their conclusion that high resolution models of the initial period of colonization may never be able to be tested using current dating techniques. Although the radiocarbon estimates have higher precision, doubts remain about their accuracy, with even the most recent advances in radiocarbon dating techniques failing to resolve all complications created by contamination or calibration.

A second factor we will mention that creates difficulties for pinpointing a date for initial human entry into Australia is the lack of systematic sampling of archaeological sites. The probability of finding archaeological traces of the earliest occupation of Sahul, even within a specific region, is very small; and the identification of one or two old archaeological deposits in any region should be considered evidence of minimum antiquity rather than a definitive statement of the antiquity of occupation. This factor is exacerbated by the tendency of archaeologists to repeatedly target specific kinds of site – such as large caves – and the focus of redating investigations during the last decade on those atypical sites. In light of this factor it is noteworthy that the oldest potentially sustainable estimate of human occupation comes not from a cave deposit but from the open lake margin site of Lake Mungo, where ESR, U-series, and OSL techniques have indicated a burial may date to $62,000 \pm 6,000$ years ago (Thorne et al. 1999). Although a date in excess of 50,000 years appears unlikely for this skeleton, based on the well established age of the sediments in which it was found (Bowler and Magee 2000), the unresolved debate about the antiquity of the Mungo material highlights two aspects of the investigation of human antiquity in the Australian continent: that since the nature of human landscape use may have varied through time, some landscape features may not provide residues of the initial movement of humans into a region, and that even the lowest reasonable estimates of the lowest artifacts at Lake Mungo deny conservative claims of continental colonization of 43,000 BP or less.

The third significant concern when interpreting age estimates for early Australian occupation is the lack of detailed taphonomic/formational studies for almost every deposit cited in these debates. Formational/disturbance processes, which can be presumed to occur in every archaeological site, create ambiguities in age estimation that are not expressed in the uncertainties provided by dating laboratories. The failure of Australian archaeologists to make taphonomic investigations a high research priority is compounded by the regular dating of non-archaeological components of these old deposits – materials such as sand grains – thereby raising questions of stratigraphic association. Where the formation processes of early sites have been subjected to scrutiny they have often proved problematic and in need of further study (see Hiscock 1990; O'Connell and Allen *in press*; Richardson 1992).

Given these complexities in the use of existing chronological evidence we conclude that Australia was most likely colonized by *Homo sapiens sapiens* at a date of $50,000 \pm 10,000$ years ago, that is 60,000–40,000 years ago. We consider this estimate to be imprecise but reliable, and to define the earliest chronological period in which humans were present on the continent and in which occupation of desert landscapes might have occurred. Accepting this estimate of the arrival of humans in Australia, we now turn to the evidence for colonization of desert areas.

Initial Human Penetration of the Australian Deserts

In evaluating the timing of initial human movements into the Australian deserts we have identified the earliest, apparently reliable age estimate for archaeological materials in each region that today is arid or semi-arid. The data-set that we have drawn on is that prepared by O'Connell and Allen (in press), and the following discussion is restricted to those sites from which dates exceeding 35,000 years have been retrieved. Again, the reader is reminded that ages provided here are in solar years, with radiocarbon values calibrated and rounded to the nearest half a millennium.

This procedure currently yields seven sites across Australia (see Figure 3.1). In the Kimberly region of northwestern Australia radiocarbon assays at two rock shelters have very similar ages for their lowest occupation levels: Carpenter's Gap 1 with a date of 45,000 years, or 46,500–43,500 years ago at two standard deviations (Fifield et al. 2001); and Riwi with a date of 45,500 years, or 47,500–44,000 years (Balme 2000). Further to the southeast, in the MacDonnell Ranges of central Australia the Puritjarra rock shelter has evidence of occupation at 39,000 years ago, or 42,500–36,500 years (Smith et al. 1997). Even further south, on the Nullarbor Plain and edge of the Great Australian Bight, Allen's Cave has yielded an OSL date of 40,000 years, or 43,000–37,000 years (Roberts et al. 1996). Far to the east of Allen's Cave, the stratigraphically lowest artifacts in the aforementioned Lake Mungo site complex are estimated, using OSL, to have an antiquity of at least 50,000–46,000 years (Bowler et al. 2003). Further northeast, Cuddie Springs appears to have archaeological material dated using OSL techniques to 35,500 years, or 38,500–32,500 years ago (Roberts et al. 2001). Finally, in the northeast of the continent, in the gulf fall zone of the Barkley Tablelands, the GRE 8 shelter has produced a radiocarbon sample of 41,500 years, or 44,500–37,500 years (O'Connell and Allen in press).

Although the radiometric estimate from Cuddie Springs is somewhat younger than the demonstrated antiquity at the other sites, we interpret these data as indicating broadly similar dates for human presence in widely separated regions. Humans are archaeologically visible in each of these locations 50,000–40,000 years ago, a pattern that must be taken to reveal the widespread distribution of hunter-gatherers across inland Australia at that time. These dates could be seen to imply that occupation of these inland regions took place substantially later than the original landfall, if claims for dates of 55,000 years or more in Arnhem Land

Figure 3.1 Early Australian sites in landscapes arid or semi-arid today (after O'Connell and Allen in press).

(Roberts et al. 1990, 1993, 1994) are accepted at face value, thereby supporting a modified version of Bowdler's (1977) model of coastal colonization; however, as we have already discussed, the imprecision of dates older than 45,000 years makes such a conclusion unsustainable, and we argue that models such as coastal colonization are currently untestable. Imprecise dates also constrain consideration of whether these inland regions were initially occupied contemporaneously or sequentially; the precise rate of human spread across the inland cannot be calculated, although the current evidence of broadly similar antiquities in each region does not favor a spread of people extended over tens of millennia. Nevertheless it is worth noting that there is no obvious directionality in these dates – the northwest and southeast have returned similar ages for occupation; hence, no directional pattern of dispersion can reasonably be read into the pattern described here. Although the dating evidence fails to provide definitive tests of fast versus slow models of population

dispersion across the Australian interior, it not only reveals that relatively early (pre-40,000 years) occupation was widespread and not restricted to coasts, but also provides the necessary chronology with which to assess the environmental context of the initial movement of people into the Australian deserts.

During the period when humans become archaeologically visible in regions of Australia that are now deserts, the climatic and hydrological regimes created landscapes that were different from those found today. Any consideration of the colonization of Australian deserts must be understood in that environmental context. Three regional paleoenvironmental records are summarized below as exemplars of the context of colonization: the strongly seasonal Kimberley region of northwest Australia; the weakly seasonal Lake Eyre and its catchment; and the relatively aseasonal Willandra Lakes (see Figure 3.2).

In the Kimberley the long-term climatic pattern has been reconstructed from northwest shelf marine cores, terrestrial lake sequences, and botanical materials from archaeological sites. The Lombok Ridge marine core indicates that the period from 130,000 until 38,000 years ago was one of high sea level and relatively wet conditions in northern Australia, with rainfall estimated to fall in the range of 500–1000 mm per year (van der Kaars 1991; Wang et al. 1999). Bowler's (1983a; Bowler et al. 2001) investigations at Lake Gregory, located on the northern fringes

Figure 3.2 The contemporary Australian arid zone (thick line), where potential evaporation exceeds actual evaporation (modified from Gentilli 1986 and Hesse et al. 2004). Rainfall seasonality is shown as the ratio of summer to winter rainfall. Three broad regions are numbered as (1) Kimberley and the northwest, (2) Lake Eyre and its catchment, and (3) Willandra Lakes.

of the Great Sandy Desert, have revealed increasing aridity during the last 300,000 years, with several lacustral phases prior to 40,000 years ago. The record from Lake Wood to the east shows similar trends, but differences in the precise timing and extent of high water conditions, indicating interregional and local variations (Bowler et al. 1998). The long-term trend towards increasing aridity is also reflected in vegetation change during the late Quaternary. Studies of soil organic matter from Lake Gregory have indicated a trend, over the last 100,000 years, away from exclusively tree and shrub floral assemblages towards a grass dominated flora as increasing water stress developed (Pack et al. 2003). These data are consistent with the evidence for vegetation change available from the phytolith record at Carpenter's Gap 1 where, 45,000 years ago, there was a diverse grassland ecology and palms outside their modern geographical range, suggesting the existence of wetter conditions at that time than in any more recent period (Wallis 2001).

In the Lake Eyre Basin of central Australia, a region in which water availability reflects not only local conditions but also seasonal rainfall patterns in its northerly catchment, broadly similar trends towards desiccation have been well documented. As evidenced by the nature of regional vegetation patterns, the Australian monsoon was more effective before 45,000 years ago than at anytime since (Johnson et al. 1999). This is also seen within Lake Eyre itself, which was for the most part a permanently wet lake until about 60,000 years ago, when it changed to a ground-water dominated system as it progressively dried out (Magee and Miller 1998). Up until about 30,000 years ago enhanced winter westerly circulation might have penetrated more regularly to the Lake Eyre region than under the present climate, bringing with it enhanced winter rainfall and wetter conditions than at any time since. Preserved tree roots and trace fossils of large roots replaced by secondary gypsum also reveal that trees were more common during that period than today (Hesse et al. 2004). These climatic differences in the Lake Eyre Basin probably stem from an interaction of enhanced winter rainfall, greater inflow from enhanced storms in northern Australia, and reduced evaporation associated with substantially lower temperatures than at present (Magee and Miller 1998; Miller et al. 1997).

In contrast, far from the influence of monsoonal rainfall in southeastern Australia the archetypal locality for describing arid/semi-arid environmental history and archaeology is the Willandra Lakes, and especially Lake Mungo. Bowler (1998) has demonstrated the alternation of dry and wet phases at Lake Mungo during the late Pleistocene, with a long-term drying trend. Prior to 45,000–42,000 years ago there was a prolonged lacustral phase with high water levels. A further series of water bodies were also present 36,000–22,000 years ago, although low and fluctuating lake levels are features of the period following 42,000 years. Other lake systems in the arid southeast have been shown to display somewhat similar trends, although with distinct hints of local variations in the timing and pattern of high water levels (Harrison 1993). This overall pattern of drying since 50,000–40,000 years ago is also visible in the activation of linear dunes, particularly during the last 25,000 years (Wasson 1984).

These brief pictures of surface hydrology and vegetation in widely separated regions of the Australian interior provide an image of the landscapes into which we

believe the first human colonists moved. Prior to about 45,000 years ago conditions were similar to, but probably cooler than, those of today, with a long-term trend towards aridification and increased aeolian activity. In many regions it is likely that up until about 45,000 years ago – and perhaps to 30,000 years ago in some locations – the availability of fresh surface water would have been at least as good, if not better, than during the Holocene. Hence at the time humans began exploring these landscapes they were still drier than many parts of the continental margins, but they were noticeably different from their contemporary state. In each of the three regions reviewed above, and many others not summarized here, seasonal floods and large standing water bodies were common and comparatively predictable prior to 45,000–40,000 years ago in ways that they have not been over the last 35,000 years. We hypothesize that human colonization of these landscapes involved a number of general patterns that reflect the environmental conditions and are likely to be unique to this particular period (a point also made by Thorley 1998).

The greater relative availability and predictability of resources, including large permanent water bodies, prior to 45,000–40,000 years ago, would have facilitated exploration and exploitation of these unique interior landscapes. It is likely that the pattern and rate of exploration and colonization varied between regions in response to the specific nature and distribution of landscape features within each region. Both ethnographic and biogeographic perspectives indicate that colonization is most likely to have taken place along corridors of distinct landscape features such as rivers or mountain ranges (Kelly 2003; Veth 1989). Since such features vary between regions we suggest that there is unlikely to have been a uniform pattern of colonization across these diverse interior landscapes.

More significantly, the movement of people into the interior of Australia prior to 40,000 years ago would have meant that their economic and social systems were developed in response to the existing environmental conditions. Hence, interior colonization may not have required a refined or specific adaptation to extreme aridity. Thorley (1998, 2001) has previously discussed this proposition for the initial human occupation of the central Australian ranges and plains, where Lake Amadeus and the Finke and Palmer rivers catchment would have provided more regular and more abundant resources at the time of colonization than today. Our review suggests that this notion should be extended to many of the inland regions for which we now have evidence. Without doubt the gradual desertification that followed the period of interior colonization (post-35,000 years ago) would have required modifications to foraging and social strategies. However, these modifications would have been made by forager groups which by that time had established familiarity with the landscape structure of each region. Readjustment of economic systems to even rapid trends towards aridity would have been facilitated by local group knowledge of the environment; these groups would have been advantaged by modifying their existing systems *in situ*, building new economic and technological strategies based on knowledge of the local landscape. In this sense we hypothesize that the widespread colonization of the Australian interior prior to the pronounced drying of the late Pleistocene meant that many foraging groups with generalized

terrestrial economic strategies probably evolved more dedicated desert economic strategies *in situ*. This "desert transformation" model removes the paradox of explaining how people were able to migrate into Australian deserts in the late Pleistocene; in some important ways the modern deserts of Australia came to inland dwelling people, rather than the reverse.

Of course, there is no connection of this model with the idea of coastal colonization (*contra* Thorley 1998), since the process we hypothesize implies that groups moving into interior lands had effective terrestrial foraging strategies suited to a variety of dry, semi-arid, and arid landscapes. These were not coastally adapted peoples (also as argued by O'Connor and Veth 2000); but our model predicts they were also foragers without many of the specific desert economic and social traits observable in the late Holocene and historic period. This prediction is consistent with features of the archaeological record in these interior lands. For instance, a number of the strategies taken to be risk reduction responses in the late Holocene desert economies are either absent or little utilized in the archaeological residues of the colonists moving into those regions more than 40,000 years ago. No compelling evidence for trade or long distance transportation of resources has been identified, perhaps not surprising given the exploratory nature of occupation and the indications in extremely low artifact discard rates that population densities may have been very low and perhaps territories large. Furthermore, although grinding stones are likely to have been a technology employed to exploit plant foods throughout Australian prehistory (Fullagar and Field 1997; Gorecki et al. 1997), the earliest archaeological assemblages contain few grindstones. This pattern probably reveals that the intensive processing of seeds, a key characteristic of risk minimization in historical arid zone economic strategies, emerged in response to specific conditions in the Holocene and was neither a central nor a universal feature of the initial occupation of the interior. The exploitation of the large lacustrine and riverine resources that existed at the time, plus the low densities of people occupying many inland territories, may be cited as likely reasons that seed processing was not given the same prominence during the pre-40,000 year old colonizing phase as it was in much later times.

These earliest inland economies were based on a broad spectrum and flexible foraging strategy. Although not all of the early archaeological sites spread across the Australian interior have good faunal preservation, the key characteristics of hunting and animal foods can be defined as follows. A wide range of small to medium sized game was hunted, including marsupials, reptiles, and, near lacustrine systems, fish and mussels. The taxa represented varied between sites and regions in response to local conditions. Plant foods were also exploited, but as explained above, the discovery of grindstones at only one locality to date also indicates variation in the way these broad spectrum systems were implemented.

A radically different view on the economy of colonizing groups proposes that early foragers targeted large land animals and were responsible for the extinction of all megafauna in Australia, during the first millennia of human occupation of the continent (e.g., Miller et al. 1999; Roberts et al. 2001). Many kinds of megafauna (species of animals exceeding 44 kg at adult weight) have become extinct in Australia

over the last 100,000 years; however, the claim that all megafauna became extinct soon after humans colonized Australia is fraught with sampling problems and fails to consider the discovery of sites where megafaunal species existed until only 30,000–20,000 years ago (Field and Dodson 1999; Wroe et al. 2002). More significantly, not a single “kill” site from the initial period of interior colonization has been identified, and it seems doubtful that there could have been enough humans in interior Australia around 50,000–45,000 years ago to cause the extinction of multiple species (Hughes and Hiscock in press). A more likely explanation is that the environmental transformation of the Australian interior through the process of aridification was the trigger for faunal changes of many kinds, including local extinctions. Humans were not immune to those environmental changes and the archaeological sequence records the impact of desertification on inland foragers.

Subsequent Use of Desert Areas of Australia

One consequence of our “desert transformation” model of pre-hyperarid colonization of the interior by generalist foragers concentrating on riverine and lacustrine resources is that desert adaptations emerged during the subsequent period. In this chapter we are concerned with two aspects of the modification of economies: the nature of economic life in the Pleistocene deserts prior to the LGM, and the impact of the LGM on desert dwellers. Archaeological evidence now reveals dynamic and varied subsistence and settlement responses to the onset of desert conditions, and suggests that these responses are not identical to the desert adaptation that emerged in the Holocene.

Following a gradual cooling and drying trend initiated at about 45,000 years ago, the last glacial cycle intensified rapidly with the onset of what is called Oxygen Isotope Stage 2 (OIS2) approximately 30,000 years ago. At that time sea levels dropped rapidly by nearly 50 m over perhaps 1,000 years or less, exposing large areas of the continental shelf and making many inland areas even more continental than they had been (Chappell 1991; Lambeck and Chappell 2001; Lambeck et al. 2002; Yokoyama et al. 2001). From 30,000 to about 20,000 years ago the monsoon was the least effective it had been over the last 100,000 years or so (Johnson et al. 1999); and average air temperatures in low latitude regions, including the continental interior of Australia, appear to have been at least 6–9°C lower than at present (Miller et al. 1997). Many inland areas show pronounced reductions in the availability and reliability of surface water, and of related food resources. For instance, by 35,000 years ago Lake Eyre had become dry and remained so until around 10,000 years ago (Magee and Miller 1998). During the same period there were lower and fluctuating lake levels in the Willandra system and the activation of dune building processes (Bowler 1983b, 1986, 1998). In many other lacustrine systems across Australia lake levels show significant decreases in this period, although the timing varies locally (Harrison 1993). The radically reduced precipitation/evaporation indices in OIS2 had severe consequences for not only water availability but also for vegetation patterns. Transitions to landscapes with reduced

amounts of vegetation, floral assemblages with fewer trees/shrubs, and an increased grassland component have been inferred across many inland regions as extreme desert conditions emerged. Examples of such transformations include Carpenter's Gap 1 in the northwest (Wallis 2001), Puritjarra rock shelter in central Australia (Bowdery 1998; Smith et al. 1995), and Cuddie Springs and Ulungra Springs in northern and western New South Wales (NSW) (Dodson and Wright 1989; Dodson et al. 1993). Changes in precipitation, temperature, and surface water availability acted in concert to enlarge the portion of Australia that would be regarded as desertic, with the semi-arid zone expanding laterally towards the continental margins, the previously semi-arid zone becoming fully arid, and deserts becoming far more inhospitable than they are today (see Jones and Bowler 1980).

At least in the early portion of OIS2 some inland forager groups appeared to have continued and even consolidated their occupation, perhaps refining their generalist economic strategies to suit the landscapes in which they found themselves and in response to the desiccation of those landscapes. Adjustment of groups to different environments implies that localized adaptations were probably emerging at this time. For instance, in some localities, such as the central Murray–Darling lake systems, the number of dated archaeological sites was greater for the period 35,000–25,000 years ago than for earlier periods (Hope 1993). In other regions, such as northwestern Australia, increases in artifact discard rates have been observed within some rock shelters during this period (Morse 1993; O'Connor et al. 1993, 1999). These patterns of increased debris have been interpreted as population growth in some interior localities (e.g., Beaton 1985; Jones 1979; O'Connor et al. 1993). While models of population increase prior to 25,000 years ago are plausible, interpretations of the evidence from some localities indicate the nature and uniformity of occupation clearly varies, and no single trend can be inferred for settlement across the inland. The question of population size raises the unresolved issue of what comprised inland occupation at this time. Although numbers of sites or numbers of artifacts are notoriously unreliable indicators of the amount of human activities or number of people visiting a site, archaeological investigations of Pleistocene rock shelters and lake margins in some regions of interior Australia, such as the northwest and southeast, may indicate relatively high levels of occupation during OIS2 (Balme 1995; O'Connor et al. 1998). In contrast, other landscapes show archaeological sequences with very low artifact discard rates in this period compared to the Holocene (O'Connor et al. 1993; Smith 1989). In some sites artifact discard rates are as low as a few specimens per meter per millennium – rates which are so slow that it is unclear whether this really represents permanent occupation of the territory, or whether occasional but extended excursions by mobile foragers from adjoining landscapes during favorable seasons might be a more accurate interpretation. Irrespective of whether these differences reflect the number of people in residence or their mobility, these indicators of occupation intensity may reveal substantial differences in occupation between regions. For instance, while occupation of lake lunettes in several localities shows systematic, intensive, and sometimes dedicated exploitation of lacustrine resources (Balme 1995; Bowler 1998), there is

minimal evidence of continuing occupation in many of the sandy deserts, except where they are bounded by other kinds of landscapes (see Hughes and Hiscock in press; O'Connor et al. 1998, 1999; Veth 1989). This variation in whether or not we have archaeological evidence for continued occupation probably reflects environmental differences between regions. This is an indication that the colonizing economic strategy, perhaps dependent on reliable access to surface water and focusing on the exploitation of riverine and lacustrine resources supplemented with nearby terrestrial resources, continued to form the core theme of many inland foragers in the period after 35,000–30,000 years ago. In a number of landscapes which retained these features, such as desert regions containing uplands, major coordinated drainage, and/or extant lake systems, archaeological evidence for occupation is found from the start of OIS2; in contrast, archaeological investigations in regions without those features have found little or no evidence of occupation. This contrast parallels Veth's (1989) model that proposed sandy deserts without coordinated drainage and large permanent lakes often acted as barriers to occupation during the Pleistocene and early Holocene. In view of the now apparent widespread colonization of inland Australia, including sandy deserts (O'Connor et al. 1998, 1999), we hypothesize that this pattern of abandonment/avoidance of barriers of sandy deserts arose only during the period of extreme desiccation marking OIS2. If current archaeological evidence can be interpreted as revealing abandonment or greatly reduced use of some desert areas at the start of OIS2, then apparent responses of inland foragers to the intensification of arid conditions around 25,000 years ago can be viewed as an exaggeration of the existing land use strategies.

The intensity of desiccation and consequent geographical expansion of arid interior Australia peaked towards the end of OIS2, during a relatively short phase spanning approximately 25,000–18,000 years ago, which we refer to as the Last Glacial Maximum (LGM). During this period conditions were both exceptionally cold and dry, and it is likely that evaporation was more effective and windiness enhanced compared to today, at least on a seasonal basis (e.g., Chappell 1991; Hubbard 1995; Magee and Miller 1998). Estimates of rainfall typically suggest levels approximately half that of today across interior Australia (Dodson and Wright 1989; Singh and Geissler 1985). The consequences of these extreme conditions must not be underestimated. Across the continent reduced vegetation cover was probably one trigger of a major phase of dune building initiated at this time (Ash and Wasson 1983; Bowler 1986; Bowler and Wasson 1984; Nanson et al. 1991; Wasson 1984) and aeolian dust storms were intense (Hesse 1994; Hesse and McTainsh 1999). Drying of lakes, and more general decline of surface water, was frequently linked to reductions in the level of water tables and, in some localities, formation of salt crusts on lake surfaces (Magee et al. 1995).

These extreme conditions during the LGM caused widespread environmental stress, triggering massive – sometimes irreversible – changes to the landscape and to plant and animal resources. Some of these changes involved the temporary disappearance of food resources, such as in the Willandra Lakes where alterations to temperature, salinity, and water levels caused the loss of fish and freshwater mussels (Bowler 1998). Other kinds of changes may have involved a reduction in

the predictability of resources, such as greater periodicity or irregularity in the refilling of water sources from rainfall. During this period it is likely that many portions of inland Australia were substantially drier than today, and archaeological research has yielded many instances of sites in which the absence of cultural material during the LGM indicates local or regional abandonment (Hiscock 1988; O'Connor et al. 1993, 1998, 1999; Veth 1989). Yet in other isolated inland regions occupation persisted, apparently within better resourced refuges. Sometimes these refuges were ranges or desert tablelands with aquifer-recharged water sources which provided plentiful, and more importantly unvarying, sources of water, as well as plants and animals (Hiscock 1984, 1988; Lamb 1996; Smith 1987, 1989). People may have exploited broader territories from these reliable bases, but in at least the case of Lawn Hill and Louie Creek Gorges in northern Queensland a contraction of territory has been demonstrated, with the residents abandoning high risk portions of the landscape from approximately 22,500 until 16,500 years ago (Hiscock 1988). Similar patterns of territorial contraction have been observed on Cape York and in northwestern Australia (Lamb 1996; Marwick 2002). These refuges would have supported only small groups of humans, and perhaps only on a semi-permanent basis, depending on the number of people and resource abundances in and around the refuge. The lake systems of western NSW represent another, perhaps shorter lived kind of refuge; there the appearance of grinding stones in archaeological deposits, either during or immediately after the LGM, is an example of the use of technological means to broaden resource use and obtain reliable access to food (Bowler 1998). Another predicted strategy would have been for groups of foragers to retreat to the semi-arid margins of inland Australia and to undertake long range trips to explore the arid zone during favorable conditions.

One implication of decreased exploitation or abandonment of many deserts is that at some time following the termination of the LGM and coincident with the amelioration of climatic conditions foragers recolonized all portions of interior Australia. The timing and process of such recolonization events appear to be complex. In some localities, such as the JSN site in the Strzelecki Desert, there may be near immediate, if fleeting, exploration or exploitation of the desert (see Hughes and Hiscock in press). Another rapid resumption of land use occurred around the Lawn Hill and Louie Creek Gorges, where resource exploitation in once-abandoned landscapes was reinitiated approximately 17,000–16,000 years ago (Hiscock 1988). However, there are regions of the arid zone in which the earliest dated evidence of human reoccupation takes place many millennia after the end of the LGM (Hughes and Hiscock in press; Morse 1988; Veth 1989). These differences may reflect the environments being recolonized, especially in the favorable climatic conditions of the early Holocene. However, they also probably reflect the historical circumstances of the colonizing groups, namely whether they derived from an LGM refuge or from non-arid lands on the continental periphery, whether the colonizing groups possessed specific economic or technological capacities that might enhance their ability in the new desert landscapes, and so on. When desert occupation recommenced and/or intensified in the Holocene the distinctive recent desert economy is clearly visible, most easily recognized by the frequent use of

grindstones to process reliable and abundant grass seeds, the abundant discard of tula adzes reflecting standardized woodworking, and the ramified long distance social and economic networks (Veth 1989). We can therefore date the emergence of that late Holocene strategy for desert adaptation to the terminal Pleistocene or early Holocene; that is, the period after the LGM. Like Veth (1989), we suspect that the roots of these Holocene adaptive systems may eventually be traced to the experiences of foragers in the refuges of the LGM.

Australian Desert Colonization in a Global Perspective

Our synthesis indicates that an arid zone adaptation, of the kind observed historically, was absent from the initial colonization of the Australian deserts, and indeed from inland economies prior to the LGM. We therefore support Veth's (1989) suggestion that the ethnographic forms of desert economy and subsistence are relatively recent, rather than representing features of inland occupation from the start (*contra* Gould 1977). Our hypothesis is that the historic form of desert adaptation in Australia emerged subsequent to the LGM, perhaps as a consequence of heavy selection/experimentation during the hyperarid conditions of that period and the later recolonization of desert areas.

Because the evidence from Australia, both archaeological and environmental, is exceptional in its extent and detail, we have developed these propositions in reference to the Australian landmass. We now turn to a consideration of whether the pattern of early desert occupation in other parts of the globe displays similarities with the Australian situation. The following review briefly examines available evidence from current desert regions of Africa, North America, and South America.

In southern Africa the environmental and archaeological history of the Kalahari Desert is known from only fragmentary records (Deacon and Lancaster 1988). As in Australia, the period leading up to the onset of OIS2 was wetter and more humid than today, while cold, dry, and arid conditions persisted through OIS2, and wetter and more humid conditions returned in the terminal Pleistocene and early Holocene (Blumel et al. 1998; Brook et al. 1996; Lancaster 1989; Robbins et al. 1996; Scott 1989; Shaw and Thomas 1996; Thomas and Shaw 2002; Thomas et al. 2003). Archaeological data from the Tsodilo Hills in the northwest Kalahari (which, it should be noted, is currently considered sub-humid rather than arid) reveals human occupation throughout the last 100,000 years, irrespective of climatic conditions (Robbins et al. 2000). Nevertheless, during periods of higher relative precipitation and more permanent water resources (such as during the terminal Pleistocene) there is evidence for more substantial occupation, with foragers exploiting nearby lacustrine resources. This image of Kalahari foragers with knowledge of the local environment adjusting to the onset of aridity offers some similarity with our interpretation of Australian prehistory.

By contrast, while it is often stated that the Namib Desert situated along the southwest coast remained hyperarid throughout the late Quaternary, there is

evidence to indicate it experienced periods of relatively increased humidity prior to the LGM and in the terminal Pleistocene–early Holocene period (Heine 1992, 1998; Lancaster 2002; Vogel 1989). Current archaeological evidence from within the Namib indicates use of the area during posited periods of relatively greater moisture availability, although given the lack of resolution about local impacts of climatic changes it is unclear whether this represents a permanent or intensive desert adaptation prior to the Holocene (Deacon and Lancaster 1988: 51–2).

At the other end of the African continent the also fragmentary archaeological and climatic records from the Sahara–Sahel Desert for the period between 100,000 and 50,000 years ago tentatively reveal a positive relationship between the timing of lacustrine phases and presence of Acheulian and Levallois-Mousterian sites, although the timing of the lacustral phases is not necessarily in concert with those in the south (Petit-Maire 1991). Unfortunately, despite good climatic records of a hyperarid LGM–terminal Pleistocene followed by a substantial wet phase during the early Holocene (Gasse 2002; Haynes et al. 1989; Hoelzmann et al. 2001; Pachur and Hoelzmann 2000; Pachur and Wunnemann 1996; Salzmann 1996), the response of foragers to these environmental changes prior to the introduction of cattle domestication in the Holocene is little known.

These three African areas share a pattern of long-term human occupation, perhaps extending back to and beyond the emergence of modern *Homo sapiens sapiens*, and there is evidence, albeit tentative, for continued occupation in some regions despite dramatic changes in climate, water availability, and food resources. Although current archaeological and paleoenvironmental evidence is limited, it appears that each region displays occupational histories that share both similarities and differences to the one reconstructed for Australia, as well as similarities and differences between each other. This perhaps suggests that no single process of desert colonization is displayed and that settlement patterns reflect the environmental and historical features of each landscape. This proposition is clarified by summaries of the situation in the New World.

Desert adaptations in the Americas offer a different context in which to test models of desert colonization, primarily because the generally accepted antiquity of humans in the New World dates to only 14,000–12,000 years ago, following the end of the LGM. Our review of the terminal Pleistocene occupation of American deserts examines three landscapes: the Great Basin of North America, the cold deserts of Patagonia and Tierra del Fuego, and the high altitude deserts of the Atacama and Peruvian coast.

In the Great Basin available evidence indicates lower temperatures and higher average annual precipitation rates in the terminal Pleistocene period compared to today (Grayson 1993; Thompson 1990; Wells 1976; Woodcock 1986). Under these conditions there would have been greatly expanded water resources available within the Basin, with one estimation suggesting there would have been perhaps ten times more surface water than at present (Grayson 1993: 84–6). When combined with the presence of glaciated mountainous regions (Osborn and Bevis 2001) these lacustrine and riverine features meant that late Pleistocene hunter-gatherers in the Great Basin operated in a very different environment to the one

that exists today. Archaeological evidence indicates people had moved into the Basin by 11,000 years ago and continued to be archaeologically visible and widespread until ca. 7,500 BP (see Chapter 5, this volume). During this period they were utilizing a broad array of resources from a wide range of environmental settings, although there seems little doubt “the lakes and marshes were key to the adaptations of these people” (Grayson 1993: 242). In contrast, high temperatures and low annual precipitation produced substantially more arid conditions during the mid-Holocene and marked economic change involving a settlement focus on remaining permanent sources of water and the emergence of seed grinding technology (Elston 1986; Grayson 1993; Thomas 1982; Warren and Crabtree 1986). This pattern of a late emergence of the historic desert economic system, during a phase of Holocene aridification, parallels the Australian experience.

In Patagonia and Tierra del Fuego people probably colonized now arid regions in the terminal Pleistocene as highly mobile foragers concentrating on forest resources, with initial colonization delayed in some deserts until climate change at the Pleistocene/Holocene boundary increased precipitation and water availability (Borrero 1999; Markgraf 1989, 1993; McCulloch et al. 1997; see also Chapter 8, this volume).

The Atacama Desert and adjacent Peruvian coastline is today a high altitude desert. Initial occupation of this desert region apparently occurred about 13,000 years ago, when environmental conditions can be characterized as relatively humid, with extensive grass cover, abundant flowing rivers, and high lake levels (Betancourt et al. 2000; Grosjean and Nuñez 1994; Latorre et al. 2002, 2003; Nuñez et al. 2002; Rech et al. 2002; Sandweiss 2003; see also Chapter 13, this volume). The extensive occupation of the region during a period prior to the transition to current environmental conditions may have facilitated the *in situ* development of a more specific desert economic strategy, a mechanism with similarities to the process apparent in Australia.

Conclusion

Colonization of deserts is a widespread and varied human experience. Our review of selected desert areas has revealed that the timing and process of colonization has varied within and between continents, but that there are themes that are displayed in the initial movement of people into landscapes that are currently deserts. This exploration of these processes has centered on what we believe to be the most comprehensive environmental and archaeological data-set, the extensive Australian deserts. Prehistoric patterns in Australia are explicable in terms of the “desert transformation” model advanced herein, in which people colonize terrestrial landscapes using flexible and generalized broad spectrum foraging focused on available riverine and lacustrine resources. This model posits that following the adjustment of these foragers to the local resources climatic trends towards aridification transformed these landscapes into desert, or more extreme desert, environments. This process of foragers developing modified economic behaviors in response to

changes to their familiar environment provides an explanation for the development of diverse practices suited to different Australian deserts. Similar processes have been observed elsewhere in the world, particularly in the Americas, and represent one mechanism by which Pleistocene foragers colonized deserts. Distinctive desert adaptations of the kind seen in historical records arose much later than the period of initial desert colonization, in many cases only well into the Holocene. The emergence and form of specific historic desert economic and social systems also varied around the globe in response to specific contingent environmental and cultural histories. For instance, the occupation of Australian deserts was interrupted, and perhaps fundamentally altered, by the severe, hyperarid conditions of the LGM. In contrast, while it seems likely that the onset of desertic conditions in the Holocene of North and South America was not as extreme as those experienced during the LGM, they were apparently still dramatic enough to precipitate substantial shifts in American forager strategies. While archaeology and paleoenvironmental data from African deserts are not as yet sufficiently detailed to allow such interpretations, we have little doubt that future sustained research in these localities will reveal unique histories of desert dwellers and their cultural responses to periods of extreme climatic change during the late Pleistocene and Holocene periods.

Exploring the dynamic and changing relationship between climate, landscape, and the human colonization and occupation of dry regions is likely to refine our understanding of the processes by which people moved into and adapted to these landscapes. The central limitation archaeologists currently face in refining models of ancient desert dwellers is the rarity of detailed, paired environmental and archaeological sequences (cf. Veth et al. 2000). As high resolution paleoenvironmental and archaeological information is obtained, the choices that past peoples made about their survival strategies, and the context in which they made them, will become increasingly clear.

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