At the close of the nineteenth century, fossil finds at Lake Callabonna altered perceptions of the inland, showing that even the driest and bleakest parts of the Australian interior once teemed with life (Editorial, *The South Australian Register*, 24 May 1893).

In 1893, members of a museum expedition to Lake Mulligan (as it was then known – a corruption of *malakanha*, the Adnyamathanha name for ‘a type of string bag’) found the saltlake covered with bones of extinct giant marsupials, ‘which have apparently died where they lie, literally in hundreds’ (Stirling 1900: iii) (Figure 3.1). The most common remains were of *Diprotodon optatum*, a large herbivore, which at 2.8 tonnes was the largest marsupial ever to have lived (Wroe et al. 2004) (Figure 3.2a). Hundreds of these animals had been trapped as they broke through the salt crust into the saturated clays below while attempting to cross the lake bed to nearby springs.

The museum dig did not get off to a good start. When Edward Stirling, the director of the South Australian Museum, visited the site, he found ‘utter carelessness, slovenliness, and want of system’. It would, he said, ‘be difficult to imagine the camp of a scientific expedition in a more disgraceful condition’ (EC Stirling, Report to Board of Governors, 28 August 1893). Stirling promptly dismissed HC Hurst, the geologist initially contracted to extract the fossils, and left ACH Zietz, a museum officer, to assume direct control of the work. For three months, Zietz and his team worked at Callabonna, under appalling conditions: ‘Innumerable flies were, in the day-time, a constant and maddening source of annoyance’ (Stirling 1894: 210). Heavy rain, frequent sandstorms, daytime temperatures of 120°F (49°C) and bad water led to ‘ophthalmia and gastro-intestinal complaints’ (1894: 211). ‘Every stick of firewood’ and every drop of drinking water had to be carried in by camels. Meat sometimes ‘went bad before the day was out’ (1894: 187). Many of the fossil skeletons were exposed on the surface, outlined by patches of fragmented bone and pieces of tooth enamel. Zietz located buried skeletons by probing through the lake mud with steel rods. Rabbits swarmed over the diggings,
destroying many bones in a frantic attempt to get at the salty groundwa-
ter seeping into hollows around Diprotodon skeletons. Bones disintegrated as
sodium sulphate salts crystallised in fracture lines and cavities.

By the close of the dig, the museum had recovered the remains of about
100 animals (Stirling 1894: 209), including the first complete skeletons of
Diprotodon and partial skeletons of Genyornis (a large flightless bird), Phascolonus
(an extinct giant wombat) and Sthenurus (an extinct short-faced kangaroo)
(Stirling 1900; Pledge 1994; Wells and Tedford 1995). In his book The Dead
Heart of Australia, JW Gregory summed up the new picture. The Lake Eyre
basin had formerly been ‘a vast inland sea’ but with declining rainfall, the lake
had dried: ‘hot winds swept across the dusty plains, and the once fertile basin
of Lake Eyre was blasted into desert’ (1906: 150–1).

Later research has shown that these arid landscapes preserve a palimpsest
of ‘lacustral’ or mega-lake phases of varying age and declining amplitude –
beginning with the perennial lakes and palaeodrainage systems of the late
Tertiary landscape (about 24 Ma), with active but more limited rivers and
apalaeolakes during marine isotope stages (MIS) 5 and 7 (132–71 ka; 236–186
ka), and a modest reactivation of semi-arid lake and river systems early in MIS3
(60–45 ka). This raises an obvious question. What was the desert like on the
eve of human settlement? Did the first people entering this region encounter
deserts and drylands, or did they find a landscape of rivers and lakes? In this
chapter, I review recent work on the age and origin of Australian deserts and their biota and look in more detail at Quaternary environments in MIS5 prior to human settlement of the region.

THE ‘DESERT TRANSFORMATION’ CONCEPT

One possibility, widely canvassed, is that at the time of colonisation, aridity may have been only modest and that the first colonists would have found a richer landscape, one with active rivers and large permanent lakes. In 1961, DJ Mulvaney wrote that ‘reliable rainfall extended across the heart of the continent. Perennial rivers drained into inland seas...there was a spread
of rain-forest flora over the centre of the continent... [and] a diversified and predominantly herbivorous land fauna’ (Mulvaney 1961: 63). Later, after Bowler’s research on the Willandra Lakes, the idea that ‘the Mungo Lacustrine Phase would have given major access to the reactivated river and lake systems which ringed the arid heart’ (Jones 1979: 453) gained currency among many researchers (White and O’Connell 1982; Hiscock 1988a; Ross, Donnelly and Wasson 1992; Thorley 1998a; Hiscock and Wallis 2005: 43). In her ‘coastal colonisation hypothesis’, Bowdler (1977) argued that early sites in the Murray–Darling basin represented a ‘transliterated coastal economy’ centred on rivers and lakes. Thorley (1998) extended this idea to Central Australia, suggesting that Lake Amadeus and the Finke–Palmer river system would have provided more regular and abundant resources at the time of colonisation than today. Hiscock and Wallis brought these ideas together in their ‘desert transformation’ model, arguing that the presence of large permanent water bodies prior to 45–40 ka ‘facilitated exploration and exploitation of these unique interior landscapes’ and that ‘the modern deserts of Australia came to inland dwelling people, rather than the reverse’ (2005: 41–3). The alternative view – which I endorse in this book – is that the first people to move into the interior found an arid landscape and xeric biota. This was a desert whose vital statistics were somewhat different from the desert today but an arid environment nonetheless.

Chronology is critical to this question. Luminescence and palaeomagnetic dating have recently provided the means to unpick the series of fluvial and lacustrine events in the interior. As a more detailed environmental history has emerged, these archaeological ideas risk creating an amalgam of landscapes of widely different age and potential, conflating evidence from the last interglacial (MIS5.5, 132–115 ka) with conditions in early MIS3 (60–45 ka).

AGE AND ORIGIN OF AUSTRALIA’S DESERTS

Australia’s deserts date to the early Pleistocene (0.9–2.0 Ma), when arid landforms such as dunefields, saltlakes and stony deserts first appear in the Cainozoic record. However, the development of aridity in Australia appears to have progressed in a stepwise fashion (McLaren and Wallace 2010), and many elements of drylands biota appear much earlier, in the Pliocene (5–2.6 Ma) (Martin 2006).

To understand the landscapes of arid Australia, we need to look beyond the Pleistocene to the late Tertiary. During the last 24 million years, Australia has been gradually transformed from a humid, forested land to an arid continent. A transition to drier conditions began in the mid-Miocene (15 Ma), as continental drift brought the continent into the mid-latitudes, and as strengthening of the Antarctic circumpolar current drove changes in global circulation (Bowler 1982). During the early part of this period, large perennial lakes dominated
the central Australian landscape. These have left distinctive sedimentary units of lacustrine clays and dolomites across much of the region. The best known of these is the Etadunna formation in the Lake Eyre basin. Palaeomagnetic dating provides a late Oligocene age (26–24 Ma) for the Etadunna formation (Woodburne et al. 1993), but biostratigraphy suggests that the upper parts of the formation extended into the late Miocene. Whatever the case, Etadunna clays and dolomites represent the basal stratum underlying most Quaternary sequences in the Lake Eyre region. The Etadunna formation records an extensive shallow alkaline lake – or series of lakes – fluctuating in depth and extent and surrounded by alluvial plain and fan sediments (Wasson 1982; Alley 1998). These lakes supported an abundant aquatic fauna, including cattail, lungfish, crocodiles, chelid turtles and river dolphins, as well as a diverse assemblage of waterfowl, including waders and flamingos (Miller 1963). Equivalent late Miocene units in Central Australia show that large perennial freshwater lakes were also present at Lake Lewis (Anmatyerre clay, English et al. 2001) and Lake Amadeus (Uluru clay, Chen and Barton 1991; Chen, Bowler and Magee 1993). Like many saltlakes, both Lewis and Amadeus are part of chains of playas following ancient palaeodrainage networks that last saw significant flows prior to 15 Ma (Van de Graaff et al. 1977; Magee 2009). Palaeomagnetic dating of the laterites that form extensive hardpans across western and central Australia also shows that the main period of laterite formation was in the late Oligocene–early Miocene (Alley 1998), consistent with warm and wet climatic conditions throughout the Miocene.

Plant fossils show that the Lake Eyre basin was covered by forest until about 24 Ma, with rainforest and swamp vegetation in valley bottoms and seasonally dry sclerophyll forest on slopes and ridges (Truswell and Harris 1982; Hill 1994; Martin 2006). There is little evidence, however, for grasslands at this time (Martin 1990). Until recently, the distinctive Livistona palms in the Finke Gorge, Central Australia, were thought to be a relict of this Tertiary climate (Latz 1975; Wischusen, Fifield and Cresswell 2004; Crisp et al. 2010), but genetic research now shows that these palms were introduced during the late Pleistocene (Kondo et al. 2012). Evidence from the Pilbara shows that dry forests – mainly eucalypts and casuarina – with small patches of rainforest extended across the interior until the mid-Miocene (Macphail et al. 1994: 229).

Increasing continental desiccation after 15–12 Ma is reflected in the end of the Miocene lakes – although these basins continued to structure later (less extensive) lacustrine phases. In Central Australia, Lake Amadeus switched from shallow freshwater conditions to a groundwater-controlled playa at 1.6–0.91 Ma, with the formation of gypsum shoreline dunes by 0.98–0.73 Ma marking the onset of pronounced seasonal aridity in the heart of the continent (Chen et al. 1993). Lake Lewis made the transition to saline conditions somewhat later, at about 350 ka (English et al. 2001).
Drier conditions during the Pliocene are also reflected in the formation of widespread silcrete duricrusts that cap the Etadunna formation and create the distinctive central Australian landscape of tabletop hills and breakaways (Mabbutt 1971b; Alley 1998). Cosmogenic exposure ages show that by 4 Ma, the stripping of soil mantles from these silcrete tablelands may have begun, leading to the formation of Australian stony deserts between 4 and 2 Ma (Fujioka et al. 2005). Exposure ages on dunes in the western Simpson Desert also show that this enormous dunefield had begun to form by 1 Ma (Fujioka et al. 2009).

Plant fossils show corresponding changes in palaeovegetation. The Pliocene saw a shift to dry eucalypt and casuarina woodlands, chenopod shrubland, and a major expansion of grasslands. Martin (2006) points out that many typically arid-zone taxa (for example, eucalypts, acacia, chenopods) were in Central Australia long before it became arid, occupying other niches (such as sandy or saline lakeshores). Continental desiccation simply filtered out taxa that could thrive in new circumstances.

These environmental changes set the stage for a rapid evolutionary diversification of a range of dryland animal taxa. Most extant Australian marsupials owe their existence to a proliferation of species adapted to drylands – the marsupial ‘radiation’ – which took place in response to increasing continental aridity and the loss of forests and rainforests after 15 Ma (Long et al. 2002; Dawson and Dawson 2006; Dickman and Ganf 2007; Byrne et al. 2008). The earliest grazing kangaroos (Macropodines) and wombats appear in the early Pliocene, and these lineages diversified rapidly to exploit the expanding grasslands. Another group that was common in the late Tertiary fauna are the dromornithids: a family of large terrestrial birds that includes Genyornis and Dromornis. The Alcoota site, northeast of Alice Springs, provides one of the few fossil assemblages from Central Australia dating to the late Miocene (at about 8 Ma) (Megirian, Murray and Wells 1996; Murray and Vickers-Rich 2004). It represents waterhole-tethered mortality during a drought and is dominated by dromornithids and diprotodontid herbivores – but also includes thylacines (marsupial wolf), crocodile, large varanid lizards (Megalania), ducks and flamin-goes.

This diversification was accompanied by an evolutionary trend towards larger body mass that reached its most extreme expression in the 2.8 t Diprotodon optatum (see Figure 3.2a). In this sense, the Australian megafauna were a product of the development of Pliocene and Quaternary drylands. Larger herbivores coped better with a low-quality fibrous diet, but this advantage was offset by longer generation times, smaller populations and a greater reliance on free water (Archer and Hand 2006). The corollary of this is that although these animals were adapted to drylands, they were unable to cope with open desert or high environmental stochasticity.
Collectively, these data suggest that much of the desert landscape we see today had taken shape by the early Pleistocene, at a time when global cooling initiated the Quaternary ice ages. Open dryland habitats, such as grasslands and stony desert, developed earlier, in the Pliocene, and were accompanied by an expansion of dryland biota. But the diverse components of the modern desert biome were not assembled until the early Pleistocene.

THE LAST INTERGLACIAL IN AUSTRALIAN DESERTS

Quaternary Context

The Pleistocene saw a much less stable climate, as global circulation adjusted to the periodic growth and decline of high-latitude ice sheets and glaciers. This period was marked by a repeated cycle of rapid global warming followed by more gradual cooling. These oscillations form a distinctive sawtooth pattern, with the warm peaks roughly 100,000 years apart (Figure 3.3). The cornerstone of this Quaternary sequence is the deep-sea oxygen isotope record from marine foraminifera, which define a series of marine isotope stages (Martinson et al. 1987; Bassinot et al. 1994). By convention, the cold, dry glacial stages are given even numbers. Warm interglacial stages have odd numbers. In Australian drylands, these climatic oscillations are mainly reflected in cyclic fluctuations in available moisture: interglacials reactivated lakes and rivers across the interior; the colder drier glacial periods are marked by active dunefields and windblown dust.
The most important of these climatic oscillations for understanding the natural prehistory of Australia’s deserts is MIS5, which encompasses the last interglacial (substage 5.5 or 5e). This period represents the last significant imprint of widespread fluvial and lacustrine activity in the arid zone. It also provides a key benchmark for comparison because we can use conditions during the last interglacial as a best-case scenario for conditions likely to have been encountered by people moving into the desert 45,000 years ago (see Chapter 4). In this context, it represents the upper limit of the range of possibilities for these inland landscapes.

Globally, the last interglacial (MIS5.5) was the last time when global climates were similar to those today (Kukla et al. 2002). It is the warmest interglacial in the 800 ka EPICA Dome C ice-core record (Mausoleum et al. 2010) and may have been a little warmer and wetter than present. It is conventionally dated to 132–115 ka (Shackleton et al. 2002), but new thermal ionisation mass spectrometry (TIMS) uranium/thorium (U/Th) ages, coupled with a δ18O record of precipitation from speleothems at Dongge Cave, China, indicate a narrower span of 129–120 ka (Yuan et al. 2004). Most records then show a shift to progressively colder and drier conditions from 116–115 ka, with rapid swings in climate (Kukla et al. 2002). MIS5 ended about 71 ka as the world entered another dry, windy glacial phase. This is also marked by a peak in windborne dust at 70–60 ka in the Vostok ice core in Antarctica (Petit et al. 1999). Palaeoenvironmental records in Australia’s deserts register these shifts in various ways: ‘reduced monsoon rain in global cold stages caused lakes and rivers to dry, vegetation to become more sparse, sand dunes to become active, and dust advection to increase’ (Hesse, Magee and van der Kaars 2004: 118).

Lakes and Saltlakes

One of the paradoxes in Quaternary research is that the history of deserts is commonly a history of lakes and rivers. In Australia, the sedimentary record of lakes and rivers in the arid and semi-arid zones has been the cornerstone of late Quaternary research in these regions. The best-developed records are those from Lake Eyre, Lake Frome and the Willandra Lakes, but important data have also come from Lake Amadeus and Lake Lewis, in Central Australia, and from Lake Gregory and Lake Woods on the northern desert margin.

Bowler’s ‘hydrological threshold’ (1981) provides the key to understanding variability in these lake basins and their differential response to climatic shifts. Lakes in closed basins are controlled by catchment size (relative to lake area) and the hydrologic balance between inflow and evaporation (Figure 3.4). Most of the large saltlakes, dotted across Central and Western Australia, have small catchments relative to their surface area and are unlikely to have ever functioned as palaeolakes during the late Quaternary. In most cases, these have remained as playas, controlled by groundwater processes, for some 700 ka. In contrast,
Figure 3.4. Bowler’s ‘hydrological threshold’ for Australian lakes. This shows the relationship between catchment and lake areas (Ac/Al) and climatic parameters. Some ephemeral lakes with large catchments will become permanent water bodies with only a modest climate change. Other lakes, which are playas under modern conditions, require large shifts in climate to change state. The climatic function (Fc) is \((0.8E - P/Pf) +\) 1, using a pan evaporation (E) factor of 0.8 for the lake surface, precipitation (P) and a runoff coefficient (f) of 0.1. (After Bowler 1981: fig. 30.4; English et al. 2001: fig. 3)

Lakes that have the ‘amplification’ of large catchments are particularly sensitive to changes in climate; with comparatively small changes in precipitation or evaporation, they can switch from dry lake basins to ephemeral or permanent palaeolakes. Amplifier lakes are rare in the desert. The main examples are Lake Eyre and Lake Lewis and lakes on the desert margins fed by catchments outside the arid zone, such as the Willandra Lakes, Lake Gregory, and Lake Woods.

Lake Eyre: ‘A continental rain gauge’
Lake Eyre, today an ephemeral playa lake (9,690 km²), forms the centre of Australia’s largest internal drainage basin, covering 1,215,000 km² (Figure 3.5). It is fed by summer monsoon rainfall in the north and receives water through the Warburton–Diamantina–Georgina and Cooper–Thomson–Barcoo river systems from the northeast, and the Macumba and Neales Rivers from the west. In the past, Central Australian rivers, such as the Finke and Todd, which are now cut off by the Simpson Desert dunefield, also reached the lake. Because Lake Eyre is sensitive to changes in precipitation over such a large proportion...
of Australia, geomorphologist John Magee has called it ‘a continental rain gauge’.

In this context, the single most important contribution to the Quaternary history of the desert has been J Magee’s reconstruction of the lake’s palaeohydrology for the last 130 ka (Magee et al. 1995; Magee 1997; Magee and Miller 1998) (Figure 3.6). His work on the stratigraphy of shoreline features and sedimentology of lacustrine sequences, and the dating and cross-correlation of these using a range of Quaternary dating techniques – including optically stimulated luminescence (OSL), U/Th, amino acid racemisation (AAR), and radiocarbon ($^{14}$C) – shows there was a major lake expansion during MIS5 that...
created a deep permanent water body between 130 and 90 ka. This immense interglacial lake was up to 25 m deep and extended over more than 25,000 km\(^2\) (see Figure 3.5). By comparison, the 1974 flooding of Lake Eyre (Bonython and Fraser 1989) – the largest historical filling on record – created an ephemeral lake only 6 per cent of the size of the MIS5 palaelake (Table 3.1). Although the interglacial palaelake was permanent, it was mostly saline, with marked salinity stratification and anoxic bottom conditions.

This ‘inland sea’ was not rich in resources compared with shallow freshwater lakes such as the Pleistocene Willandra Lakes. Shells and shell fragments are abundant in beach sediments. These are mainly *Corbiculina* bivalves and the lake-bottom gastropods *Coxiella* and *Coxiellada* (Magee 1997), none of which is a prime shellfish species for hunter-gatherers. The most common eggshell in these beach deposits is pelican. Numerous small fish bones (vertebrae, head plates and spines) are present, including some dense, thin, horizontally

<table>
<thead>
<tr>
<th>MIS</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5.1</th>
<th>5.2</th>
<th>5.3</th>
<th>5.4</th>
<th>5.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age ka</td>
<td>0</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>40</td>
<td>50</td>
<td>60</td>
<td>70</td>
<td>80</td>
</tr>
<tr>
<td>Lake level (m relative to AHD)</td>
<td>-20</td>
<td>-10</td>
<td>0</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>40</td>
<td>50</td>
<td>60</td>
</tr>
<tr>
<td>Dates shown are pooled ages (TL/OSL) for each lacustral phase. Lake levels are plotted relative to Australian Height Datum (AHD).</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 3.6.** Lake-level curve for Lake Eyre (after Magee et al. 2004: fig. 2, updated from Magee 1997: fig. 6.4). Dates shown are pooled ages (TL/OSL) for each lacustral phase. Lake levels are plotted relative to Australian Height Datum (AHD).

### Table 3.1. Lake Eyre, comparing the size of the last interglacial lake and the largest historical filling

<table>
<thead>
<tr>
<th>Lake Eyre</th>
<th>Lake area km(^2)</th>
<th>Water depth m</th>
<th>Lake volume km(^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modern playa</td>
<td>9,690</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Historic 1974 flooding</td>
<td>8,020</td>
<td>6</td>
<td>21</td>
</tr>
<tr>
<td>Final deepwater lake 65 ka</td>
<td>9,920</td>
<td>19</td>
<td>74</td>
</tr>
<tr>
<td>Last interglacial MIS 5.5(^a)</td>
<td>25,260</td>
<td>25</td>
<td>332</td>
</tr>
<tr>
<td>Last interglacial MIS 5.5(^b)</td>
<td>34,250</td>
<td>25</td>
<td>430</td>
</tr>
</tbody>
</table>

\(^a\) Excludes Frome-Gregory basin.

\(^b\) Includes Frome-Gregory basin.

*Source:* DeVogel et al. 2004
continuous accumulations of fish bone. These suggest a cycle of boom and bust associated with flood events. Today, ephemeral floods are notable for the high levels of nutrients flushed into the lake, leading to blooms of invertebrates, followed by rapid growth of fish and waterfowl populations, and the collapse of this system as the halite crust dissolves. Because any disruption to the salinity stratification of lake waters has catastrophic consequences for invertebrates, fish and waterfowl populations, the ecology of the interglacial lake is likely to have been characterised by high levels of environmental stochasticity.

After 90 ka, the lake entered a long unstable phase, during which it frequently switched state – occasionally drying out, or oscillating among shallow ephemeral conditions, a deep saline lake, and brackish or fresh interludes. The final pulse of the lake was at 65–60 ka, when water returned in a still-stand that created a beach rich in tiny *Coxiellada* shells (a ‘coquina’): ‘This represents the last deep-water perennial lake in the basin’ (Magee et al. 2004: 886). From 65 ka to 60 ka, the lake switched to a groundwater-dominated playa (Magee and Miller 1998) – apart from minor lacustrine events around 50–40 ka and between 12 ka and 4 ka that each created a saline lake 5 m deep, smaller than the 1974 filling.

**Other Inland Lakes**

The palaeohydrology of Lake Eyre reflects a stronger, more active monsoon during MIS5, and it is not surprising, therefore, that other inland lakes, especially in northern Australia, share the imprint of this. On the northern margins of the desert, Lake Gregory and Lake Woods have palaeo-shorelines that indicate both were much larger perennial lakes about 100–96 ka (Bowler et al. 1998; Bowler, Wyrwoll and Lu 2001). Both remain active ephemeral lakes today, representing terminal lakes fed by inflows from the northern subtropics. These are likely to have been freshwater systems: at Lake Gregory, this is confirmed by the remains of beds of *Velelesunio* mussels.

The northern lakes are matched on the southeastern margin of the desert by the Willandra Lakes, which are fed by runoff from the southeast Australian highlands. These also appear to have had high lake levels during MIS5 (represented by the Golgol unit at Lake Mungo), but this is only poorly dated (>126–98 ka) or defined (Bowler and Price 1998). All of these lakes appear to have been reactivated to varying extent early in MIS3 (50–45 ka), making them an obvious focus for hunter-gatherer groups moving into the desert (for example, Bowler et al. 1998; Veth et al. 2009).

In Central Australia, Lake Amadeus was a hypersaline playa during the last interglacial, although the regional water table was higher than it is today. The deposition of shoreline gypsum before 82 ka and from 60 ka to 45 ka shows that the lake waters were mainly saturated brines, subject to seasonal drought, with deflation of sand-sized CaSO4 from the near-shore seepage zone to form local dunes (Chen et al. 1993). Nearby Lake Lewis shows a similar pattern...
The Empty Desert: Inland Environments Prior to People

By 80–70 ka, this was a groundwater-controlled basin, with shallow lake waters, high levels of salinity and precipitation of carbonates and sulphates (Chen, Chappell and Murray 1995; English et al. 2001).

To the southeast of Lake Eyre, Lake Frome appears to have been a perennial standing body of brackish water during the last interglacial (this mega-lake is termed Lake Millyera by Callen, 1984). This dried towards the close of MIS5. Callen saw this as recording ‘the demise of permanent brackish lakes in the northeast of South Australia’ (1984: 172). However, recent research shows Lake Frome refilled again around 70–60 ka and 48–45 ka (Cohen et al. 2012), with fluctuating salinities and water levels since then (De Deckker, Magee and Shelley 2011). From 30 ka, the lake became increasingly saline and ephemeral, with occasional flushes of fresh water and, after 20–15 ka, it was mostly a saline, groundwater-controlled playa. This shows that fluvial and lake systems on the southeastern margins of the desert responded to shifts in winter rainfall and reduced evaporation and that they may have different histories from lakes further north. Lake Callabonna is one of a chain of salt lakes linking Lake Eyre and Lake Frome. An OSL age of 75 ± 9 ka for sediments inside one of the excavated *Diprotodon* crania (Roberts et al. 2001) suggests this system last carried water towards the end of MIS5. Both the presence of surface skeletons and the preservation of *Diprotodon* trackways on the lake floor (Tedford 1984) show that there cannot have been significant reactivation of this lake since that time.

### THE ARID RIVERS

The river systems feeding Lake Eyre indicate stronger stream flows during the last interglacial, with waning activity after 85 ka.

The Diamantina River and Cooper Creek are Australia’s best known arid river systems. Two characteristics warrant comment here. First, these are river systems on an immense scale. The catchments of the Georgina–Diamantina–Warburton and the Thomson–Barcoo–Cooper drainages begin in northern Australia and extend for more than a thousand kilometres into central Australia, feeding monsoonal floodwaters into Lake Eyre. Second, the dynamics of the slow movement of floodwater into the heart of the continent – through a variety of sumps and storages – adds another layer of environmental variability over and above that due to fluctuations in precipitation.

The fluvial history of the Cooper and the Diamantina is now known in some detail. The major phase of fluvial activity on the middle and lower reaches of these rivers peaked around 110–109 ka and left a series of large palaeochannels, now buried by desert dunes and modern floodplains (Wells and Callen 1986; Nanson, Price and Short 1992; Magee 1997; Nanson et al. 2008). These ancestral rivers created a broad meandering channel system up to four times the width of the modern floodplain. The palaeochannels contain a wide range of fossil fauna (which attracted the attention of JW Gregory in 1901–2) and
are filled with fine cross-bedded white sand, indicating higher discharges than the present mud-dominated channels. Collectively, these channel deposits are known as the Katapiri formation, usually divided into the upper Katapiri last interglacial and the lower Katapiri (260–220 ka). OSL ages for the upper Katapiri show that these deposits range in age from 120 ka to 60 ka. Higher in the catchment – in the Channel Country – sand-dominated bed-loads indicate higher discharges around 120 ka (Nanson et al. 1988), but these were replaced from 85 ka by the network of low-energy anastomosing muddy streams that today give this region its name.

Stream flows along Cooper Creek appear to have become strongly seasonal towards the end of MIS5. By 85 ka, it formed large, sandy, meandering channels, with seasonally dry beds that allowed the prevailing winds to blow channel sands into source-bordering dunes. OSL dates for these source-bordering dunes form several age clusters, ranging from 120 to 100 ka and from 85 ka to 40 ka (Maroulis et al. 2007; Cohen et al. 2010). After 40 ka, a switch to increasingly low-energy flows inundated the floodplains and channels with mud. For Cooper Creek, ‘increasing aridity had greatly diminished this major Australian inland river by about 40–35 ka’ (Nanson et al. 2008: 126).

The fluvial histories of other arid zone rivers are not known in any detail. In Central Australia, major alluviation along the Finke River took place around 100–90 ka, with no evidence of later activity until the Holocene (Nanson, Chen and Price 1995). The Todd River was active 75–21 ka, but little is known about its flow regime during the last interglacial (Hollands et al. 2006). The Sandover River may have been a more energetic fluvial system during MIS5, but the limitations of thermoluminescence (TL) and U/Th dating of palaeochannels and alluvial terraces in this part of Central Australia leave us without a solid Quaternary chronology for this system (Tooth 1997).

The balance of the evidence suggests that by 85 ka, even the largest of these inland river systems had switched to strongly seasonal flows and that by 60 ka (the close of the Katapiri), they were operating primarily as arid fluvial systems. In Central Australia and along Cooper Creek, short-lived high-magnitude flows occurred throughout the late Pleistocene (Bourke 1998; English et al. 2001; Nanson et al. 2008), but these probably reflect the interdecadal variability that characterises these arid rivers today.

Desert Dunes and Dust

The history of desert dunes provides a counterpoint to the records of palaeohydrology from rivers and lakes. The widespread availability of luminescence dating techniques has allowed a chronology of dune activity to be reconstructed in increasing detail and at scales ranging from the vertical accretion and longitudinal growth of individual dunes through to the history of entire
Figure 3.7. Kocurek’s model of aeolian system response to climate change. Sediment accumulated during earlier conditions is mobilised under an arid climate. Dune construction is initially limited by ground cover (availability-limited influx) and later by wind speed (transport-limited availability). Dunes are reworked or destroyed as the supply of sand is exhausted. (Simplified from Kocurek 1998: fig. 4)

dune fields. In Australian deserts, just as in deserts in Southern Africa, this has complicated the conventional view that dune systems have a straightforward correlation with periods of aridity (Lancaster 2008).

Recent work suggests that interactions between sediment supply and availability and wind speed govern the response of dunes to climate change and define a series of states of dune systems (Kocurek 1998: fig. 4) (Figure 3.7). Kocurek’s model of aeolian response shows that sand starvation will cause an aeolian system to flip from dune construction to dune reworking. One implication is that some apparent gaps in dune chronologies may be processual, not simply climatic. Where sediment is freely available, winds play a major role in determining periods of dune activity (a transport-limited system). Where sediment is not freely available, variations in rainfall and vegetation cover play a dominant role in development of dunes (an availability-limited system). Vegetation cover mostly limits dune activity in the Australian arid zone. However, Ash and Wason (1983) have argued that wind speed determines dune mobility in the arid core, where the sparse vegetation cover is not sufficient to stop sand movement today. In contrast to linear desert dunes, source-bordering dunes are dependent on stream flow to deliver sediment and on seasonally dry conditions to allow it to be blown into transverse dunes.
Dune chronologies across the Australian arid zone show that a widespread phase of construction of linear desert dunes began at 70–60 ka, at the close of MIS5. Around Lake Frome, OSL ages show phases of dune activity at 66–57 ka and 22–11 ka (Fitzsimmons, Bowler, Rhodes et al. 2007). In the Strzelecki and Tirari dune fields, the onset of major dune activity is dated to about 70 ka (Lomax et al. 2003; Fitzsimmons, Rhodes, Magee et al. 2007), with multiple periods of dune reactivation at 73–45 ka, 35–28 ka, 22–18 ka and 14–10 ka, punctuated by episodes of environmental stability. On the western margins of the Simpson Desert dunefield, phases of linear dune activity date to 75–65 ka and 28 ka (Hollands et al. 2006). At Lake Gregory, on the northern margin of the desert, linear desert dunes built over the old lake floor at 70 ka (Bowler et al. 2001). There is a broad consistency among these records, showing the onset of widespread dune activity after 70 ka, with a peak in activity during the last glacial maximum (30–18 ka).

The Tasmann Sea dust record also registers an increase in dust concentration from 74 ka, with distinct peaks at 61 ka and 52 ka (Hesse 1994). Both dune and dust records reflect increasing disturbance to vegetation and ground cover across the interior as the climate became increasingly arid and more seasonal and as the northern monsoon weakened.

**Inland Vegetation during the Last Interglacial**

Direct data on inland vegetation during the last interglacial are scarce. The only long pollen sequence is from a marine core, Fr10/95 GC17, near Exmouth, in northwestern Australia. This provides a record of vegetation, fire and climate for the last 100 ka (van der Kaars and De Deckker 2002; van der Kaars, De Deckker and Gingele 2006). Although taken 60 km offshore, wind patterns mean that Fr10/95 GC17 provides a strategic record of vegetation across adjacent parts of northern Australia: there were grass-rich eucalypt woodlands in the northern part of the arid zone between 100 ka and 81.5 ka, with a shift after this time to open arid woodland with chenopods and the native dryland conifer *Callitris*. Palaeoclimatic reconstructions (van der Kaars, De Deckker and Gingele 2006) suggest that regional rainfall after 81.5 ka was about 440 mm per annum (p.a.), bringing the region within the arid-zone range (500 mm p.a. is taken as the northern bound of the modern arid zone). The record from Fr10/95 GC17 is corroborated by carbon isotope records from OSL-dated sediment cores at Lake Gregory (Pack et al. 2003), which also show a long-term trend towards a more arid climate.

In Central Australia, the phytolith sequence from Puritjarra rockshelter (Bowdery 1998; Smith 2009b) shows that local grasslands were well established during the last interglacial (MIS5), with grass values at about 96 ka approaching modern levels. The evidence suggests an interglacial landscape with open,
grass-rich vegetation and at least seasonally active dunes, analogous to conditions around the rockshelter today.

Attempts to retrieve a long, continuous pollen record from Lake Eyre have been frustrated by deflation of the lake floor and periodic dissolution of the salt crust. The LE82/2 core from Madigan Gulf is poorly dated and provides only a broken record of vegetation change, but it does show that Callitris woodlands were an important component of the regional vegetation before 30 ka (Luly 2001). Pollen has also been recovered from upper Katapiri sediments at Punkrakadarinna waterhole on Warburton River (Hesse, Luly and Magee 2005). This shows that the interglacial environment included significant areas of open vegetation made up of Poaceae and Asteracea (grass and daisies), similar to the modern vegetation of the area.

Carbon isotopes in fossil emu eggshell (Dromaius novaehollandiae) provide an alternative record of palaeovegetation in the Lake Eyre region over the last 65 ka (Johnson et al. 1999). These show that C₄ grasses – associated with summer precipitation – were more abundant in the early part of this record, between 65,000 and 45,000 years ago, and then declined, which implies that the Australian summer monsoon was more effective then than now.

The overall picture is of open arid or semi-arid vegetation across much of the interior during the last interglacial, with a shift towards more dryland taxa, including Callitris and chenopods, towards the end of MIS5. However, it is clear that even after MIS5, summer monsoon rainfall was more effective in the interior than today and did not collapse until 45 ka.

Last of the Dryland Megafauna

By the last interglacial, significant guilds of dryland megafauna were restricted to the southern part of the Lake Eyre basin, mainly in the Cooper Creek area. This regional fauna – associated with the upper Katapiri formation – collapsed around 65 ka and contracted to the margins of the desert, where some megafauna species persisted until 50–45 ka.

A recent review of the continental distribution of these species shows that the late Quaternary megafauna had a predominantly southeastern distribution, with greatest species diversity in the woodlands, plains and forests of southeastern Australia (Webb 2008) (Figure 3.8). Except for the Cooper Creek–Lake Eyre area, the arid zone appears to have been largely empty of megafauna by 132–115 ka. Isolated finds of Diprotodon optatum across the western interior and along the west coast all appear to be much older than the last interglacial but are undated. In this context, the rich fauna found in upper Katapiri sediments is an extension of the southeastern megafauna, from the desert margins along major inland river systems into the Lake Eyre region.
The Katapiri Fauna

At the regional level, the Katapiri fauna provides a striking picture of a rich interglacial savanna environment, with a mosaic of habitats, including riparian forest and woodland, seasonally inundated floodplains, deep permanent waterholes and back-swamps, as well as open drylands with chenopods, grasslands and Callitris pine woodlands. JW Gregory may have been thinking of the Serengeti when he commented, ‘when I noticed the richness of the soil, I could not but think what a paradise this country would be if only it had an East African rainfall’ (1906: 112).

The most comprehensive listing of fauna from upper Katapiri sediments is by Webb (2009; see also Tedford and Wells 1990) (Table 3.2). The major macropods present are the short-faced kangaroos, Procoptodon and Sthenurus. Other large herbivores include Diprotodon optatum and the giant wombat Phascolonus gigas. Arboreal species, such as possums (Trichosurus vulpecula) and koalas (Phascolarctos), are also present, as well as smaller taxa characteristic of arid-zone faunas such as bandicoots (Isoodon obesulus, Macrotis lagotis), rat kangaroos (Betongia lesueur) and hare wallabies (Lagorchestes leporides). Large flightless birds include the emu (Dromaius) and the much larger Genyornis, estimated to weigh as much as 275 kg. This fauna supported a range of carnivores and scavengers, including a large varanid lizard (Megalania prisca), the marsupial lion (Thylacoleo carnifex), thylacines and the freshwater crocodile Palimnarchus. The latter is represented in these fossil deposits by numerous cranial fragments, scutes, teeth and vertebrae. Crocodile teeth marks on Diprotodon bones record its effectiveness as a predator in these inland waterways. These channels and waterholes also supported a range of fish, freshwater mussels and chelid turtles. The large fish vertebrae in these assemblages indicate that some individual fish weighed as much as 36–50 kg (Webb 2009).
TABLE 3.2. List of taxa, Upper Katapiri fauna (MIS4–MIS5), Cooper Creek–Lake Eyre region

<table>
<thead>
<tr>
<th>Group</th>
<th>Megafauna &gt;50 kg</th>
<th>Other species &lt;50 kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marsupial carnivores</td>
<td><em>Thylacoleo carnifex</em></td>
<td><em>Sarcophilus laniarius</em></td>
</tr>
<tr>
<td>Bandicoots and bilbies</td>
<td><em>(Thylacinus cynocephalus)</em></td>
<td><em>(Isoodon obesulus)</em></td>
</tr>
<tr>
<td>Koalas</td>
<td><em>(Phascolonus gigas)</em></td>
<td><em>(Lasiorhinus latifrons)</em></td>
</tr>
<tr>
<td>Wombats</td>
<td><em>(Procoptodon brownorum)</em></td>
<td><em>(Trichosurus vulpecula)</em></td>
</tr>
<tr>
<td>Possums</td>
<td><em>(Procoptodon gilli)</em></td>
<td><em>(Bettongia lesueur)</em></td>
</tr>
<tr>
<td>Rat-kangaroos</td>
<td><em>(Procoptodon goliah)</em></td>
<td><em>(Bettongia lesueur)</em></td>
</tr>
<tr>
<td>Short-faced kangaroos</td>
<td><em>(Procoptodon pusio)</em></td>
<td><em>(Bettongia lesueur)</em></td>
</tr>
<tr>
<td>Other kangaroos and wallabies</td>
<td><em>(Procoptodon rapha)</em></td>
<td><em>(Bettongia lesueur)</em></td>
</tr>
<tr>
<td>Diprotodonts</td>
<td><em>(Simosthenurus orientalis)</em></td>
<td><em>(Bettongia lesueur)</em></td>
</tr>
<tr>
<td>Rodents</td>
<td><em>(Simosthenurus pales)</em></td>
<td><em>(Bettongia lesueur)</em></td>
</tr>
<tr>
<td>Large ground birds</td>
<td><em>(Simosthenurus occidentalis)</em></td>
<td><em>(Bettongia lesueur)</em></td>
</tr>
<tr>
<td>Large varanid lizards</td>
<td><em>(Sthenurus atlas)</em></td>
<td><em>(Bettongia lesueur)</em></td>
</tr>
<tr>
<td>Crocodiles</td>
<td><em>(Sthenurus andersoni)</em></td>
<td><em>(Bettongia lesueur)</em></td>
</tr>
<tr>
<td>Fish and turtles</td>
<td><em>(Sthenurus stirlingi)</em></td>
<td><em>(Bettongia lesueur)</em></td>
</tr>
<tr>
<td>Crustaceans</td>
<td><em>(Sthenurus tindalei)</em></td>
<td><em>(Bettongia lesueur)</em></td>
</tr>
<tr>
<td>Shellfish</td>
<td></td>
<td><em>(Bettongia lesueur)</em></td>
</tr>
</tbody>
</table>

Tedford and Wells (1990) list a range of other species but do not distinguish between upper and lower Katapiri fauna.

Source: Webb 2008

There are few dryland faunas that allow comparison with the upper Katapiri fauna. The spectacular pitfall assemblages from the Nullarbor caves are middle Pleistocene and date from at least 780 ka through to 200 ka (Prideaux et al. 2007). These represent an older, arid-adapted fauna occupying a mosaic of
TABLE 3.3. Comparison of middle Pleistocene herbivore dietary guilds across Australia

<table>
<thead>
<tr>
<th>Guild</th>
<th>Leewin/Naturaliste</th>
<th>Naracoorte</th>
<th>Nullarbor</th>
<th>Lake Eyre Basin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arboreal</td>
<td>19</td>
<td>24</td>
<td>12</td>
<td>9</td>
</tr>
<tr>
<td>Fungivores</td>
<td>24</td>
<td>16</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>Browser</td>
<td>38</td>
<td>42</td>
<td>36</td>
<td>50</td>
</tr>
<tr>
<td>Mixed feeders</td>
<td>5</td>
<td>3</td>
<td>16</td>
<td>18</td>
</tr>
<tr>
<td>Grazers</td>
<td>14</td>
<td>16</td>
<td>28</td>
<td>18</td>
</tr>
<tr>
<td>Species N</td>
<td>21</td>
<td>38</td>
<td>25</td>
<td>22</td>
</tr>
</tbody>
</table>

Data are number of species.
Source: Prideaux et al. (2007) – supplementary table 5

woodland and shrubland. Comparisons across a number of middle Pleistocene assemblages (Table 3.3) show that browsers dominate all of these, but the dryland faunas from the Nullarbor and Lake Eyre basin characteristically have more grazers and mixed feeders than do woodland and forest faunas, and fewer arboreal species. It seems likely that this would have also been the case for the late Pleistocene Katapiri fauna.

LAKE CALLABONNA
The fauna from Lake Callabonna is more limited than that in the Cooper basin (Table 3.4), presumably because the Callabonna area is a more marginal environment. The Callabonna fossils are OSL-dated to $75 \pm 9$ ka (Roberts et al. 2001). Gillespie et al. (2008) also report a minimum radiocarbon age of 53,400 BP for the gut contents of a Diprotodon (see next section). At the time of the

TABLE 3.4. List of fossil fauna from Lake Callabonna

<table>
<thead>
<tr>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dromaius novaehollandiae</td>
</tr>
<tr>
<td>Genyornis newtoni</td>
</tr>
<tr>
<td>Diprotodon optatum*</td>
</tr>
<tr>
<td>Phascolonus gigas</td>
</tr>
<tr>
<td>Macropus cf. tian</td>
</tr>
<tr>
<td>Macropus sp.</td>
</tr>
<tr>
<td>Proteomodon cf. brehus</td>
</tr>
<tr>
<td>Sthenurus andersoni</td>
</tr>
<tr>
<td>Sthenurus stirlingi</td>
</tr>
<tr>
<td>Sthenurus tindalei</td>
</tr>
</tbody>
</table>

* Following Price (2008), D. australis and D. minor are merged into D. optatum.
Callabonna diprotodons, the area was a shallow, seasonally dry saline lake, surrounded by saltbush and Cypress pine, with eucalypts along watercourses draining into the lake. Trackways and footprints preserved as carbonate-cemented imprints on the bed of the lake show there was well-established traffic across the lake (Tedford 1984). The Lake Callabonna diprotodons died attempting to cross mud flats to nearby mound springs when the lake level was low.

**POPULATION ECOLOGY**

Information about the ecology of these animals has come from a range of sources. Distribution patterns within the Lake Eyre basin (Webb 2009) show that most species favoured the main river channels and floodplains (11–17 species), with the highest species diversity along Cooper Creek. Only seven species are regularly found in arid terrestrial habitats away from rivers; these include Diprotodon and Genyornis, which are known to have been wide-ranging species. The distribution of Procoptodon fossils suggests that this was another species able to forage in the arid backcountry.

Analyses of carbon isotopes in tooth enamel for upper Katapiri fauna confirm that Diprotodon was a mixed feeder, consuming C3 and C4 plants ($\delta^{13}C -18.8 \pm 3.0$) (Grocce 1997). In contrast, Sthenurus was a browser, consuming a diet of C3 shrubs ($\delta^{13}C -24.3 \pm 0.9$) and was probably more restricted to woodlands and riparian habitats. Other isotopic work has shown that Procoptodon was a chenopod-browse specialist (Prideaux et al. 2009) and that Genyornis was a mixed feeder that selectively ate C4 plants (Miller et al. 1999; Miller, Fogel, Magee et al. 2005). This must have included saltbush because this dietary signature is also observed in its eggshell in temperate areas well beyond the distribution of C4 grasses (Smith 2009a).

One of the remarkable finds at Lake Callabonna was the recovery of gut contents of Diprotodon; this provided a direct record of the diet of this giant marsupial. Stirling records that ‘associated with the skeletons of Diprotodon, in a relative position which corresponded with that of the abdominal cavity, were occasionally found loosely aggregated globular masses of what were judged to be the leaves, stalks, and smaller twigs of some herbaceous or arboreal plants’ (1900: xii). At the time, these were tentatively identified as ‘Salsolaceae’ or ‘the allied orders Amaranthaceae or Nyctagineae’, indicating that these are most likely a chenopod. This has been confirmed by recent analyses (using x-ray diffraction and stable isotope measurements) showing that this material is Atriplex (saltbush), a C4 halophyte shrub (Gillespie et al. 2008).

**COLLAPSE OF THE KATAPIRI FAUNA**

The end of this distinctive dryland megafauna coincides with the collapse of the regional ecosystem, as rivers, lakes and swamps failed in the shift to the drier conditions of MIS4. Diprotodon remains from Punkrakadarinna on Warburton River are TL dated to 64.9 ± 5 ka (Webb 2009) and mark the last evidence...
of significant populations of megafauna in this region. A couple of factors are likely to underlie local extinction of this fauna. First, many macropods have a marked dependence on shelter to avoid thermal stress, so an increasingly open vegetation would have created problems for larger species. Even today, medium to large kangaroo species are rare in the heart of the Lake Eyre basin. Second, larger body size also brought a need for free water, as well as late maturity and slower reproductive rates. Most megafauna species, therefore, would not have tolerated the increasing environmental stochasticity and the fragmentation of riparian habitats (Main and Bakker 1981; Horton 1984).

The disappearance of this dryland megafauna represents one of the clearest examples of climate-driven extinction at the regional level. Although other studies have shown the resilience of megafauna communities in the face of Quaternary climatic fluctuations (Prideaux et al. 2007), the collapse of the Katapiri fauna demonstrates the critical importance of biogeographic factors. The interglacial palaeohydrology of the Cooper Creek–Lake Eyre region effectively made this area part of the desert margin. The switch to drier and more variable conditions appears to have disrupted migration corridors between the main body of megafauna in southeastern Australia (a source) and animal populations in the Lake Eyre basin (a sink) (Webb 2009). Without these connections, the dryland megafauna could not recover from environmental crashes.

Some species, however, survived into the period 50–45 ka. An isolated find of a *Diprotodon* cranium near Lake Eyre, associated with an OSL date of 46.6 ± 3 ka (ANU-OD 1251), suggests that these animals persisted in the better-watered upper reaches of these drainage systems, dispersing downstream after exceptionally heavy rain (Webb 2009 and personal communication). Similarly, at Lake Menindee, the regional megafauna persisted into the period 66–51 ka (Cupper and Duncan 2006). *Genyornis newtoni*, a large flightless dromornithid bird, is the only megafauna species likely to have been widely encountered by the first people to move into the desert.

**Genyornis**

*Genyornis newtoni* was widely distributed across arid and semi-arid parts of southeastern Australia until 50 ± 5 ka (Miller et al. 1999) (see Figure 3.2b). The presence of nasal salt glands indicates that this bird could tolerate saline waters (Murray and Vickers-Rich 2004). However, the distribution of its distinctive eggshell suggests that *Genyornis* was probably tethered to riparian corridors for nesting, perhaps moving up and down channel systems and floodplains as seasonal conditions allowed. *Genyornis* had a wide range in those parts of the arid interior that are interlaced with river channels – in western New South Wales, the Lake Eyre basin, the Murray–Darling basin, and in southwestern Queensland. But bones of the bird are not present in the Nullarbor fossil assemblages and, despite several field surveys, its eggshell has not been found in the Great
Victoria Desert or around Lakes Gregory or Mackay. There appear to have been isolated populations of *Genyornis* at Lake MacLeod on the arid west coast and at Lake Lewis in Central Australia. The latter almost certainly represents a limited extension of range following the corridor of the Finke River during good years. In the Lake Eyre basin, the eventual extinction of *Genyornis* coincided with a significant decline in summer monsoon rainfall (Johnson et al. 1999; Murphy, Williamson and Bowman 2012), which potentially disrupted both its summer breeding pattern and its preferred diet of C₄ plants. It may also coincide with the arrival of people in these landscapes, especially because any predation on eggs and young birds would have put additional pressure on these birds.

**OVERVIEW: THE DESERT PRIOR TO PEOPLE**

**Interglacial Landscapes**

What was the last interglacial like in the interior of Australia? A bird’s-eye view across these interglacial landscapes would reveal open, arid woodlands and grasslands across much of the inland. Looking across the interior, we would see a landscape with significant fluvial and lacustrine systems inset into arid and semi-arid landscapes on the desert margins and in the Lake Eyre basin. Outside of these areas, the interior was a landscape of saltlakes, stabilised desert dunes and xeric vegetation.

There were active freshwater lakes on the desert margins – at Lake Gregory and Lake Woods in the north and the Willandra Lakes in the southeast. These are terminal lakes fed by stream flows originating outside the desert, and all are likely to have been rich in fish, shellfish or crustaceans. In the heart of the continent, Lake Eyre was a large, deep, saline lake during the interglacial, a greatly expanded lake that incorporated Lake Callabonna and Lake Frome. This was also a terminal lake, on an immense scale, fed by river systems rising in the sub-tropics. But the lake itself was too saline to support significant resources for people, except for ephemeral resource blooms, when floods flushed nutrients and fish into the lake from connecting river systems.

It is the lower and middle reaches of the Cooper–Diamantina channels that represent the richest resource zone associated with the lake. Here, the rivers and waterholes supported a rich biota that included fish, crocodiles, turtles, freshwater mussels and waterfowl. A regional mosaic of swamps, floodplains and riparian woodlands supported a diverse array of large herbivores. This megafauna was tethered to the major channels and floodplains. In open desert away from the floodplains, these animals were rare: the greater part of the interior did not support comparable communities of megafauna.

Continuing our bird’s-eye view would show that the Cooper–Diamantina area was not typical of the desert. The western half of the continental interior
does not have the long coordinated river systems of the Lake Eyre basin. There were no active Quaternary lakes (saline or otherwise) in the western half of the desert: here, the old Miocene lake basins were now saltlakes. And in Central Australia, Lake Amadeus and Lake Lewis had become hypersaline playas by the late interglacial.

The Landscapes of Colonisation

The first human movements into the interior took place \(45 \pm 5\) ka (see Chapter 4). Most Quaternary records indicate that the interior was significantly more arid at this time than at any stage during the last interglacial (Hesse et al. 2004). People moving into the interior early in MIS3 would have encountered extensive deserts and drylands, with a xeric vegetation of grasslands, chenopod shrublands and open woodlands often dominated by the dryland conifer *Callitris* (van der Kaars and De Deckker 2002; Hesse et al. 2004; Smith 2009b).

The vegetation around Puritjarra, in western Central Australia, at \(45\) ka, was an arid, open shrubland or herbland, with isolated trees and little grass in a landscape that was already registering the impact of intensified aridity (Smith 2009b). Continental dunefields had been widely reactivated by \(70–60\) ka, and greater dust fluxes at this time register increasing land surface instability.

Most large palaeolakes ended well before the first human movements into the desert. The last deepwater phase of Lake Eyre ended 65,000 to 60,000 years ago (Magee and Miller 1998), coinciding with declining fluvial activity in the associated river systems and with the collapse of the Katapiri fauna. The flightless *Genyornis* was the only megafauna species still widely extant across the interior when people entered the desert.

The exceptions to this pattern were the freshwater lakes on the desert margins. In the southeastern section of the arid zone, rivers and lakes in the Darling basin and Willandra region were active during MIS3 and MIS2 (especially between \(55\) ka and \(15\) ka; Bowler 1998), feeding runoff from the southeastern Australian highlands into a chain of terminal lakes, the most famous of which is Lake Mungo. Elsewhere, MIS3 saw some reactivation of rivers and lakes in the Lake Eyre basin – especially at Lake Frome – but appears to have had little impact in Central Australia or the Western Desert. There were episodic strong flows along Cooper Creek and presumably also along other channels in the Georgina–Diamantina system (Nanson et al. 2008: 119). However, given that regional dunefields in the Tirari and Strzelecki Deserts were also active at this time (Fitzsimmons, Rhodes, Magee et al. 2007), the picture during MIS3 is of an arid environment with high submillennial variability and strong seasonality. This suggests that the channels feeding Lake Eyre (Warburton River and Cooper and Kallakoopah Creeks) functioned as classic arid rivers: mostly dry channels with saline groundwater outcropping in places but periodically reactivated during ‘boom’ years, when they funnel...
large flows of floodwaters into Lake Eyre. Lake Eyre filled again during MIS3, creating a saline water body no larger than that created by modern floods.

There is little evidence to support the proposition that early occupation of Australia’s deserts selectively relied on lacustrine or riverine resources or that it took place during a ‘lacustral phase’ (Hiscock and Wallis 2005). Late Pleistocene human groups in the Darling and Willandra regions had access to active river and palaeolake systems. But further inland, along the channels and back-swamps of Cooper Creek and the Warburton River, riverine resources are likely to have been less predictable and increasingly seasonal. People moving further into the interior would have been faced with an open, arid landscape of dunes and saltlakes, one that lacked coordinated river systems.

By the time people entered the interior, this was an arid ecosystem that had been shaped by tens of millennia of selective pressure. However, its ecological structure and controls may have been subtly different from those of Australia’s deserts today. It is significant that although the Australian monsoon weakened substantially after MIS5, it remained stronger than it is today until 45 ka. Potable water, in clayspans, small soakages, waterholes and springs, is likely to have been more widely available due to lower evaporation and a more active summer monsoon. These small waters would have given people greater flexibility in their annual and seasonal subsistence movements than today, allowing more efficient access to the plant and animal resources of these drylands. Mobility is crucial for desert hunter-gatherers, and these small water points would have provided an effective way of ‘stepping through’ these unique landscapes.

Moving into the ‘dead heart’ of the continent, the first people would have found the old floodplains and dry lake beds littered with the bones of megafauna – as can still be seen today in a few areas, such as Lake Callabonna. In the Lake Eyre region, Thirrari, Diyari and Wangkangurru people incorporated the fossil bones into their cosmology, associating them with Kardimarkara (the Rainbow Serpent), a creative being of immense size closely associated with rain and waterholes. In the 1970s, Mick McLean Irinjili described how the old people had found big bones at a waterhole and had covered them over, ‘out of respect and pity’.