CHAPTER 8

THE CHAIN OF CONNECTION: TRADE AND EXCHANGE ACROSS THE INTERIOR

The first desert song to be written in English was linked with expeditions to bring red ochre from the famous Pukardu mine (Gason 1874; Hill 2002: 1–3; Jones 2007). It was sung during the making of bags for carrying the ochre and on the long journey from Pukardu, near Parachilna in the Flinders Ranges, to Cooper Creek.

Put colours in the bags,
Close it all around,
And make the netted bag
All the colours of the rainbow.

The original Diyari was translated by Mounted Constable Samuel Gason some time between 1865 and 1871. More than a century later, a Wangkangurru man from the Simpson Desert – Jimmy Russell Wangamirri – still knew the verses (Hercus and Koch 1997). ‘They sing the Pukardu song,’ he said, ‘for setting out and returning. They sing the song of Pukardu Hill, they sing it for a long time’ (Russell, in McBryde 2000: 160).

In the late nineteenth century, the Diyari on the lower reaches of Cooper Creek were at the centre of a long trade route that connected the Flinders Ranges in the south with the Mt Isa uplands 1,200 km to the north (Figure 8.1). At the southern end of this exchange system was the red ochre mine at Pukardu and a complex of grindstone quarries at Tooths Nob. At the northern end, the extensive stone-axe quarries in the Mt Isa–Cloncurry meta-basalts, and the groves of the desert narcotic *pituri* west of the Mulligan River, provided a counterweight. Constable Gason was uniquely placed to see this system in operation. As a police trooper stationed at Lake Hope on Cooper Creek between 1865 and 1871, just as pastoralists and missionaries were moving into this district, he witnessed at first hand the departure of the red ochre expeditions as they headed south and the return of expeditions bringing *pituri* from the north. Reviewing this ‘chain of connection’, DJ Mulvaney famously commented that ‘it was possible for a man who had brought pituri
from the Mulligan River and ochre from Parachilna to own a Cloncurry axe, a Boulia boomerang and wear shell pendants from Carpentaria and Kimberley’ (1976: 80).

Despite its prominence in the ethnography, however, the long-distance trade system observed by Gason was not typical of exchange in arid Australia. The more usual pattern was one of individual gift exchange, either between kin or between exchange partners at ceremonial gatherings. A myriad of small individual transactions was sufficient to rapidly transfer objects deep into the desert, often thousands of kilometres from their source (Mulvaney 1976). The shift from this relatively undifferentiated gift economy to a more complex mix of exchange transactions, with long-distance expeditions by groups of men (as witnessed by Gason) coupled with large-scale production of prestige goods, appears to have taken place within the last millennium. It was limited to the eastern margin of the arid zone, where the inland river systems channelled trade into a corridor, creating a critical mass of intergroup exchange that was unique in the desert. This chapter reviews what is known about the development of
Figure 8.2. The southern sector of the Lake Eyre basin, showing the location of the major quarries for red ochre (open triangles) and for millstones (squares). Archaeological sites mentioned in the text are numbered: (1) Marapadi, (2) MG4, (3) White Crossing hearths, (4) JSN, (5) Hawker Swamp, (6) Arkaroo Rock, (7) Balcoracana Creek, (8) Panaramitee, and (9) Karolta engraving site.
Figure 8.3. Major quarries and mines mentioned in the text. Red ochre mines: (1) Wilgie Mia, (2) Karrku, (3) Pukardu. Stone-knife quarries: (4) Kanti, (5) Kankiritja. Grindstones: (6) Kurutiti (Helen Springs), (7) Anna Creek (Palthirri-pirdi), (8) Tooths Nob (Wadla wadlyu), (9) the Innamincka grindstone quarries, (10) Yambacoona Hill. Stone-axe quarries: (11) the Mt Isa axe quarries.

these exchange systems, their differentiation and antiquity, and the history of the major mines and quarries (Figures 8.2 and 8.3).

It is often said that to understand hunter-gatherer societies, we need to broaden out from place-based or regional studies to examine how they articulated within larger spatial and social entities (Wobst 1978). Nowhere is this more true than in Australia’s deserts. One of the distinctive features of desert societies was their large geographical scale and their permeability to the movement of goods, ceremonies and social phenomena. During the recent past, social institutions such as subsections (McConvell 1985), practices such as subincision (Tindale 1974) and ceremonies such as the ‘Molonga’ (Mudlungga) (Mulvaney 1976; Hercus 1980) diffused widely across the interior. Earlier cultural spreads that linked up large areas of the desert are registered by the diffusion of stone tool types, such as geometric microliths or Panaramitee-style rock art and the
spread of Pama-Nyungan (PN) languages across an already well-peopled intei- rior (see Chapters 6 and 7). Exchanges of this kind countered the tendency for small population isolates to diverge culturally and linguistically. They also show how much the cultural history of the desert was encapsulated by developments on the desert margins, or outside the arid zone. Whereas Chapters 6 and 7 looked at the development and consolidation of regional societies, the focus of this chapter is on how these were interconnected through trade and exchange – and how this changed over time.

**THE SYSTEMATICS OF TRADE AND EXCHANGE**

In Australia, ethnographic exchange systems were scaled in terms of organisation, quantity of goods and distance (Mulvaney 1976; Keen 2004). Regional studies are available for groups in tropical northern Australia (Stanner 1933–4; Love 1936; Thomson 1949; Berndt 1951; Warner 1958; Falkenberg 1962) and for the arid interior (Roth 1897; Howitt 1904). There were named exchange cycles in many regions, such as the Warlpiri warntarri ‘when people exchange gifts with each other... All sorts of things. The ones that people give away to each other in turn’ (Laughren 1994).

At one end of the spectrum was gift exchange between individuals. This was usually intragroup and involved kin or named exchange partners. These interpersonal exchanges were underlain by networks of obligation that formed the infrastructure of social relations in hunter-gatherer societies. Reciprocity was fundamental. Desert Pintupi expected exchange relations to be reciprocal or ngaparrku (level) (Keen 2004: 358). Ceremonial gatherings often provided the occasion for conducting a range of individual transactions on the side or, as Stanner put it, ‘in the shadow of more impressive events’ (1933–4: 160). The net effect of numerous small transactions through multiple connecting links was the wide diffusion of durable goods, ceremonies and new social forms across the interior of the continent.

At the next level were formal intergroup exchanges between neighbouring language groups. These sometimes involved specific trade ceremonies, as well as preparation to receive visitors and stockpiling of food and exchange goods – as Berndt (1951) describes for Arnhem Land, and Roth (1897) and Aiston (1937) describe for the Lake Eyre basin. Mudburra and Jingili people on the northern margin of the desert initiated such exchanges because ‘they felt that a formal exchange of goods would communicate that the local community was able to assert its place within the wider area’ (Paton 1994: 180). In this context, exchange was as much about political economy as sociality.

Thomson’s classic study (1949) of the ceremonial exchange cycle in Arnhem Land also shows how sensitive this was to external factors. In Arnhem Land, the turnover of goods accelerated as people sought to obtain exotic items brought by Macassan traders to the north coast. They did this by manipulating
the exchange cycle, using the production of goods for exchange to trigger obligations for reciprocity. The acquisition of goods was fundamental to the exchange gatherings described by Berndt (1951) and Roth (1897), and these are located firmly towards the commodity end of the gift–commodity dichotomy. Outside of residential groups, food was rarely exchanged. Most of the goods changing hands derived their value from their properties as exotic or prestige goods – although this value was refracted through the ritual and totemic associations inherent in the object or its place of origin. In this context, local sources of red ochre or grindstones were sometimes bypassed in favour of material from more distant sources.

In contrast to these ‘down-the-line’ exchange systems, the Lake Eyre basin saw the direct ‘long transfer’ of goods over 400–500 km via organised expeditions mounted specifically to acquire red ochre, pituri, grinding slabs and stone axe heads. These involved exchange on a corporate rather than an individual level, and the direct transfer of goods over long distances rather than a chain of small transactions. They were also distinctive in their large scale. For example, each red ochre expedition occupied fifty to eighty men on a two-month 800 km round trip that brought in about 2 t of ochre per expedition. In many respects, these ‘long-transfer’ systems represent an elaboration of the intergroup trade ceremonies described for northern Australia. Trade goods obtained through ‘long transfer’ also rapidly entered local reciprocal exchange networks, creating a secondary pattern of diffusion of goods.

ARCHAEOLOGICAL APPROACHES

Archaeological research on trade and exchange has followed two complementary lines of approach: distribution studies looking at the spatial spread of exchange items, often using petrology or geochemistry to identify material from specific sources; and studies of production focusing on the major quarries.

DS Davidson and FD McCarthy provide important early studies of distribution patterns (Davidson 1938, 1952; Davidson and McCarthy 1957; McCarthy 1938–40). The key to much modern research, however, is the 1973 review by DJ Mulvaney (1976), who argued that anthropological studies of trade and exchange needed to be more strongly grounded in the material evidence. McBryde’s work on the distribution of ground-edge axes in southeastern Australia (Binns and McBryde 1972; McBryde and Watchman 1976; McBryde 1978) provided the model for a range of other archaeological studies: on grindstones (McBryde 1987, 1997), on pearl shell and baler shell objects (Akerman and Stanton 1994) and on red ochre (Sagona 1994; Smith, Fankhauser and Jercher 1998). McBryde later extended her study of stone axes to include petrological examination of museum specimens from the Lake Eyre basin, but results are not yet available. She also initiated a similar project on grindstones
in the Lake Eyre region, but this did not proceed beyond a pilot study. Geo-
chemical sourcing of red ochres has been the subject of several studies (David et al. 1993; David, Watchman, Goodall et al. 1995; Ford, MacLeod and Haydock 1994; Goodall, David and Bartley 1996; Jercher et al. 1998; Smith and Fankhauser 2009), but its application to museum and archaeological collections is still in the early stages.

Much of what is known about the distribution of axes, grindstones and red ochre still relies heavily on the ethnography. And these ethnographic distribution patterns are yet to be tested against archaeological data (except for rather limited analyses by Tibbett 2002 and Smith and Fankhauser 2009). Even where there is fine-grained distribution data, there may be problems distinguishing (a) passage of a gift along a chain of exchanges from (b) direct long-distance transport or from (c) direct acquisition of ochre or grindstones during the normal cycle of seasonal movements (‘embedded procurement’). Multiple individual exchanges can create the appearance of a long-distance exchange system, without requiring a network of fixed, formalised point-to-
point trade routes – as Lawrence (1994) cautioned for customary exchange in the Torres Strait. The usual means of discriminating between these processes is to assume that well-developed distance-decay patterns result from ‘down-the-
line’ exchange. In contrast, direct long-distance transport may be implicated in cases in which the comparative lack of wear (or reduction) on transported axes or grinding slabs indicates that they have been transferred without an extended time in circulation. One question rarely posed is whether these exchange systems only become archaeologically visible when particular durable goods (grindstones, axes, red ochre, shell pendants) are added to existing networks.

A second line of research has focused on the production centres. Davidson et al. (2005) and Hiscock (2005) provide the best accounts of the Mt Isa axe quarries, although much of their research on this large complex is yet to be published. Of the grindstone quarries, only three have been described in detail: Tooths Nob (Reap Hook Hill) (McBryde 1997), Kurutiti (Mulaney 1997) and Narcoonowie (Smith, McBryde and Ross 2010). Information on the major red ochre quarries in the arid zone is compiled in Smith and Fankhauser (2009), and studies of individual ochre quarries are available for Wilgie Mia (Woodward 1914), Karrku (Peterson and Lampert 1985) and Pukardu (‘Bookartoo’) (Jones 2007). Silcrete quarries associated with the production of large blades (150 mm long) for hafted stone knives are known throughout Central Aus-

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rarely recovered dateable material. Where fragments of grindstones or stone axes have been excavated from occupation sites, it is often uncertain whether these are made on quarried blanks or on stone derived from natural outcrops and exposures of the same material.

Australian archaeologists have generally stressed the intangible value of exchange goods: their ritual properties, cosmological or totemic associations or their inherent symbolic values (McBryde 2000; Jones 2007; Brumm 2010). However, this does not account for why certain places and not others became foci of exchange and production, given that the entire landscape was interlaced with powerful mythological associations.

Others have argued that the social networks and reciprocity created by exchange are crucial for buffering ecological risk in marginal environments. This may have been true for intragroup and regional exchange, but there is no evidence that ‘long-transfer’ systems functioned in this way. In any case, ‘ecological reciprocity’ was probably more dependent on the widely ramified kin networks created by exchange of women as wives than on reciprocal gift exchange (Yengoyan 1968; Peterson 1986: 50). The converse argument is that long-distance exchange systems were dependent for their operation on extended chains of social obligation, and that these in turn required a prerequisite degree of social solidarity and cultural integration at interregional level.

One extension of the ‘risk and reciprocity’ argument is the claim that more effective social exchange networks – and the extended systems of reciprocity they generated – underpinned late Holocene settlement in the sandy deserts (Lourandos 1983: 91, 1985; Veth 1989b, 1995b, 2006: table 1). The proposition originally put forward by Lourandos (1983, 1985) was that increasing intergroup and interpersonal competition in these hunter-gatherer societies led to changes in ceremonial exchange, providing the crucial incentive for economic expansion and resource intensification, and leading to population growth. This created a spiral of change towards greater social complexity and the abrupt late Holocene ‘appearance of intensive and possibly ceremonially based occupation of marginal zones, for example wetlands, rainforests, highlands . . . and arid zones’ (Lourandos 1983: 91). Archaeological fieldwork in the desert since the 1980s has weakened much of the basis for this argument but leaves us with important questions about the role of expanded social networks (‘alliances’) in the growth of desert societies and about whether an escalating demand for goods for ceremonial prestation may have driven an expansion of trade and exchange and the restructuring of social relations between groups.

Other studies show that the turnover of these exchange systems was sensitive to external supply of exotic goods (demand-driven) and to opportunities for interpersonal contact (density-dependent) – both likely to increase with demographic growth in the desert (Thomson 1949; Akerman and Stanton 1994).
The following sections present a series of case studies that look at the history of some major exchange commodities: marine shells, red ochre, grinding slabs, stone axes, *piti*ri and stone knives.

**EXCHANGE OF COASTAL BALER AND PEARL SHELL INTO THE INTERIOR**

Marine shells were traded deep into the interior of the continent and provide the best archaeological evidence for ‘down-the-line’ exchange systems. The most prominent examples are baler shell (*Melo amphora*) and pearl shell (*Pinctada maximus* or *P. albina albina*).

*Melo amphora* is a large volute widely used as a container and for a range of objects with other functions, including scrapers, adzes and spoons (Schall 1985). Ethnographic accounts show that much of the shell exchanged into the interior of the continent was used for pendants: these brilliant, white, polished oval pendants, about 100 mm long and pierced for suspension, were important in rain-making ceremonies (Akerman 1973a). Although *M. amphora* is widely found in coastal waters around northern Australia, most ethnographic baler-shell artefacts in the interior came from either the northwest coast of the continent or the Gulf of Carpentaria (Akerman 1973a; Mulvaney 1976). In the Western Desert, baler shell was transferred through ‘down-the-line’ exchange between individuals across 1,700 km of desert, reaching western Central Australia and the southern margin of the Great Victoria Desert.

Archaeology provides some evidence of the antiquity of these exchange networks. Baler shell is common in archaeological assemblages from Pleistocene sites along the arid west and Kimberley coastlines (see Chapter 4) but appears to be limited to within 100 km of the coast. This pattern changed dramatically during the last few millennia. Radiocarbon dates on small pieces of baler shell at campsites near Aboriginal wells in the Great Sandy Desert (Table 8.1) show that it was being exchanged into the arid interior by 2.3 ka (Smith and Veth 2004).
Although the exchange of pearl shells mirrors many aspects of the exchange of baler shell, it differs in being largely a postcontact phenomenon. Pearl shells – either *Pinctada maxima* or the smaller *P. albina albina* – were made into large ovoid pendants up to 20 cm long for breastplates or pubic ornaments (Akerman and Stanton 1994). For desert people, the nacreous iridescent shell shimmered with the brilliance widely associated with ancestral power in Aboriginal Australia (Morphy 1989); more specifically, it was symbolically linked to water, rain and the rainbow serpent. Like baler shell, pearl shell originated on the Pilbara and Kimberley coasts and along the shores of Cape York Peninsula. There is little evidence for its trade into the arid interior until the pearling industry provided a ready source of shells from the 1870s onwards. By the final decades of the century, plain pearl-shell pendants were widely distributed across the continent – although Stirling (1896: 109) records that in Central Australia in 1894, baler shell was still more common than pearl shell. Akerman and Stanton (1994) show that there was a rapid increase in the production and exchange of pearl-shell pendants around 1900 and a shift towards decorated pendants with engraved designs vividly inlaid with red ochre and fat or with powdered charcoal. And, from the 1920s, these designs were dominated by a distinctive interlocking key motif that originated on the northwest coast (Davidson 1949a (Figure 8.4)).

The diffusion of pearl shell illustrates some important properties of exchange systems in the desert. First, there is the speed and efficiency of transfer. The continental distribution of pearl-shell objects is the result of less than a century of exchange. Akerman and Stanton (1994) examined 800 engraved pearl-shell pendants and showed that some were moved over 4,000 km in just 20 years. An ethic of hand-to-hand exchange historically made the desert an open system for the dispersal of prestige objects and practices. Second, the rate and intensity of exchange is very sensitive to changes in external factors. The efflorescence in the exchange of pearl shell was fuelled by greater access to the shell through the pearling industry; an acceleration of social interaction and ceremonial activity triggered by the concentration of the Aboriginal population in missions, ration depots and on cattle stations; and by greater opportunities to travel using motor vehicles, railways or camels. These provided ‘oxygen’ for the ‘ritual engines’ of desert life, removing some of the constraints on precontact ceremonial exchange systems.
THE RED OCHRE MINES: PUKARDU, WILGIE MIA AND KARRKU

Fragments of red ochre recovered from dated occupation deposits show that exploitation of some ochre sources began in the late Pleistocene, but evidence from the mines and quarries also suggests a more recent escalation of production.

Ochres are natural earthy red or yellow pigments, containing iron oxides or hydrated iron oxides, sometimes as crystalline haematite. Aboriginal people used red ochre for a variety of purposes: as body paint during ceremonies, as a covering to cool the skin, as a preservative on balls of dried fruit, as decoration on wooden implements and as pigment in rock paintings. Ochres were ground into a dry powder and rubbed onto the body either directly or after rubbing the body with grease. Both men and women used red ochre as a ritual cleanser during ceremonies. Mirroring European use of the term ‘haematite’, many red ochre deposits are equated mythologically with the blood of totemic beings. As Jones puts it, red ochre was ‘a medium or agent of transcendence, from sickness to health, death to renewal, ritual uncleanness to cleanness, the secular to the sacred, the present reality to the Dreaming’ (2007: 349).

The most desirable ochres were those with a deep red colour, good covering qualities and a distinctive metallic lustre (produced by small, aligned flakes of crystalline haematite). The diagenesis of ochre is complex: earthy haematite, limonite or goethite often originate in ancient marine sedimentary formations, and may occur as pockets of reworked and deeply weathered sediment in joint-lines or cavities in bedrock; ochre is also found in Tertiary-age laterites, whereas crystalline haematite mostly derives from gossans and hydrothermal lodes or veins (Smith and Fankhauser 2009). Across Australia’s deserts, ochre was widely obtained from outcrops of laterite or ferruginised sandstone. In some locations, small pits or tunnels were dug into earthy iron-rich sediments to extract the ochre. The best-known ochre mines – Pukardu, Wilgie Mia and Karrku (see Figure 8.3) – are discrete deposits where Aboriginal people extensively used open-cut pits or tunnels to follow an ochre seam. The high-grade red ochre from these sources was exchanged over hundreds of kilometres, sometimes involving organised expeditions.

Pukardu (also known as ‘Bookartoo’) provides the best-documented ethnographic example of these red ochre expeditions (reviewed in detail by Jones 2007). The name comes from ‘the term for the heart’s blood of the fierce dog-like animals, which was spilt at the site’ (Jones 2007: 352). Gason (1874) witnessed red ochre expeditions leaving Cooper Creek on the 400-km journey to Pukardu in the Flinders Ranges. These annual expeditions usually took place in winter. Gason noted that

the party travels about twenty miles a day, and on arrival at the mine each member of it digs out his own ochre, mixes it with water, making it into
loaves of about 20 lbs. weight, which are dried. Each man carries an average weight of 70 lbs. of ochre, invariably on the head, and has to procure his own food; the party seldom resting a day while on the journey, which lasts usually from six to eight weeks (1879: 281).

In most cases, these appear to have been parties of Diyari men, but some accounts mention men from 'the source of the Diamantina and Herbert Rivers' (1,200 km to the north) (Masey 1882). Howitt notes that the Yandruwantha also mounted annual expeditions to Pukardu (1904: 713), and there are first-hand accounts of Wangkangurru men taking part in some expeditions (Hercus and Koch 1997; Jones 2007).

By 1860, the Pukardu mine lay well within the bounds of European settlement. Because large parties of armed men entering the pastoral districts posed a problem for colonial authorities, police and sheep station managers, there are a number of independent accounts of red ochre expeditions between 1864 and 1890. These corroborate Gason's observations of the scale of these expeditions: reports of group size range from fifty to eighty men, with estimates of the average load of ochre ranging from 23 to 45 kg per man (Masey 1882; Howitt 1891, 1904: 712; Jones 2007). In one case, a party of fifty-six men was intercepted carrying between them '30 cwt' (1.5 t) of red ochre (The South Australian Register, 26 July 1864). These accounts also make it clear that senior men of the local group regulated access to the ochre, and at least one party was ambushed and killed at the mine for breaching this protocol (Jones 2007).

Despite its fame, Pukardu is a relatively small ochre mine. It is located on a spur high in the northern Flinders Ranges. The deposit is an earthy haematite, in-filling joints and cavities in dolomite (Keeling 1984). The remains of six open-cut pits (2–6 m in diameter) record the last major phase of quarrying at this site. Today, these are choked with silt and boulders and only 0.5 m deep. Local subsidence shows there are subterranean cavities nearby, suggesting that the pits were once deep enough to allow adits from their sides. Surrounding the pits, a raised rim of spoil skirts the spur – enclosing about 240 m² of worked ground (all of the available area of the spur). Assuming the pits were originally 2 m deep, the visible workings account for about 40 m³ of excavated ochre. If we extrapolate to the entire area of the spur (and reconstruct the line of the ridge, allowing for 1.5 m of ochre quarried away, and assume that 25 per cent of this was dolomite spoil), then a maximum of 600 t of ochre may have been quarried at Pukardu. On these figures, Pukardu could not have sustained the scale of extraction recorded ethnographically (2.1 t per year) for much more than 300 years.

Pukardu ochre is chemically and physically distinctive, ranging from friable dark pink ochre to a heavy greyish-red haematite (Jercher et al. 1998; Smith and Fankhauser 2009). Pieces of this ochre, identified by their geochemistry, have been found on surface sites along the lower Cooper (SAM A66497 and
The Wilgie Mia red ochre mine, photographed in about 1910 by WH Kretchmar. This shows the base of the initial open cut. A large subterranean gallery, running off to the RHS, slopes down to a depth of 30 m below surface. (Photograph courtesy of Department of Anthropology and Archaeology, Western Australian Museum)

A66498, Smith and Fankhauser 2009), but so far it has not been found in dated archaeological contexts. The nearest excavated site, Arkaroo Rock, has a sequence spanning the last 7,000 years, with a large assemblage of ochre pieces dated to within the last 5.5 ka (Draper 1989). However, none of these ochres has the geochemistry or petrology characteristic of Pukardu ochre (Smith and Fankhauser 2009). The present picture, therefore, is of a mine mainly used within the last few hundred years.

The scale of production at Pukardu is dwarfed by that at Wilgie Mia, the largest of the ethnographic ochre mines (Figures 8.5 and 8.6) (Woodward 1914; Kretchmar 1936; Davidson 1952; Baynes 1984). Here, the workings form a large open-cut quarry, which leads into a massive subterranean gallery excavated under a cap-rock of ironstone on the crest of a ridge in the Weld Range. Davidson provides a description of the quarry in 1939:
From the summit on the north side a great open cut varying between fifty and one hundred feet in width and possibly sixty-five feet in depth has been laboriously excavated. On the sides around the bottom are deeper chambers, while underneath them numerous tunnels follow the seams of red and yellow ochre, often for several yards. The excavation is so stupendous that it is difficult to attribute such an accomplishment to a people with a simple technology. (1952: 82)

From the main chamber, a series of smaller galleries and crawl spaces – up to 60 m long – follow steeply dipping pockets of earthy haematite into the hill. Wooden scaffolds were used to provide access to seams of ochre, and hammer-stones and fire-hardened wooden digging sticks were used to wedge and pry out the blocks of ochre. Woodward (1914) provided the most detailed report on the mine. He estimated that about 15,000 cubic yards (11,468 m³) of rock and ochre had been quarried at Wilgie Mia, equivalent to about 24,000 t. Because the earthy ochre and haematite is in thin bands, interbedded with shale and jaspilite, much of this may have been mining waste. However, even a conservative estimate of yield (assuming 75 per cent mining waste) indicates that some 6,000 t of ochre may have been extracted.

Commercial exploitation of the deposit began in 1945 and continued until 1978, extracting a further 9,131 t of ochre (Elias 1982: 20). In 1963, Crawford
carried out an archaeological excavation in part of the main chamber left undisturbed by commercial mining (1963) (see Figure 8.6). This revealed more than 6 m of floor deposits – made up of fine layers of ash, quartzite rubble and haematite dust, with a concentration of mining implements in the upper 4 m. Other finds included a tula adze, a geometric microlith and a bone point. Crawford obtained two 14C dates – on wood in layer 12 (560 ± 70 BP Gak 1769) and in layer 23 (at 6 m depth) (1,100 ± 90 BP Gak 1770) – showing that use of this mine spanned the last millennium. These dates also imply that significant excavation of ochre had already occurred by the time the floor deposits in this part of the mine began to accumulate 1,000 years ago.

Based on Aboriginal informants in 1939, Davidson (1952) concluded that Wilgie Mia quarry provided most of the red ochre used in the southwestern sector of the arid zone, up to 450–600 km from the mine. For such a large mine, however, it is surprising that there is so little direct archaeological or ethnographic evidence for the trade and exchange of this ochre. Wilgie Mia ochre was used in rock paintings at nearby Walga Rock (Clarke 1976), but it has not been found in dated excavated contexts at this site (Bordes et al. 1983) or ‘down-the-line’ in Western Desert sites such as Kaalpi, Serpents Glen or Puntutjarpa (Smith and Fankhauser 2009).

Karrku is a regional red ochre mine in the Campbell Range in the western part of Central Australia. Like Wilgie Mia, ochre mining at Karrku has formed a substantial subterranean chamber beneath the cap-rock of a flat-topped hill, with tunnels tracing a seam of ochre into the hillside for about 35 m. Peterson and Lampert (1985:2) estimate that 240 m³ of ochre has been dug up at Karrku, equivalent to 500 t (on my calculation that the density of Karrku ochre is 2.1g/cm³, equivalent to 2.1 t/m³). Today, Warlpiri people still use the mine. Before about 1940, Karrku ochre was traded locally to the north and south of the Campbell Range, reaching the Ehrenberg Ranges, 65 km south of Karrku. As with other ochre mines, access to Karrku was controlled by a group of closely related kin – although, in this case, this also involved a competitive assertion of rights by senior men belonging to different clan estates (Peterson and Lampert 1985). The remains of wood brought into the mine as firesticks are present among mining debris at the base of the modern work face. Radiocarbon dating of torches from the surface of the south chamber gives ages ranging from modern to 230 years (211 ± 37 BP Wk-21266; 223 ± 35 BP Wk-21267; 183 ± 34 Wk-21268; modern Wk-21269 – MA Smith, unpublished field data).

Earlier evidence of use is provided by the identification of Karrku ochre in the long archaeological sequence from Puritjarra rockshelter, 125 km to the south (Smith et al. 1998). Karrku ochre is a distinctive, dark-red micaceous haematite with a high proportion of lanthanide elements, characteristic of deep weathering (Smith and Fankhauser 2009). The archaeological ochres at Puritjarra superficially resembled Karrku material but were subject to a nested
series of analyses to test this: looking at major and minor oxide composition, petrology, mineralogy, quartz provenance identity using stable isotope ratios, and trace-element analysis. The results show that people visiting the rockshelter around 35,000 years ago brought with them red ochre from Karrku, indicating that exploitation of this deposit had begun by this time. The slightly higher proportion of kaolinite to muscovite in the archaeological specimens indicates that these samples have undergone greater weathering than contemporary samples from the mine. This suggests that the late Pleistocene ochres were obtained from parts of the lode more exposed to surficial weathering, perhaps indicating an early stage in the development of the mine (viz. a time before the subterranean chambers were established).

Whatever the case, archaeological evidence suggests that Karrku lay within the catchment of people using Puritjarra during the late Pleistocene, and that the ochre was obtained directly (‘embedded procurement’) rather than by long-distance exchange. At Puritjarra, Karrku ochre is the most common type found in late Pleistocene levels, but its use declined after 15 ka, coinciding with other evidence for shifts in site territory. During the last millennium, it once again became the dominant ochre at Puritjarra. Smith et al. (1998) suggested that this reflected new exchange links with the Karrku area, but increased production at the mine might also have been a contributing factor.

Age estimates are available for two other desert ochre quarries. The first, Ulpunyali, is a regional quarry in western Central Australia, where local Aboriginal people dug a series of open pits to extract coarse-grained, greasy, purple or dark-red ochre. Red ochre from Ulpunyali first appears in significant amounts in the Puritjarra sequence from 15 ka (Smith et al. 1998). Because this site is only 50 km from Puritjarra, the ochre is likely to have been obtained directly by the people using the rockshelter. The second example is the Anvil Creek ochre quarry (Ridges 2003: 63). Here, a shallow subsurface ochre-rich layer with charcoal is dated to 250 ± 70 BP (Beta 40523). Lichen on the surface of the ochre outcrop is dated 140 ± 100 BP (NZA 5730), suggesting that use of this quarry ceased before 1800 AD. Red ochre from this source (or a related source) was found in a heat treatment pit (hearth 5) excavated at Cuckadoo 1 rockshelter, dating to 4.8 ka (4,270 ± 70 BP Beta 38562) (Davidson, Sutton and Gale 1993), showing that roasting was used to improve the adherence of the ochre on rock surfaces.

These ochre quarries have contrasting histories. Regional quarries with limited local distribution clearly have some antiquity, as shown in the case of Karrku, Ulpunyali and Anvil Creek. Pukardu – a ‘long-transfer’ quarry with large-scale production of ochre – seems to have operated for only a few hundred years. On present data, we cannot say where Wilgie Mia fits into this scheme. The scale of ochre mining at this site suggests that it must have fed into a ‘long-transfer’ network involving red ochre expeditions organised on a similar scale to those along the inland rivers on the eastern side of the desert.
However, there is no direct ethnographic or archaeological evidence for this. If ochre was extracted at the rates recorded ethnographically for Pukardu (about 2.1 t per year), Wilgie Mia may have had an operating life of 3,000 years. On the other hand, Crawford’s radiocarbon dates indicate production rates within the last millennium at Wilgie Mia that were well in excess of those at Pukardu, suggesting the ethnographic workings need not have an antiquity much beyond 2 ka.

GRINDSTONE QUARRIES AND THE TRADE IN MILLSTONES

The importance of grass and acacia seeds as grain led to substantial demand by desert groups for replacement grinding slabs. Tindale notes that in the Western Desert, ‘there is a woman’s song that laments the inertia of her husband who would not make the journey to fetch new tjungguri stones [topstones] for her. Her hand stone is worn so thin the tips of her fingers are bleeding as she makes his bread’ (1974: 100). In Central Australia and parts of the Western Desert, these replacement slabs were locally obtained as natural tabular blanks in the sandstone and quartzite ranges dotted across the desert. In sandy regions of the Western Desert, however, they were a scarce resource. ‘Men travelled to the known sources of stone, utilizing kinship ties with people in these areas,’ notes Hamilton. ‘The further diffusion of the stones depended on men replacing the grindstones of their wives, then appropriating the older ones and passing them on in trade to men of the west’ (1980: 8).

In other areas, this demand was met by specialised grindstone quarries, which supplied sandstone slabs for local needs or fed finely finished millstones into long-distance exchange networks (McBryde 1987). These grindstone quarries are typically positioned on the edge of large tracts of sand plain, dune-field or stony ‘gibber’ desert – areas where suitable stone is scarce (see Figure 8.3). The best-known examples are the quarries at Helen Springs (Kurutiti), on the edge of the Barkly Tableland (Mulvaney 1997); Anna Creek (Palthirripirdi), near Lake Eyre (Hercus 2005); Tooths Nob (Wadla wadlyu), north of Reaphook Hill in the Flinders Ranges (McBryde 1997); Narcoonowie, in the Strzelecki dunefield (Smith et al. 2010); and the quarry complexes north and south of Cooper Creek at Innamincka (including Wild Dog Hill and Mount McLeod) (Hiscock and Mitchell 1993; McBryde 1987). Access to the major quarries and local knowledge about the production of grinding slabs appears to have been carefully regulated. It was usually in the hands of senior men, although ethnographic accounts are sketchy. For instance, at the Walaya quarry in the Toko Ranges, Roth noted ‘the exact locality and process of removal from out of the natural rock is said to be a secret among the old men: that the slabs are in some way detached by means of fire and then split with bone pegs’ (1904: 25).
TABLE 8.2. Production estimates for arid-zone grindstone quarries

<table>
<thead>
<tr>
<th>Quarry</th>
<th>Quarry pits (number)</th>
<th>Excavated volume $^b$ m$^3$</th>
<th>Estimated number of millstones$^c$</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Regional</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yambacoona Hill</td>
<td>370</td>
<td>3,700 (2,775)</td>
<td>68,300$^d$</td>
<td>Field et al. 2003</td>
</tr>
<tr>
<td>Kurutiti</td>
<td>200</td>
<td>2,000 (1,500)</td>
<td>87,200$^e$</td>
<td>Mulvaney 1997</td>
</tr>
<tr>
<td>Narcoonowie</td>
<td>39</td>
<td>196 (150)</td>
<td>2,050$^f$</td>
<td>Smith et al. 2010</td>
</tr>
<tr>
<td><strong>Long-transfer</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anna Creek</td>
<td>—</td>
<td>1,032 (774)$^h$</td>
<td>71,000$^i$</td>
<td>Worsnop 1897</td>
</tr>
<tr>
<td>Innamincka</td>
<td>—</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tooths Nob</td>
<td>1,100$^d$</td>
<td>19,800 (14,850)$^j$</td>
<td>731,500$^d$</td>
<td>McBryde 1997</td>
</tr>
</tbody>
</table>

$^a$ McBryde 1997, figs. 6 and 7, shows 370 quarry pits covering 30 per cent of the quarry complex. By extrapolation, there are approximately 1,100 pits in total.

$^b$ Figures in brackets assume 25 per cent wastage in the form of quarry debris. These figures are used for the net production estimates. Excavated volume is calculated assuming that an average quarry pit is 6 m in diam and 1 m deep = 10 m$^3$.

$^c$ Net millstone production assumes rough-outs are 50 per cent greater volume than finished millstones and uses the following estimates of millstone dimensions and volume:

$^d$ Here I use figures for Innamincka millstones, 52 $\times$ 41 $\times$ 9.5 cm = 0.0203 m$^3$.

$^e$ Kurutiti, 55 $\times$ 26 $\times$ 6 cm = 0.0086 m$^3$.

$^f$ Narcoonowie, 65 $\times$ 40 $\times$ 25 cm = 0.073 m$^3$. This is an overall figure for rough-outs and is relatively high because the sandstone is poor and without good tabular cleavage.

$^g$ Anna Creek, 46 $\times$ 30 $\times$ 8 cm = 0.0110 m$^3$.

$^h$ Worsnop’s estimate includes only a proportion of this extensive quarry. Actual production rates are likely to be three to four times greater, perhaps 200,000–280,000 millstones.

$^i$ Quarry pits at Tooths Nob and Innamincka are larger on average than 10 m$^3$. The figure used for these quarries is 18 m$^3$ per pit – a figure midway between 10 m$^3$ and 26 m$^3$ (the larger pits are assumed to average 10 m in diameter and to be 1 m deep = 26 m$^3$).

A distinction between regional and ‘long-transfer’ quarries is important here. The great quarry complexes at Anna Creek, Tooths Nob and Innamincka provided sandstone slabs that were traded hundreds of kilometres north into the immense Simpson dune field and along the arid inland rivers on its eastern margin. Supplementing the major grindstone quarries was a second tier of quarries based on smaller outcrops, often exploited less intensively, and serving the needs of communities within their local area or region. McBryde’s unpublished research shows that this difference is documented in the distribution of surface finds and museum collections of grindstones across the Lake Eyre region. Finally, as Table 8.2 shows, there is a significant scaling up of production from regional quarries to those identified as ‘long-transfer’ quarries.

The Lake Eyre Basin Quarries

The most striking concentration of grindstone quarries in the arid zone lies in the southern part of the Lake Eyre basin (see Figure 8.2), where there are at
least five known quarries in addition to the major complexes at Anna Creek, Tooths Nob and Innamincka.

West of Lake Eyre, the Anna Creek quarry is known to Arabana-Wankangurru people as *Palthirri-pirdi* (lit. millstone [*palthirri*] quarry [*pirdi*]). Mythologically, this long narrow outcrop of fine grey-white sandstone, 200 m long, is said to represent a fish bone. Field surveys and oral accounts point to a wide distribution of Anna Creek grindstones across the southern part of the Simpson Desert, especially in the Kallakoopah area. The full extent of trade in this stone is yet to be established, but the quarrying activity at Anna Creek was clearly intensive: numerous quarry pits crater the outcrop. Worsnop calculated that 1,354 t of stone (1,032 m³) had been excavated from the main part of the quarry, which he estimated represents the production of about 71,000 millstones (he allowed for 25 per cent wastage and used field observations that showed the largest millstones measuring $46 \times 30 \times 8$ cm) (1897: 98). Because he dealt with only part of the quarry, and because the quarry pits extend along the entire length of the outcrop, the actual production rate of millstones may have been three to four times this figure, perhaps around 200,000 millstones.

The Wadla wadlyu quarry complex at Tooths Nob, on the eastern slopes of the Flinders Range, represents an even larger scale of production. Quarry pits extend for 1 km along sandstone ridges, with more than 370 quarry pits mapped (McBryde 1997; this represents a net production of between 500,000 and 1.5 million millstones. The quarrying was standardised both in product and process: tabular sandstone was split using stone wedges and, like most grindstone quarries, was excavated in oval pits up to 10–20 m in diameter and up to 2 m deep. Of all the quarry complexes, Tooths Nob is the site most explicitly linked to long-distance trade along the inland rivers. Millstones from Boulia, 1,000 km to the north, have been petrologically sourced to this quarry. Howitt links acquisition of the grindstones to ethnographic red ochre expeditions to the Pukardu ochre quarry, noting ‘the flagstones used for grinding seeds were obtained not far from the red ochre mine. Each man carried back either a slab of stone or lump of red ochre on his head’ (1904: 713); with ‘some kind of permit from the intervening tribes’ (1878: II, 305).

At Innamincka (*Jidniminka*), Cooper Creek debouches from the bedrock-controlled section of its channel and spreads out into a maze of floodplains among the dunefields to the west. At this point, the sandstone hills have been extensively quarried for grinding slabs. Reuther reports ‘these millstones are brought from *Jidniminka* for purposes of trade. The Jandrowonta and Jauru-worka people are the owners of this stone pit which is of great importance to them for the bartering trade’ (1981 [1914]: II, 238, 1081). In fact, there are a number of discrete grindstone quarries at Innamincka, extending along hillslopes and escarpments for 10 km on both sides of Cooper Creek. The distinctive, gritty brown sandstone was extracted in quarry pits, 2–20 m in diameter and up to 2 m deep, with rock slabs piled around the rim, forming a maze of intersecting craters on some hills. Grinding slabs appear to have
been roughed out on the spot: flaked to shape, bifacially thinned and then hammer-dressed to produce ovoid millstones with a biconvex cross-section. Production appears to have been on a large scale, with a standardised approach to the reduction and dressing of grindstone slabs. However, the scale of these quarries presents difficulties for study and, at present, there is no detailed survey plan of the Innamincka quarries or any formal analysis of the production and distribution of the millstones.

Narcoonowie provides a contrast to the large quarries. This is a small satellite quarry in the Strzelecki dunefield, 85 kilometres south of the main Innamincka quarry complex (Smith et al. 2010). The Narcoonowie quarry is made up of a series of shallow circular pits (Figure 8.7) – covering a total area of
4,000 m²– excavated into a low subhorizontal bed of low-grade sandstone exposed in a dune swale. The superimposition of pits shows that quarrying initially exploited a low bench of sandstone exposed in the swale and progressively extended to the northwest over the life of the site. Quarrying initially produced irregular, subangular to tabular slabs that were worked into standardised grindstone blanks in workshop areas adjacent to the quarry, in a process similar to those at the Innamincka quarries. Nearly 345 t of stone has been removed from the quarry area (assuming 1 m³ sandstone weighs 2.3 t), which translates to about 2,052 dressed millstone blanks. Many of the grindstones produced here were used locally within the Strzelecki Desert: implements made from Narcoonowie stone are mainly found within 65 kilometres of the quarry.

Smith et al. (2010) calculated that the use-life of a millstone was 1,600 hours, effectively about 9 years using ethnographic consumption rates for native cereals (assuming an average daily preparation of 0.5 kilograms of flour per adult woman for 90 days each year, a total of 180 hours of grinding time per woman per year). The Yandruwantha (in whose country the Narcoonowie quarry lies) would have needed to replace 1,400 millstones per century. These figures suggest that small quarries such as Narcoonowie could not have met local demand for more than 150–300 years.

Kurutiti (Helen Springs)

Kurutiti – in the Ashburton Range, northern Central Australia – is an example of a major regional quarry outside the Lake Eyre basin (Mulvaney and Gunn 1995; Mulvaney 1997). It supplied grinding slabs to an area of about 135,000 km², extending from the eastern part of the Tanami Desert to the Barkly Tableland. The workings extend over 5.5 ha, with more than 200 pits ranging from 1 m to 20 m in diameter and up to 2 m deep, surrounded by sandstone quarry debris up to 5 m deep in the main part of the site. Remarkably, the workings are associated with large numbers of petroglyphs: Mulvaney and Gunn (1995) record 2,249 engraved motifs, mostly in the classic desert Panaramitee style.

Like all of the quarries discussed here, production methods at Kurutiti were standardised – although the thick, uniform beds of sandstone demanded a distinctive approach. Small pits were pecked into exposed sandstone surfaces, 5–15 cm apart, to split the sandstone along the resulting stress lines, using both fire and hammer-stones. This method produced slabs 5–6 cm thick that were then flaked to shape, bifacially trimmed along the margins and then hammer-dressed to produce finished millstones. The grindstones appear to have been manufactured on demand because there is no evidence for stockpiling of finished slabs.
The Chronology of Grindstone Quarries

The development of seed-gathering economies around 3,000–4,000 years ago, and their expansion within the last millennium, would have required the provisioning of large areas of sandy desert with grinding slabs, an ongoing challenge for desert groups in these areas. The appearance of seed-grinding implements in archaeological deposits across the arid zone between 1 and 3.8 ka provides an upper limit for the age of the grindstone quarries. The large-scale production of grinding slabs in the Lake Eyre basin, however, goes well beyond the immediate provisioning needs of these landscapes: the major quarry complexes at Anna Creek, Tooths Nob and Innamincka alone represent production of perhaps 1–2 million millstones over the life of these quarries. One scenario is that grindstone quarries initially developed to meet local and regional economic needs around 3–4 ka, and that later, as the quarries in the Lake Eyre basin were incorporated into long-distance exchange networks, production had to be scaled up to meet the new demands.

Current data allow few opportunities to test this at present. Grindstones made on quarried slabs have not been distinguished in analyses of excavated assemblages. The chronology of the quarries themselves is uncertain. The northern part of the Innamincka complex appears to have been operating by at least 2,000 BP. This is suggested by a $^{14}$C date of 1,700 ± 140 BP (Beta-30777), on charcoal (associated with the use of fire to break up the sandstone) from a sealed context at the base of a quarry pit on Mt McLeod (Smith et al. 2010). On its own, however, this does not help to discriminate between production for local use and the hyper-production associated with ‘long-transfer’ quarries.

At Narcoonowie, a range of circumstantial evidence suggests that this quarry is no older than 600 years and that it represents a late expansion of grindstone production at a marginal site. At Kurutiti, the presence of a late Holocene artefact assemblage that includes ground-edge axes (N = 15, all locally made on dolerite pebbles) (Mulvaney 1997) suggests that use of this quarry dates to no more than 1,000 BP.

PRODUCTION OF STONE AXES FOR TRADE AND EXCHANGE

The accelerated production of stone axe heads for trade and exchange provides one of the best examples of the transformations underway in the scale of these exchange systems during the last millennium.

Stone axe heads formed part of a composite implement, more properly called a hatchet than an axe (Figure 8.8). Australian stone hatchets usually had a dolerite, diorite or basalt head (500–700 g), with a ground edge, bound with an adhesive (either resin or beeswax loaded with a cellulose filler) into
a wrap-around split-wood handle (Dickson 1981). In woodlands and savanna, they were an indispensable tool (Sharp 1952) – widely used to extract honey or possums from tree hollows, cut footholds in tree trunks, remove bark for shelters or canoes or cut and dress blanks for wooden implements. In Australian drylands, they were used in the northern and eastern parts of the arid zone, but historically they were absent from the south and west (Figure 8.9). This pattern is not simply due to more open desert terrain or an absence of suitable stone because pockets of acacia and eucalypt woodland, as well as outcrops of dolerite, occur across much of this region (e.g., Wingate, Pirajno and Morris 2004). One explanation, suggested by Hayden (1977b), is that the costs associated with making and maintaining a stone axe are only justified in areas where wood-working is extensive (and where the associated turnover of stone implements is relatively high). This may well be the case, but clearly it does not account for the archaeological distribution of stone axes because early Holocene woodlands were more extensive than today’s woodlands, and the wooden tool kit appears to have diversified around 3–4 ka, well before the earliest axes appear in the interior (see Chapter 6). An alternative view is that the ethnographic distribution of stone axes in the arid zone is an historical legacy of shifts in patterns of exchange.

Stone axes entered desert societies by several different paths. On the margins of the desert, axes were traded into the region from the southern Kimberley in the north and from temperate regions in the southeast (Binns and McBryde 1972; McBryde 1978). For instance, stone axes from the Mt William quarry in central Victoria were exchanged along the Murray–Darling River system, reaching the Barrier Ranges in the southeastern sector of the arid zone, more than 700 km from their source. Within the desert, there were also local axe quarries in Central Australia: in the Stuart Pass dolerite in the
Figure 8.9. The chronological distribution of ground-edge axes in Australia. The earliest axes are from late Pleistocene sites in northern Australia (open squares). Axes are common in archaeological assemblages in eastern and northern Australia during the last 4,000–5,000 years (dark grey shading). They spread into the eastern part of the desert during the last millennium (light grey shading) (black triangles show excavated desert sites with stone axes dating less than 1 ka) but are rare or absent in the western half (unshaded), where they only occur in recent prehistoric or ethnographic contexts (open triangles), often as items traded from the north. (Updated from Davidson 1938; Davidson and McCarthy 1957; Dickson 1981: fig. 1; and Morwood and Hobbs 1995: fig. 1). Hatched area shows the distribution of axes from the Mt Isa quarries (black square). (Adapted from Davidson et al. 2005: fig. 13.3)

MacDonnell Ranges, in diorites near Yuendumu in the Treuer Range, and near Kurundi in the Davenport Range (Spencer and Gillen 1899: 590).

The largest arid-zone axe quarries – as well as an extraordinary density of quarries – occur in the meta-basalts around Mt Isa (Davidson et al. 2005) (see Figure 8.3). These quarries were pivotal in interregional trade because of the systematic large-scale mining and production that took place here, and their strategic position near the headwaters of the Georgina–Mulligan River system. Some forty discrete axe quarries are known in the Eastern Creek Volcanics (Davidson et al. 2005). The major quarries concentrated on ridges of meta-basalt (with a distinctive green schist facies), with less extensive quarrying of local rhyolite outcrops, mafic dykes and meta-andesites.

Hiscock (2005) provides details of Lake Moondarra 1 (LM1), the largest of the meta-basalt quarries in the Mt Isa area. This quarry extends over an area of 2.4 km² – with large volumes of debris, stockpiles of finished goods and clearly
differentiated activity areas – and is comparable in scale to the better-known Mt William quarry in Victoria (McBryde and Watchman 1976). Quarrying activity focused on ridgetops, where circular pits, 3–10 m diameter and more than 0.6 m deep, were dug to extract the stone. Hiscock (2005) estimated that on the ridge crests, there is one quarry pit per 100 m². Between these pits are dense piles of flaking debris up to 1 m deep and also piles of axe rough-outs, retouched to shape and then stacked. Further bifacial trimming of axe blanks took place on the flats between the ridges; some flaked blanks were ground to form finished axes, which also appear to have been stockpiled.

The scale of production reflected in the Mt Isa quarries was immense. At LM1, Hiscock (2005) estimated that 800,000 axe rough-outs were stockpiled across the site. If we assume that this reflects only 75 per cent of production, and that use of LM1 spans no more than a millennium (see the following discussion), then this quarry alone represents production of about 1,000 axes per year. And if we scale up to include the other quarries in the Mt Isa district, it is clear that axe production may have been on the order of 10,000–15,000 axes per year, reflecting a considerable surplus above normal replacement needs for these implements within the region. But it is not just the scale that suggests large-scale production for exchange: finished implements were also highly standardised in size and shape, reflecting routine application of a set sequence of production. The ground-edge axes from this region ‘up to 23 cm in diameter and 2 kg in weight, smoothly flaked all over both sides, and often ground all around the edge, are ranked among the finest axes in Australia’ (McCarthy 1976a: 50).

Ethnographic accounts of control and access to the Mt Isa quarries are sketchy. The Mt William and Central Australian axe quarries were controlled by men of the local patri-clans (Spencer and Gillen 1899: 590) – and this might also have been the case at Mt Isa. WE Roth (1897: 151) noted that it took a day to rough out an axe blank and another day to grind the finished axe, the latter ‘a tedious process, sometimes said to be the work of the women’ (1904: 19). Such an investment of time is corroborated by Spencer (1928: 498), although some experimental work indicates that flaking and grinding a basalt axe head need only take four hours (Dickson 1981: 41). On these figures, the production of axes at the Mt Isa quarries must have involved about 20,000–25,000 man/hours per year, representing a significant investment of time by local hunter-gatherer groups outside normal subsistence activities. The Mt William quarries were worked in response to demand, whereas the stockpiling of axes and axe blanks at LM1 suggests the Mt Isa quarries were worked in anticipation of demand.

Axes from these quarries have a wide distribution along river systems north and south of the Mt Isa district (see Figure 8.9). Their distribution extended 1,000 km south to the lower Cooper and Reap Hook Hill area in the Flinders Ranges, where axes petrologically sourced to these quarries have been found.
Table 8.3. Sites with axe fragments in dated contexts in the arid zone

<table>
<thead>
<tr>
<th>Site</th>
<th>Levels with axe fragments</th>
<th>Region</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Leichardt River</td>
<td>&lt;1,100 cal BP</td>
<td>Mt Isa</td>
<td>(6)</td>
</tr>
<tr>
<td>Anvil Creek 1</td>
<td>&lt;850 cal BP</td>
<td>Selwyn Ra</td>
<td>(1)</td>
</tr>
<tr>
<td>Cuckadoo 1</td>
<td>&lt;1,067 cal BP</td>
<td>Selwyn Ra</td>
<td>(1), (2)</td>
</tr>
<tr>
<td>James Range East</td>
<td>&lt;800 cal BP</td>
<td>Central Australia</td>
<td>(3)</td>
</tr>
<tr>
<td>Thereyertete</td>
<td>&lt;590 cal BP</td>
<td>Central Australia</td>
<td>(3)</td>
</tr>
<tr>
<td>Puritjarra</td>
<td>&lt;800 cal BP</td>
<td>Central Australia</td>
<td>(4)</td>
</tr>
<tr>
<td>Tjungkupu 1</td>
<td>&lt;974 cal BP</td>
<td>Central Australia</td>
<td>(3)</td>
</tr>
<tr>
<td>Wannarra</td>
<td>&lt;1,000 cal BP</td>
<td>Central Australia</td>
<td>(3)</td>
</tr>
<tr>
<td>Vlaming Head Midden 2</td>
<td>Surface find</td>
<td>NorthWest Cape</td>
<td>(5)</td>
</tr>
</tbody>
</table>

Sources: (1) Ridges 2003: 63; (2) Davidson et al. 1993, 2005; (3) Smith 1988; (4) Smith 2006; (5) Przywolnik 2002; (6) Hiscock personal communication. Fragments of dolerite with traces of grinding are found throughout Holocene and late Pleistocene levels of Mesa J 24 in the Pilbara but are not identified as axe fragments (Hughes and Quatermaine 1992).

on archaeological sites (Veth, Hamm and Lampert 1990: 55; McBryde 1997: 604–5). Trade along these inland river systems is known from the ethnography (Horne and Aiston 1924: 34) and from trade axes found cached along this route (Winnecke 1884: 12; Kelly 1968; Davidson et al. 2005). The uniformity of the axes, traded over hundreds of kilometres, is striking: the median length of axe heads from the Cooper Creek area (129 mm) is little different from that at the Mt Isa quarries (121 mm) (Tibbett 2002), consistent with rapid, long-distance transfer of these commodities. However, the evidence also indicates that ‘long-transfer’ quarries such as LM1 co-existed with small-scale production from local sources and secondary exchange systems (reciprocal ‘down-the-line’ exchange) that distributed axes away from the inland river systems (Tibbett 2002; Davidson et al. 2005). For instance, Mt Isa axes were used in the Selwyn Ranges, not just traded through this region.

Although there is little direct evidence on the age of the Mt Isa quarries, the chronology of ground-edge axes provides some broad constraints on their antiquity. Ground-edge axes are found in late Pleistocene assemblages in tropical Northern Australia but only appear within the last 4,000–5,000 years in the woodlands of eastern and southeastern Australia (Morwood and Hobbs 1995) (see Figure 8.9). In Central Australia, they occur somewhat later and have not been found in contexts earlier than 800–1,000 years ago (see Table 8.3). Stone axes are not found on archaeological sites in the Great Sandy Desert but were traded into the region (Cane 1984: 167). Further afield, in arid northwestern Australia, there is little evidence that the presence of axes has any antiquity: despite the large number of archaeological excavations, axes have only been
found in undated surface contexts in the Pilbara and Northwest Cape regions. These finds may reflect ‘down-the-line’ exchange from northern Australia into the desert within the last 200 years. It is relevant that, ethnographically, their use in the Pilbara was limited to rain-making ceremonies (axes are mythologically associated with lightning and the ‘lightning man’).

Excavations in rockshelters near the Mt Isa quarries confirm this broad pattern: flakes and fragments of edge-ground axes only occur in levels dating less than 1.1 ka, although it is not definitely established that these are from quarried axes rather than meta-basalt river cobbles. At Cuckadoo 1, two meta-basalt axe fragments in levels dating less than 1,170 ± 50 BP (Beta 25057) have been sourced to the Group III (greenschist) meta-basalts at Mt Isa. On this evidence, the large-scale trade in stone axes along these inland river systems cannot be much earlier than the last millennium. The east-to-west chronology for the appearance of axes in the desert also suggests that the trade in Mt Isa axes in the eastern part of the arid zone may have stimulated interest in the value of axes as prestige and prestation goods in adjacent parts of Central Australia.

THE DESERT NARCOTIC PITURO

The trade in pituri provides another example of long-distance exchange that was organised on a corporate and logistic level rather than on ‘down-the-line’ exchange between individuals.

Colonial interest in the pharmacological properties of pituri was intense (Bancroft 1879; Howitt 1904: 710–12; Johnston and Cleland 1933–4; Watson 1983). The drug – technically both a stimulant and an analgesic – was reported ‘to produce a voluptuous dreamy sensation’ (Bancroft 1879: 7). Europeans first encountered it on Cooper Creek in 1861, when members of the Burke and Wills exploring expedition were given ‘bedgery or pedgery’, which was mixed with acacia ash to form a quid for chewing (Wills 1863: 283). Abandoned and starving, the sole survivor of that expedition, John King, noted that ‘after chewing it for a few minutes I felt quite happy and perfectly indifferent about my position’ (in Moorehead 1985: 118).

It took some time for Europeans to identify a sandhill shrub (1–2 m high), Duboisia hopwoodii, as the source of pituri. D. hopwoodii is widespread across the arid zone, but herbarium records show that it has a markedly disjunct distribution, with a small isolated population near the upper reaches of the Mulligan River, where there are groves of these shrubs (Silcock, Tischler and Smith 2012). Mulligan River Duboisia also has a distinctive chemistry, which suggests that taxonomic revision may eventually show it to be a separate variety, even though a recent analysis of plant DNA rules out the possibility that this is a clonal population with low genetic variability (French, James and Walsh 2012). The active agent is the alkaloid nicotine, present in Mulligan River
pituri at levels ranging from 2.4 to 5 per cent (more than twice the content of commercial cigarettes or of the Nicotiana gossei bush tobacco used elsewhere in the desert). Chemical analysis shows that in Central and western Australia, D. hopwoodii is toxic because of high concentrations of D-nor-nicotine, a much more powerful alkaloid (Watson 1983; Watson, Luanratana and Griffin 1983). This explains why only Mulligan River Duboisia was exploited as a narcotic and widely traded.

To prepare the drug, Duboisia shrubs were burnt to promote regrowth. Leaves and small stems were harvested in early March and artificially cured in heated sand in pits (Hodgkinson 1877; Gason 1882; Aiston 1937); this drying process took about two hours and arrested the enzyme action that normally degraded the nicotine level. The dried leaves and stems were then broken up and packed into small semicircular net bags, each containing about 1.4 kg (Gason 1882) and often painted with bands of red and yellow ochre.

The scale of the trade was impressive. Aboriginal groups in the Cooper Creek area – including the Diyari, Wangkangurru and Yandruwantha – mounted annual expeditions involving a round trip of 800–1,200 km to obtain supplies of pituri (Gason 1882; Howitt in Smyth 1878; Howitt 1904; Horne and Aiston 1924; Aiston 1937). Pituri was also traded to groups outside the desert: 300–400 km northwards from the Mulligan along the Flinders and Gregory Rivers. And the word pijiri, originally a Pitta Pitta word from the upper Mulligan, appears to have followed the trade downstream. Gason, who witnessed the last of the traditional pituri expeditions, estimated that each man returned fully loaded with 70 lb (32 kg) of dried pituri – and this is loosely corroborated by other sources. If expeditions consisted of combined parties of about thirty to fifty Diyari, Yandruwantha or Wangkangurru men, we can estimate that about 900–1,600 kg of dried pituri was transported annually. If this figure is right, then 500–900 Duboisia shrubs would have to be harvested to sustain the Cooper Creek trade (the dry weight of foliage averaged 2 kg per shrub; Silcock et al. 2012). And if we factor in local demand as well as the trade to the north, the actual harvest may have involved 2,000 plants. Field data on the distribution and density of Mulligan River Duboisia suggests this was well within the productive capacity of these pituri groves (where there are an estimated 24,000 plants today), even if it would have been logistically difficult because the main pituri groves are in a dunefield 20 km from the nearest reliable water.

What is important here is that this was direct, corporate, long-distance transfer of a commodity rather than dissemination of prestige goods through a diffuse network of individual contacts. The latter was undoubtedly important but as part of a secondary distribution process that dispersed the pituri obtained by these expeditions. Gason (1882) noted that within a few months of a pituri expedition, the Diyari had exhausted their supplies, presumably through demand-sharing and exchange as well as use. In this fashion, pituri
reached the Flinders Ranges and Barrier Range a further 200–400 km to the south.

Direct access to groves of pituri, as well as the use of the drug, appears to have been restricted to older men and was governed by totemic affiliations (Bancroft 1879; Howitt 1904; Aiston 1937). Some accounts suggest that particular descent groups (‘clans’, ‘pitcheri moora’ or mura) were associated with the pituri expeditions (Elkin 1931; Aiston 1937). The contact period saw rapid changes in the character and scale of this exchange system. After 1880, most observers noted pituri being used freely by women; most pituri after this time was sun-dried rather than heat-cured; and much larger net bags from this period (up to 80–90 cm wide) appear in museum collections (e.g., Duncan–Kemp 1968: 185). Both Roth (1897: 100) and Aiston (1937) recorded large exchange centres, involving hundreds of people, operating as markets for exchange – apparently without the social prescriptions that applied earlier. European contact appears to have provided conditions for a rapid rise in production and more general consumption of pituri as a commodity.

The archaeology of the pituri trade is unknown at present. We could expect to find evidence of processing pits associated with stands of Duboisia hopwoodii, as well as large, ephemeral open sites clustered on the periphery of the major groves. In the pituri heartland, along the Mulligan River, two major archaeological projects have been undertaken, by Barton (2001) and by Davidson (Davidson 1983; Davidson, Tarragó and Sullivan 2004; Ridges 2003). Neither provides any direct indication of the antiquity of this trade, although Barton notes that the surface archaeology in the Ethabuka area (including a site located within one of the major pituri groves) is exclusively late Holocene. Other evidence for activity along this trade network comes from a trade cache of tula adzes – artefacts that Roth (1904: 20) described as common trade items in this region. At Mucklandama Creek, near Boulia, Hiscock (1988b) excavated a pit containing thirty-three neatly stacked adzes, as well as seventeen flakes representing adze preforms. This cut through a charcoal lens dated 1,190 ± 120 BP (Beta-21518), indicating that the cache itself probably dates to within the last few hundred years.

STONE KNIVES AND LEILIRA BLADES

The production of large stone blades for men’s knives shows that the restructuring of trade and exchange that occurred during the last few hundred years was not limited to the Lake Eyre basin. The 1894 Horn Scientific Expedition provided the first account of these knives. They were large ‘lanceolate blades’ about 15 cm long, mounted with spinifex resin in a short wooden handle, together with a sheath of Melaleuca bark, bound with fur-string and ‘ornamented by a small plume of feathers’, to preserve the keenness of
the sharp edge (Stirling 1896: 96–7) (Figure 8.10). Spencer and Gillen (1899, 1904) coined the term *lalira* or *leiira* blades (from the Arrernte *alyweke*, or stone knife). Ethnographically, these were men’s fighting knives and were also mythologically and symbolically linked with subincision (although never used for this purpose).

As trade items, they were widely exchanged across northern and central Australia. In Arnhem Land, the quarry at Ngillipidji was a key production centre for parcels of blades circulated by the exchange cycle described by Thomson (1949). Across northern and central Australia, there are a series of large blade quarries where these knives were produced, usually exploiting outcrops of silcrete or (less often) chalcedony. In the arid zone, the best-known examples are Kanti, near Yuendumu (Graham and Thorley 1996), Kankiritja and Renner Springs in the Ashburton Range (Murgatroyd 1991; Paton 1994) and several quarries in the James Range (Smith 1988) and near Macdonald Downs in Central Australia (Binford and O’Connell 1984). Typically, these sites consist of mantles of flaking debris, blades and cores (in places up to 30–50 cm deep), surrounding a quarried outcrop or quarry pits and extending over 1–6 ha. Flaking aimed at the production of massive trigonal blades 15–20 cm long, struck from prepared cores along facetted ridges (e.g., Binford and O’Connell 1984; Binford 1986; Graham and Thorley 1996).

In northern Australia, dates from archaeological deposits with large blades or fragments of these blades show that their production was limited to the last millennium. Despite the number of quarries, and the size and prominence of the stone knives, these artefacts are rarely found in archaeological deposits or on surface occupation sites in Central Australia (Graham and Thorley 1996; Allen 1997). One of the few reports is from Intirtekwerle (James Range East), where they are found in contexts dating sometime within the last 800 years (Gould 1978a: 109). Allen (1997) suggests their production was limited to the last millennium, whereas Graham and Thorley (1996) argue that it can be more tightly defined as a contact-period phenomenon: an archaeological manifestation of the acceleration of the northern exchange cycle described by Thomson (1949). The production of these stone knives, they argue, represents the expanded production of a local valuable for exchange, driven by the desire for the exotic goods circulating in northern Australia. If this is correct, it provides another example
of the ‘encapsulation’ of desert trade and exchange by developments outside the arid zone.

REGIONAL AND TEMPORAL VARIABILITY IN DESERT EXCHANGE SYSTEMS

Direct archaeological evidence for trade and exchange is still quite poor, and the best evidence comes from quarries, mines and production centres associated with ethnographic exchange systems. It is useful at this stage to group the available evidence in terms of (a) embedded procurement, (b) ‘down-the-line’ exchange and (c) long-distance transfer.

Embedded Procurement

In Australia’s deserts, the archaeological record documents widespread transport of red ochre during the late Pleistocene. In most cases, the distances involved are less than 200 km and so probably represents ‘embedded procurement’, the acquisition of material during the course of seasonal or annual movements of residential groups. Evidence for long-distance exchange of goods – whether this is indirect transfer through multiple small reciprocal exchange transactions or by direct long-distance transfer – is limited to the late Holocene, mostly within the last 2 millennia.

‘Down-the-Line’ Exchange

Reciprocal gift exchange or ‘down-the-line’ exchange is likely to have a long history in these desert societies. The earliest archaeological evidence, in this case for the exchange of coastal baler shell into the interior, dates to 2,300 years ago. But we can expect that much earlier evidence will eventually be found because sites on the northern margin of the desert show late Pleistocene exchange of coastal Dentalium shells 350–400 km inland (Balme and Morse 2006).

Is there evidence for an expansion of exchange networks in Australia’s desert around 3–4 ka? The evidence is too poor to rule this out, but there is little to suggest an abrupt acceleration of ‘down-the-line’ exchange at this time. It is simpler to see the increasing visibility of exchange in the late Holocene record as one consequence of the trend towards higher regional populations in the desert. Birdsell (1958) has shown mathematically that higher population density increases opportunities for intergroup contacts (Figure 8.11). And ethnographic studies indicate that the turnover of exchange goods increased as opportunities for interpersonal contact grew. From this perspective, increased exchange activity is a likely corollary of growing population density. In turn,
any acceleration of gift exchange would increase demand for exotic goods. This may explain the initial diffusion of ground-edge axes into the desert around 1.5 ka and the pressure to initiate local production of stone axes on the margins of the desert in the Mt Isa area. Some grindstone quarries, whose original purpose would have been to ‘provision’ parts of the desert with replacement grinding slabs, were co-opted by these exchange cycles. Intensive mining of red ochre at Wilgie Mia may have a similar history, although the exchange network that supported it seems not have persisted into the ethnographic period.

The relationship of exchange turnover to population density also helps explain why the exchange of some commodities (e.g., stone axes, stone knives) and diffusion of certain social traits (e.g., subsections) began in higher density regions outside the desert and later spread into the arid interior, creating a repeated pattern of cultural ‘spreads’ from desert margins to desert core.

‘Long-Transfer’ Systems

In the Lake Eyre basin, a more complex ‘long-transfer’ exchange system developed out of this undifferentiated gift economy around 1,500–1,000 years ago. In its early stages, this involved trade in stone axes and grinding slabs but later grew to include red ochre and probably pituri, within the last few hundred years. This system was limited to the arid rivers along the eastern margin of the desert and grew to take advantage of a particular set of geographic circumstances in which scarce resources were clustered in uplands at either
end of a long riverine corridor. It also involved a significant expansion of production compared to ‘down-the-line’ exchange. Estimates for the total production of goods over the operation of this exchange network include 1–2 million grinding slabs, more than 800,000 stone axes (possibly several million), 600 t of red ochre and an annual harvest of 900–1,600 kg of dried *pituri*.

We can speculate what drove the development of this ‘long-transfer’ exchange system. One possibility is that once population growth provided initial conditions for a high turnover in gift exchange, the interplay of a range of local circumstances created a further escalation of demand and production. Several factors stand out:

- The geography of this part of the desert acted to funnel exchange into a long riverine corridor, which created a critical mass of intergroup exchange. The arid rivers also form a chain of ecological, social and historical connections across 10 degrees of latitude. This provided the prerequisite framework for long-distance expeditions to acquire Pukardu ochre or Mulligan River *pituri*.

- There was a high level of interpersonal and intergroup competition along these arid river systems (W Jones 1979). Aboriginal groups along Cooper Creek, at the centre of this exchange network, had some of the highest population densities recorded for the arid zone (up to 1 person per 8 km² – W Jones 1979: 138). Most early exploring parties met large groups of people, and ceremonial gatherings could number up to 1,000 people (Gason 1895: 174). This population was sustained by the extraordinary productivity of a network of channels, floodplains and ephemeral swamps. But although Cooper Creek has the highest flow rates of any dryland river in Australia, periods of high primary productivity (‘booms’) are punctuated by long dry periods (‘busts’) (Kingsford, Curtin and Porter 1999), accentuating environmental stresses on these groups. By the late nineteenth century, these stresses were evident in a number of ways: these groups had an extensive famine vocabulary; hunting had depressed the local availability of large macropods; there was extensive use of the seed-like sporocarps of *ngardu* (*Marsilea drummondii*), although this is nutritionally poor grain; and there was active intergroup conflict (summarised in W Jones 1979), as well as formalised duelling with *murravirrie* (a large boomerang up to 180 cm long, which a fighter used like a broadsword, holding it with both hands over his head – Horne and Aiston 1924: 72–3, fig. 10). In this context, gift exchange between individuals, and ceremonial prestation between groups, assumed more than usual importance as components of the political economy: creating alliances and mutuality, reinforcing group solidarity and resolving feuds.
Figure 8.12. Mound of kopi mourning caps on a grave, Eyre Creek, central Australia. These skull caps, made of gypsum plaster, were worn by women in the southeastern sector of the desert and the Murray–Darling basin as part of mourning rituals following the death of a relative and later placed on the grave (Davidson 1949b). In this example, the large number of mourning caps (forty to sixty individual caps) suggests the death of a senior figure. This site has not been radiocarbon dated, but an age of around 500 years would be consistent with the good condition of these fragile caps and the absence of European items, such as metal objects, or net, string or hessian liners. Associated artefacts include freshwater mussel shells (m), chipped stone implements (triangles) and a grindstone for ngardu (Ng). Goddard (1936) reported a similar grave – in this case of a woman – with seventy caps from the upper Darling region. (Source: Unpublished field plan by MA Smith and J. Bertini)
Gerontocratic privilege (a form of social hierarchy in which older men monopolise women and resources) was marked among these groups, together with a well-developed system of community and ritual leadership (Howitt 1904; Horne and Aiston 1924) (Figure 8.12). In this politico-ritual economy, charismatic individuals with forceful personalities were able to assume the role of ‘bigmen’, redistributing exchange goods to reinforce their personal standing and create webs of social obligation. These structures also provided the capacity to organise long-distance expeditions, while the expeditions themselves provided a theatre for the exercise of leadership.

The interplay of these factors may well have created a spiralling demand for exchange goods, especially exotic or prestige goods, putting strong production pressure on stone axe, grindstone and red ochre quarries and pituri groves on the geographic margins of this system. If so, the development of the long-distance exchange system was driven by the political economy of Aboriginal groups in the Cooper basin rather than by interannual shortfalls in the subsistence economy or by the need for ecological buffering (something that, in any case, was more effectively addressed within a region).

Comparisons

Reciprocal gift exchange in Australia’s deserts has parallels in other desert societies. For example, in the Kalahari Desert, the *hxaro* exchange system created a network of reciprocity among families of San hunter-gatherers, mostly with exchange partners within 50 km (Wiessner 2002). However, the geographic scale of Australian gift-exchange systems is generally greater than those recorded for other comparable parts of the world (for southern Africa, see Mitchell 1996), reflecting patterns of residential movement. There are also examples of expanded production at mines and quarries in other deserts. In the northern Kalahari, there was intensive mining of specularite (a crystalline form of haematite) and native copper by hunter-gatherers (Robbins et al. 1998). But these supplied commodities to neighbouring Iron-Age pastoralists and illustrate how production among hunter-gatherer groups can become ‘encapsulated’ within wider economic systems (Gordon 1984; Wilmsen 1989; Sadr 2005).

In contrast, the elaborate long-distance exchange system in the Lake Eyre basin appears to be unique among desert hunter-gatherers: an autonomous system of trade and exchange extending across half a continent, from the southern margins of the desert to its northern edge. Writing about Arnhem Land, Donald Thomson commented that objects acquired by ceremonial exchange have ‘a history, a background, a personality which . . . gives them a greatly enhanced
value in the eyes of the people who receive them. Here then, is the nucleus of a great system of exchange’ (1949: 80). Similar forces were at work in the Lake Eyre basin during the last millennium and increasingly differentiated the eastern part of the desert, with its great dryland river and channel systems, from Central Australia and the Western Desert.