Australasian Quaternary Association Inc.
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Willandra Lakes

A guide to the AQUA post-conference field trip
4 -5th July, 2014

Compiled by Harvey Johnston

from contributions by

Jim Bowler (Regional Setting, Joulni, Mungo silcrete & western shore)

Nikki Stern (central Mungo lunette)

Jacqui Tumney (central Mungo lunette)

Tim Barrows (Mungo lunette palaeomagnetic site)

Ed Rhodes & John Magee (Outer Arumpo)

Tony Dare-Edwards (Chibnalwood lunette)

Michael Westaway (Outer Arumpo & Garnpang footprints)

Wilfred Shawcross (Outer Arumpo)

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Itinerary

(Approx. and subject to weather and unforeseen events)

Location	Approx Time	Presenters
Friday 4th July Sunrise 7:30am, Sunset 5:30pm		
Depart Mildura	8:00 am	
Mungo Visitors Centre	10:00 – 11:00am	3TTG Elders Morning tea and Welcome to Country
Joulni – Walls of China southern Mungo lunette	11:00 – 1:00pm	3TTG Elders, Jim Bowler, Harvey Johnston
Lunch at Mungo Visitors Centre	1:00 - 1:30pm	If staying overnight, this is a chance to find your quarters
Central Mungo Lunette Site 969660	1:30 – 4:00 pm	La Trobe University ARC project Nikki Stern, Jacqui Tumney, Caroline Spry
Those who are only staying for 1 day may wish to leave at this point to drive home before it gets dark. Otherwise stay on for….		
Walls of China Palaeomagnetic site	4:00 – 5:00 pm	Tim Barrows
Sunset Walls of China Red Top viewing platform	5:00 – 5:30 pm	Scenic stop, if we have time
Dinner Mungo Lodge	7:00 pm - late	
Saturday 5th July Sunrise 7:30am, Sunset 5:30pm		
Depart Mungo Lodge	8:30 am	
Outer Arumpo lunette	9:00 – 10:00 am	John Magee, Michael Westaway
Chibnalwood dune	10:00 – 11:00 am	Tony Dare-Edwards
Mungo silcrete ridge	11:00 – 12:00pm	Jim Bowler, Nikki Stern
Lunch Mungo National Park Visitors Centre	12:15 – 1:00 pm	
GL7 Garnpang footprints, via Mungo Interconnecting channel, Leaghur lakebed and lunette	1:00 – 2:45 pm	Harvey Johnston Michael Westaway
Western shore Lake Garnpung, GL13	2:45 – 4:00 pm	Michael Westaway
Return to Mildura	5:30 pm	

AQUA Willandra Lakes 2014

Welcome to the AQUA 2014 post conference field trip to the Willandra Lakes. One reason the Willandra is significant, especially for AQUA, is that this landscape has taught and inspired many people to pursue careers in fields that seek to understand the history of the Australian landscape, environment and its people.

Weather permitting, this field trip will allow us to visit some of the sites that have helped to unravel this history and make the region a world heritage site, including:

- Joulni, at the southern end of the Walls of China, where scientific investigations of the area commenced in the 1960's;
- Central Walls of China, where the LaTrobe University/Wollongong University team have been working since 2007;
- The palaeomagnetic site, on the Walls of China to review recent OSL dating of the Mungo lunette;
- Outer Arumpo lunette, where the Mungo Youth Project is held, and where recent OSL dating and excavations have taken place;
- Chibnalwood clay dune;
- The Mungo silcrete outcrop, and western shore of Lake Mungo
- Garnpang Pleistocene footprints locality, and
- GL 13 where Griffith University are currently studying faunal assemblages from the late Pleistocene.

Background

There are many interpretations of how the Willandra Lakes were formed. In 1885 Cameron recorded one 'tradition'. Willandra Creek and lakes were formed when two dreamtime figures, or Bookoomuri, chased a giant kangaroo south from Hillston along the Willandra Creek until they lost sight of it. They followed the kangaroo's track for some days and came upon another Bookoomuri, who, with the help of his dog, had killed and partly cooked the exhausted kangaroo. The two Bookoomuri refused an offer to share the kangaroo meat and instead restored it to life. The two Bookoomuri placed a spell over the dog to prevent it from chasing the kangaroo, and then resumed the chase. The Willandra Creek is the track of the Kangaroo as it fled the Bookoomuri. The hills (lunettes) are the camps of the Bookoomuri as they followed the kangaroo. The Bookoomuri chased and finally killed the kangaroo near the junction of the Murray and Darling Rivers (Cameron 1885: 369).

The Willandra Lakes are a series of 6 large and 13 small lake basins, set within a dry linear dune system in the southwest of New South Wales. The lake basins range in size from 4 hectares to 38,000 hectares and each is surrounded on its eastern side by a lunette, or transverse dune. The Lake Mungo lunette is called the 'Walls of China'. The specific origins of the name are unclear but the 'China' referred to is possibly either a reference to porcelain and the extensive white sand dunes that cap the lunette, or a label developed in association with Chinese labourers who worked at Lake Mungo in the 1880's.

The Willandra Lakes, and more specifically the Walls of China at Lake Mungo, were propelled into archaeological fame in March 1969 with the discovery of one of the world's oldest cremated remains; that of a young woman, Mungo Woman or Mungo 1 (Bowler et. al, 1970). Early in 1974 another Pleistocene burial was found (Mungo Man, or Mungo III) (Bowler & Thorne, 1976), this time surrounded by ochre stained sands that indicated a ceremonial burial. This further enhanced the reputation of the region as an outstanding location for understanding the patterns of life, death, ceremony and burial within Australia's earliest Aboriginal people. These early discoveries were followed by further studies on the geology of the region and the archaeology of the first Willandra people (Allen, 1972, 1974, Bowler & Magee, 1978, Barbetti & Allen 1972, Bowler et. al., 1972, Thorne 1971, 1976, Shawcross 1975, 1998, Webb 1989). Since the original discovery in 1969, the antiquity of Mungo Woman and Mungo Man has been debated (Thorne et. al., 1999, Bowler & Magee, 2000, Bowler et. al., 2003) but the dating of this burial appears resolved at 41- 42,000 years BP (Olley, et. al., 2006). This age indicates the skeletal remains of Mungo Man and Mungo Woman are some of the earliest modern *Homo sapiens* outside Africa.

The lakes held water through much of the late Pleistocene, including the last glacial maximum, and dried ca. 18,500 years BP (Bowler et. al., 2012). An extensive research program over more than four decades by Jim Bowler and others have established lunettes as key archives for the interpretation of late Pleistocene climates in south eastern Australia and the southern hemisphere (e.g. Bowler & Magee, 1978, Bowler, 1998, Bowler et al., 2012).

The earliest archaeological indications in the area date to between 46,000 and 50,000 years B.P. (Bowler et al., 2003). Extensive archaeological evidence in the form of burials, shell middens, fireplaces, fauna, stone artefacts and quarries is present from ca. 45,000 years BP through to recent times. Archaeologically the location has provided a forum for debate on the origins and physical characteristics of ancestral Australians (e.g. Thorne, 1976, Brown, 2000, Pardoe, 2006), contributed to the discussion on the extinction of megafauna in Australia (McIntyre & Hope, 1978) and on the development of Australian stone tool technology (Allen, 1974, Allen & Holdaway, 2009).

For Aboriginal people the region has provided a key place of symbolic value in their claims for self-identity, assertions of native title, and ancestral ownership and occupation of Australia (McBryde, 1995). In the words of Elders:

Well you see that area out over there now. Now you can't see anything there. You mightn't see anything at all there, bones or anything. But the spirits are there, and that's our beliefs.
Elsie Jones, 1989, Barkindji Elder, quoted in Donaldson n.d.

Lake Mungo is inherited culture. …. Because all our laws, our rituals, our moral codes are all here. We're not just looking at sand and stone.
Alice Kelly, Mutthi Mutthi Elder, quoted in Aboriginal Catholic Ministry, 1989.

In recognition of these cultural and geological values the Willandra Lakes Region was inscribed on the World Heritage List in 1981 in a dual listing recognising; its outstanding universal value under both cultural heritage (iii) and natural (viii) criteria.

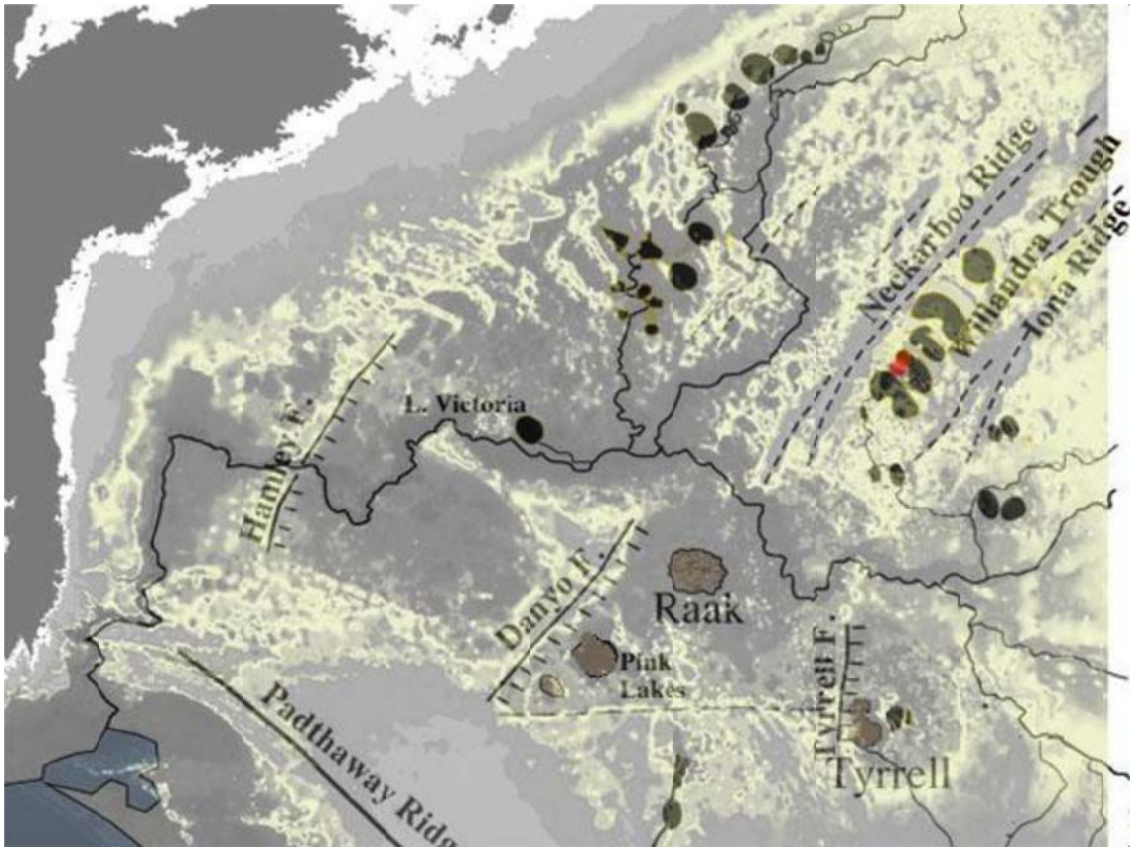
> *(iii) bear a unique or at least exceptional testimony to a cultural tradition or to a civilization which is living or which has disappeared;*

(viii) be outstanding examples representing major stages of earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features

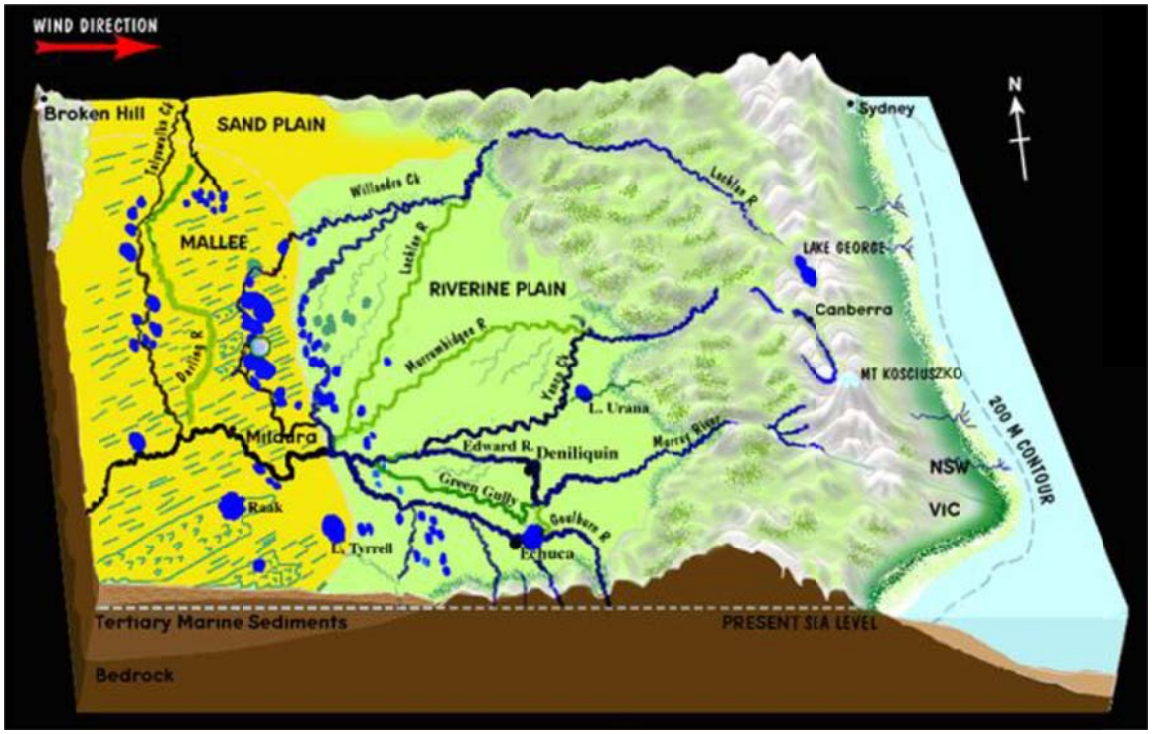
In recent years new research projects have further reinforced the area's claim for world heritage status. The Garnpang fossil footprint trackway (Webb et al., 2006, Westaway et. al., 2013) has provided new and intriguing detail on the footprints and behaviour of a group of men, women, children and animals some 20,000 years ago. Further investigations into the physical anthropology of various ancient burials has taken place (Durband, et. al., 2009, Durband, 2011) and two research projects by Griffith University to study ancient Aboriginal DNA and the Pleistocene fauna of the region are underway [Lambert and Westaway pers comm].

The largest current program of research is a project aimed at documenting and increasing understanding of the region's environmental and cultural record via a 3 year project (2007 – 2010) funded with an Australian Research Council linkage grant. This project, a co-operative venture between NSW NPWS, La Trobe University, the Australian National University and the traditional tribal groups of the area, and has been followed by a second ARC Discovery grant. The outcomes of this research are just beginning to emerge (e.g. Fitzsimmons, et. al., 2014, Long et. al. 2014, Tumney, 2011, Stern et. al. 2013, Spry, 2014) and promise to radically expand our understanding of late Pleistocene environment and Aboriginal society in the Willandra.

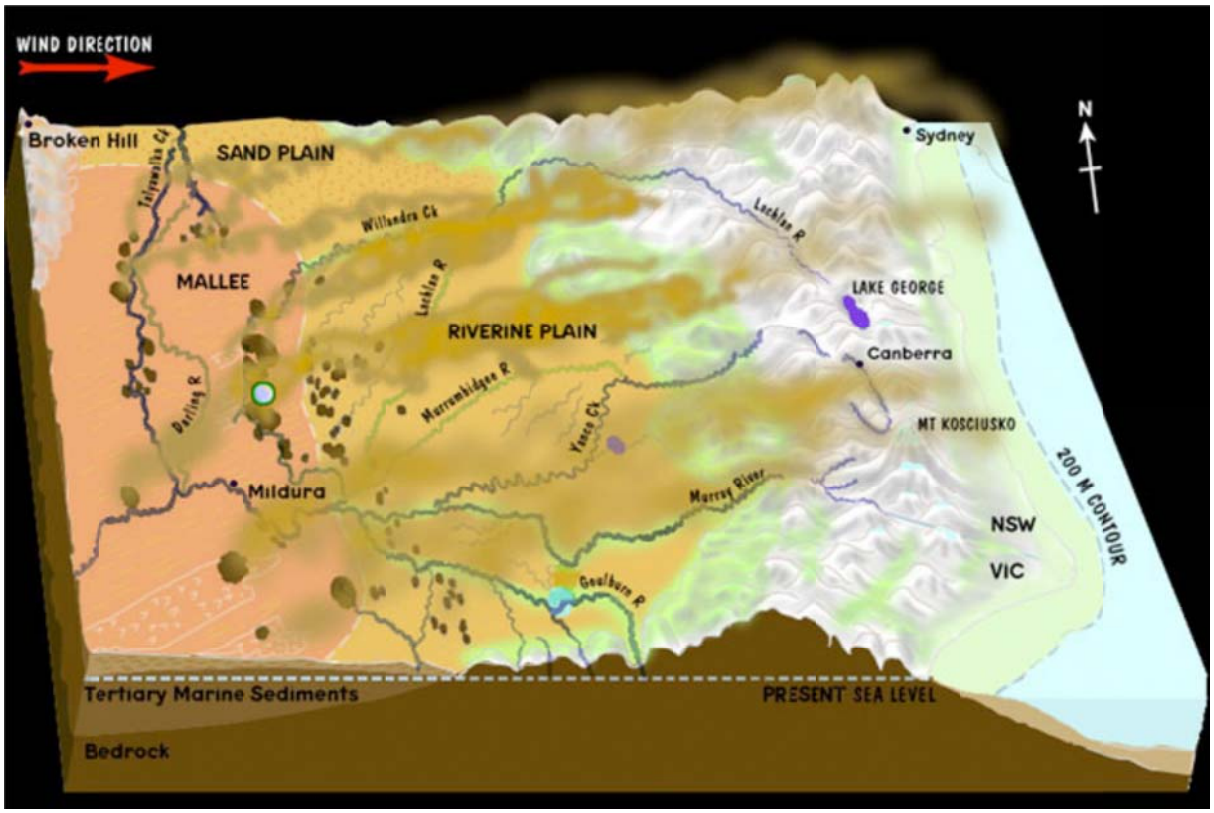
Regional Setting



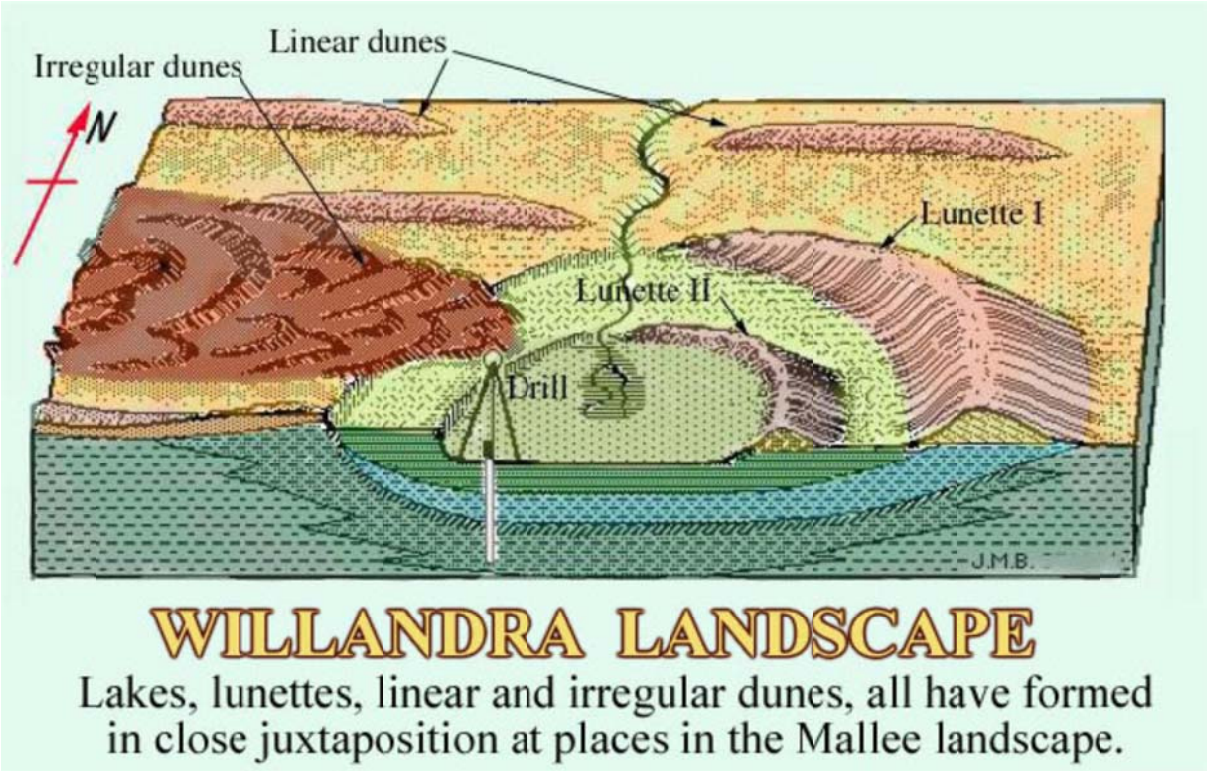
Digital elevation showing structural setting of Willandra Lakes between the fault lines of the Neckarboo Ridge and the Iona Ridge (Jim Bowler)



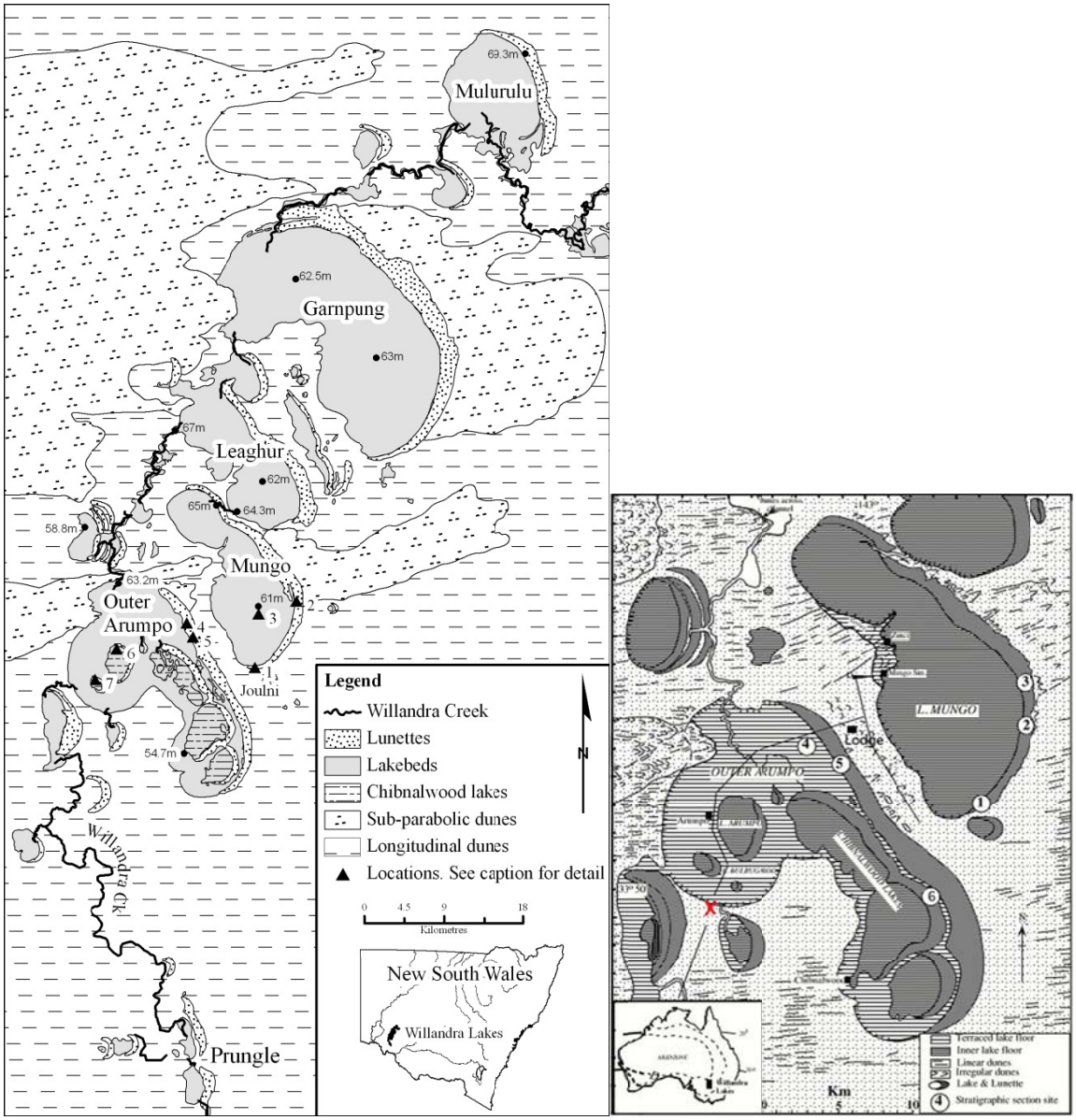
Southeastern Australia block diagram near 60 ka. Cooling in highlands, major water discharge across the plains. High lakes, high groundwaters. Big rivers (source, Jim Bowler).



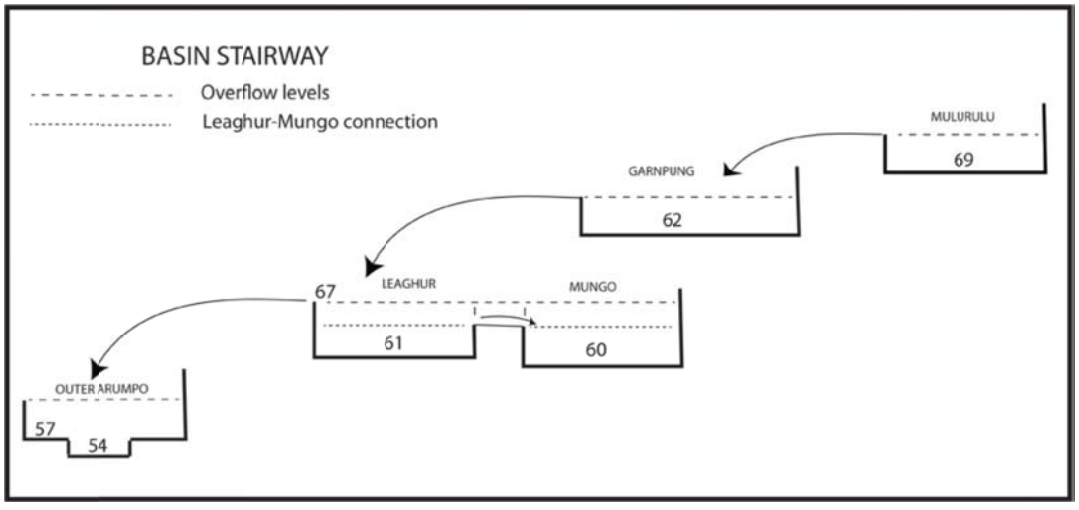
Southeastern Australia near 20ka arid glacial maximum. Glacial and periglacial action in highlands, dune building, dust transfer across southeastern Australia. Groundwaters remain high after previous wet phase, drain into dry basins, high salt production. Time of maximum salinity. (source. Jim Bowler)



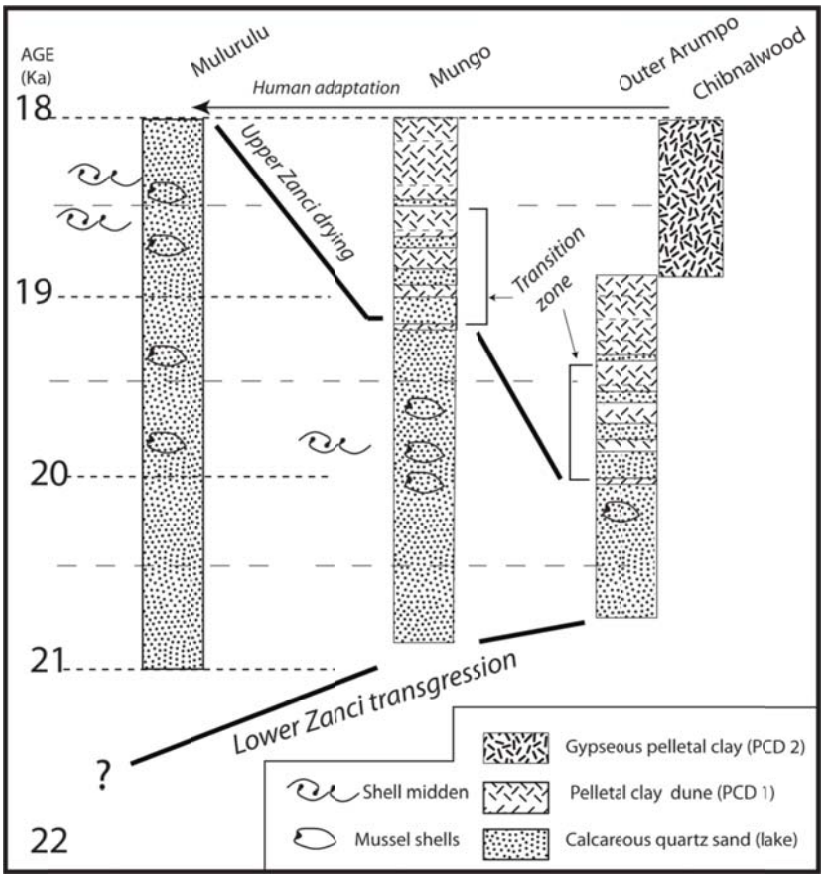
(source, Jim Bowler)



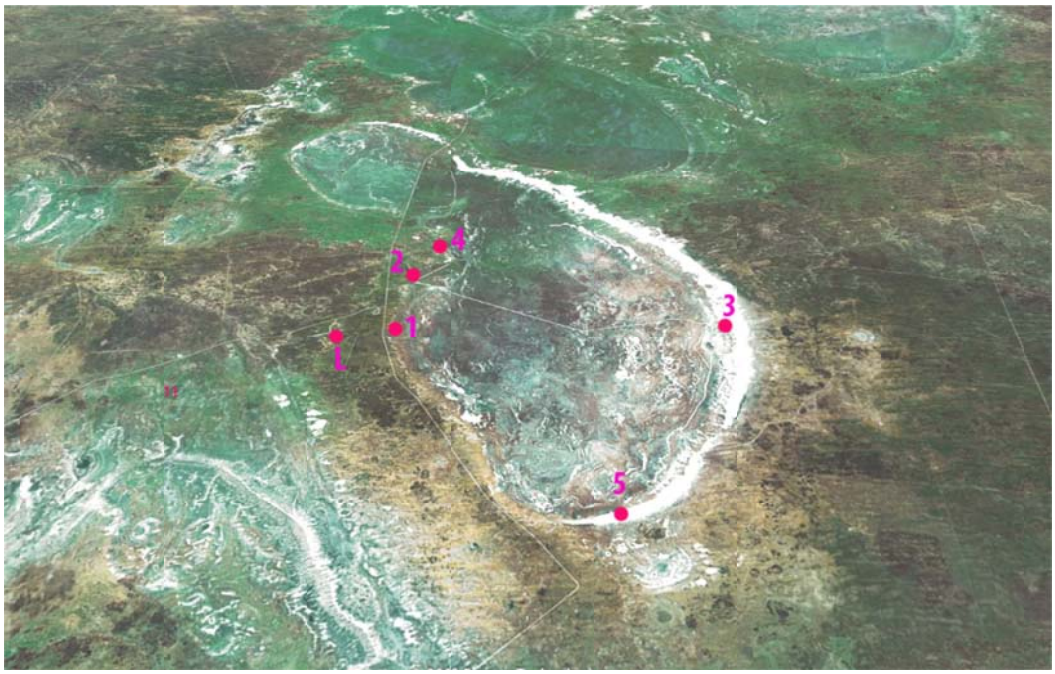
Willandra basin settings within Mallee dunefields. X marks road entry into southern basin margin (source Bowler et. al. 2012).



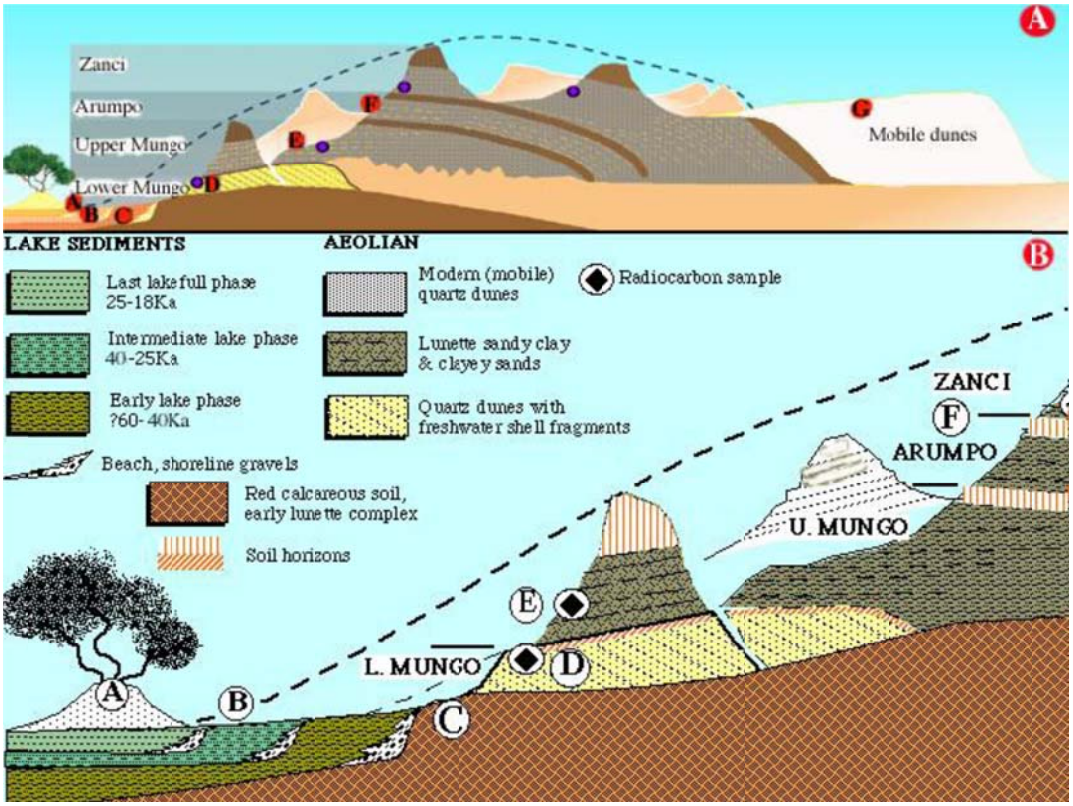
Stairway structure emphasises sequence of filling and drying. Numbers are metres AHD (source Bowler et. al. 2012).



Stratigraphic reconstruction of glacial maximum. Dune building south at Chibnalwood simultaneously with fishing at Mulurulu. (source Jim Bowler).

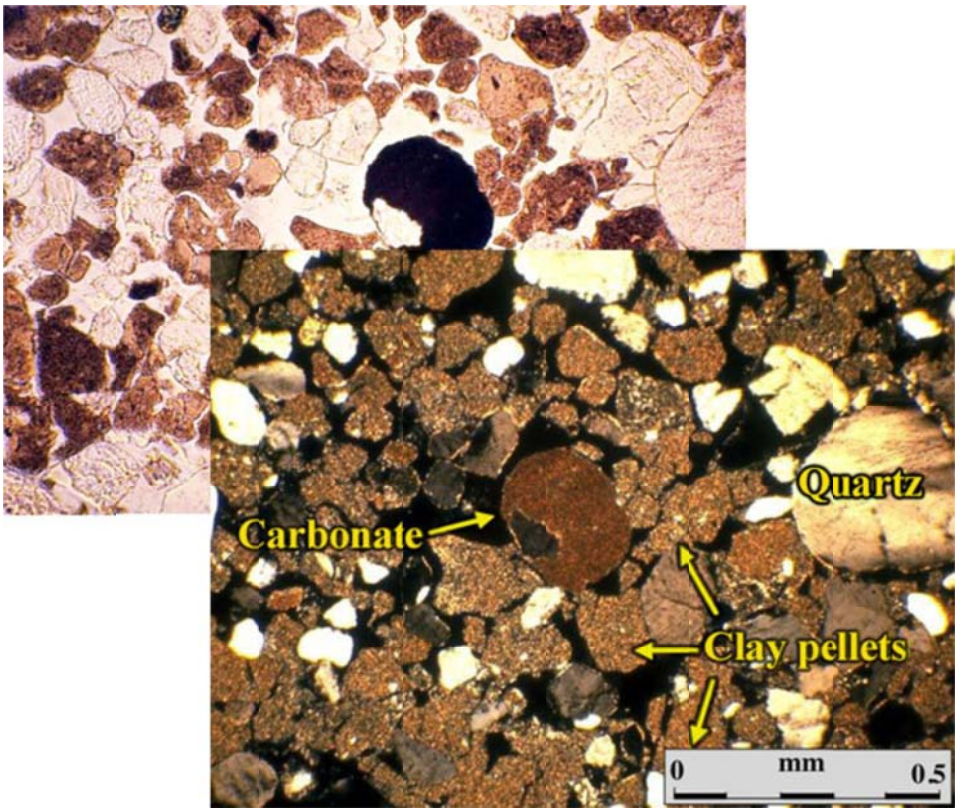


Oblique Google view of Lake Mungo. L. Mungo Lodge. 1. Orientation point. 2.Visitors Centre. 3. Walls of China Visitors site. 4. Silcrete outcrop and stromatolite crusts. 5. Joulni southern end of Walls of China (source Jim Bowler)

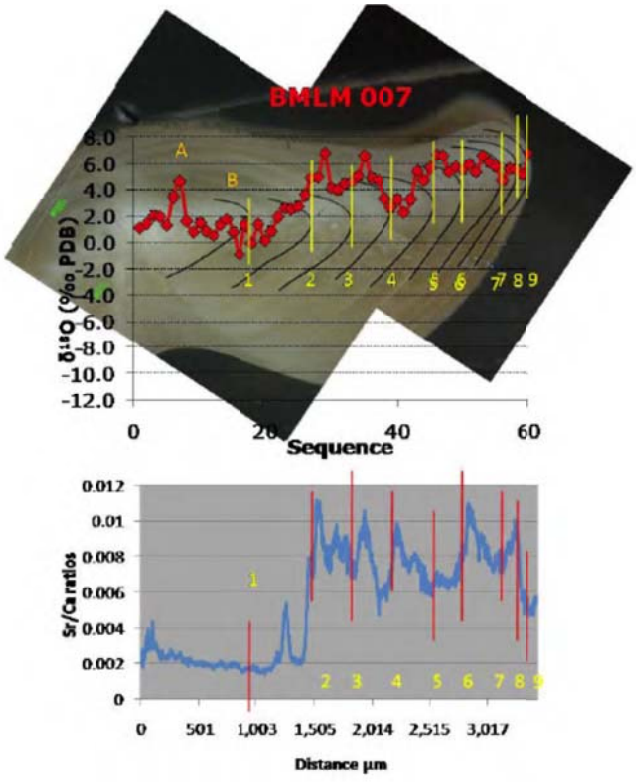


Stratigraphic cross-section through Walls of China visitors area. Note presence of 3 gravels in shoreline location. (source, Jim Bowler).

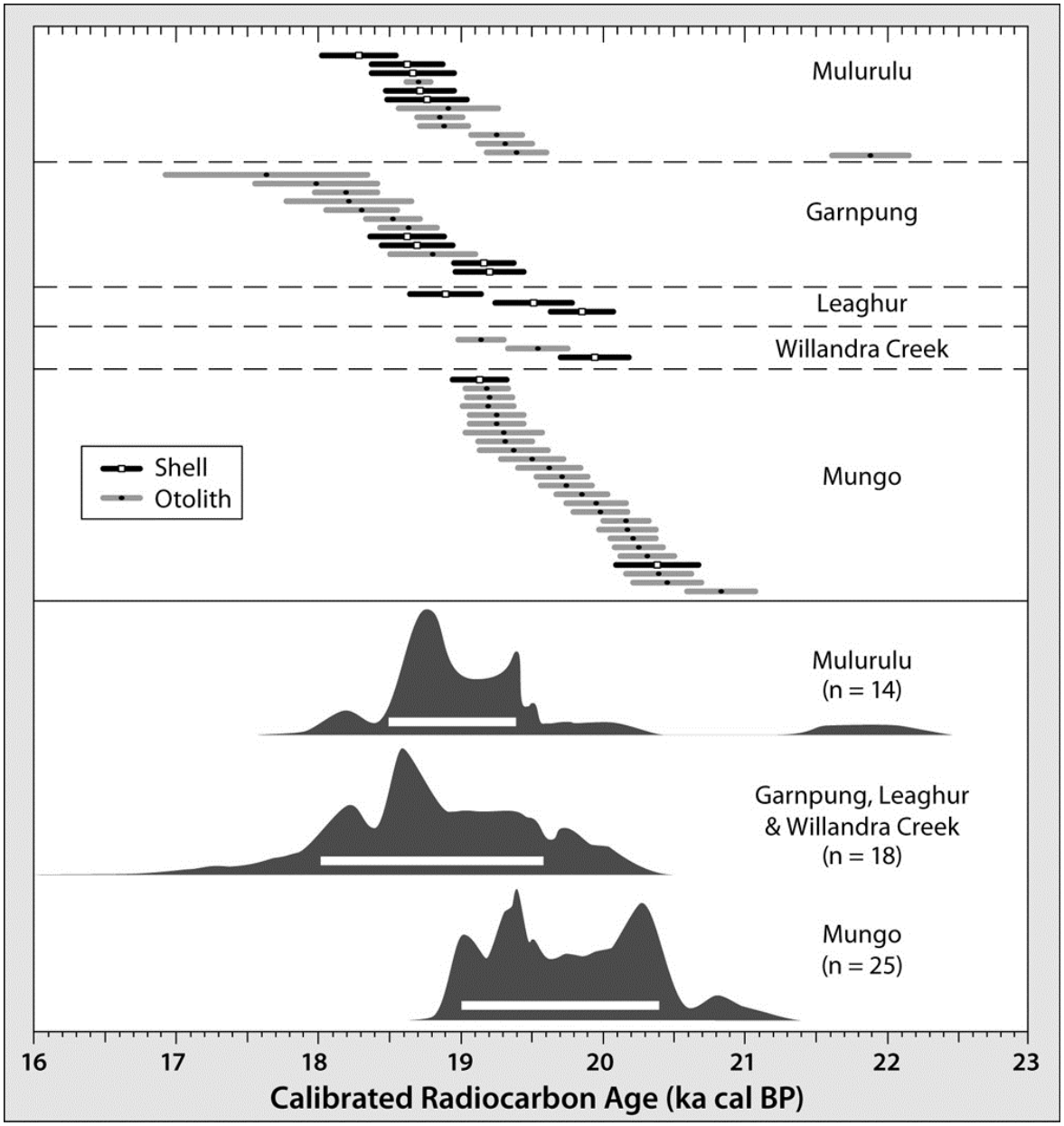
Laminated sediments of quartz sand [freshwater] overlain by pelletal clay. (source, Jim Bowler).



Thin section showing pelletal clay structure. Plain light and crossed-polarised. (source, Jim Bowler).



Isotope and strontium data through otolith of 9 year old Golden Perch. Salinity variation and seasonal temperature change (from Boljkovac in Bowler et al., 2012).



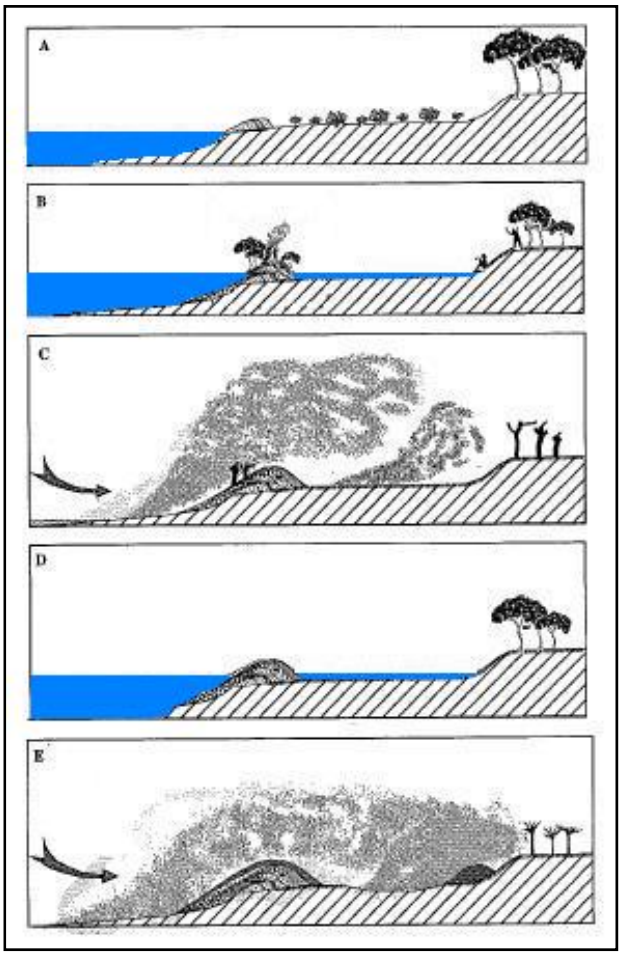
Dates of glacial maximum variation between Mungo and upstream basins. Garnpung & Mulurulu (from Gillespie in Bowler et al., 2012).

Joulni, southern Walls of China

Well you see that area out over there now. Now you can't see anything there. You mightn't see anything at all there, bones or anything. But the spirits are there, and that's our beliefs.
Elsie Jones, 1989, Barkindji Elder, quoted in Donaldson n.d.

Lake Mungo is inherited culture. …. Because all our laws, our rituals, our moral codes are all here. We're not just looking at sand and stone.
Alice Kelly, Mutthi Mutthi Elder, quoted in Aboriginal Catholic Ministry, 1989.

Joulni Station was added to Mungo National Park on the 1st January 2011. Joulni Station includes the southern end of the Lake Mungo, and encompasses the southern end of the Mungo lunette, or 'Walls of China". The Walls of China, Joulni, is the location where the international significance of the Willandra Lakes region was first brought to light. Here, in 1969, an extensive cultural landscape was recorded, including the remains of Mungo Woman and the remnants of thousands of years of Aboriginal occupation of the land. In 1974 the remains of Mungo Man were also found in the same area.



A. Initial filling of the Lake Mungo basin, and development of shoreline gravels evolving into a 'barrier beach' later capped with aeolian sediments. Lower Mungo unit.

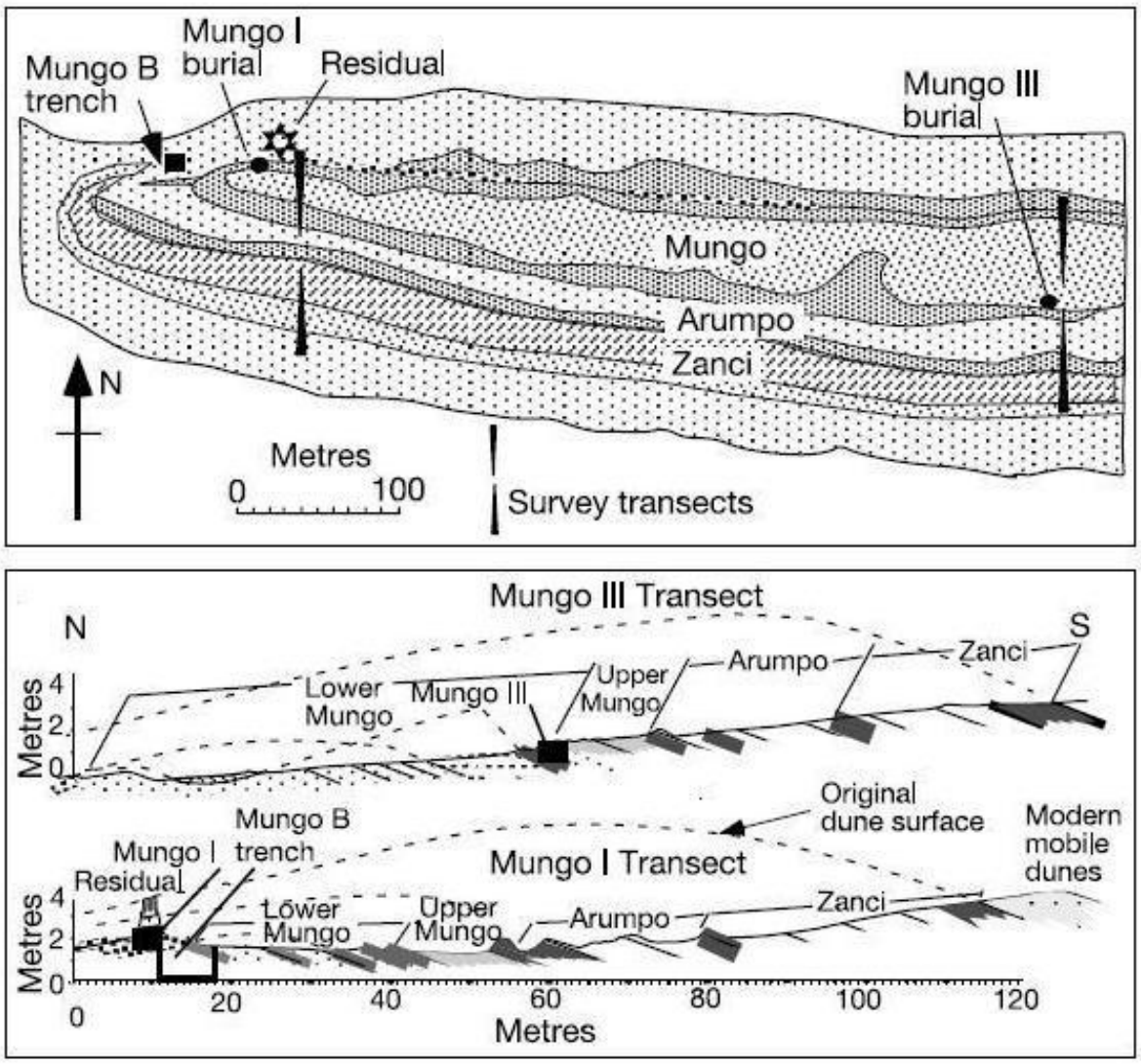
B. The barrier beach was overtopped periodically and water flooded the Joulni basin. The barrier beach continued to build with gravels and a stable dune developed with vegetative cover. Mungo Woman and Mungo Man lived during this time. Lower Mungo unit.

C. Lake levels fell briefly around 35 -40,000 years and a layer of pelletal clay, deflated from the adjacent dry lake bed, was deposited on the dune. This pelletal clay covers and seals the burial of Mungo Man. Upper Mungo unit, 35-40,000 years.

D. Brief return to high water levels, but with a small beach dune component. This period witnessed increasing periodic clay pelletal deposition from the dry lake floor. Arumpo Unit, 22-35,000 years.

E. The final phase of lunette building was associated with deposition of thicker pelletal clay deposits from the dry lake bed. Zanci Unit, 19-22,000 years.

Reconstruction of the evolution of the Walls of China, Joulni. N-S cross section through the lunette. Lake Mungo basin is the larger blue area on the left hand side, Joulni basin is the smaller blue area on the right hand side (based on Bowler 1998: Figure 17A).



Plan of the Walls of China, Joulni, showing the location of Mungo, Arumpo and Zanci sediments (above) and two detailed stratigraphic transects through the Mungo III (Man) and Mungo I (Woman) locations. The Walls of China lunette on Joulni has been truncated to a nearly horizontal surface, exposing in plan the internal dune stratigraphy. The two main units (Lower and Upper Mungo) form the inner core of the dune, which contains evidence of human occupation. The Mungo Woman and Mungo Man burial sites are located on the northern (lake-shore) and southern (lee) sides of the dune axis, respectively. (source Bowler et.al. 2003).

The area is as an outstanding location for understanding elements of lifestyle, economy, health, ritual and burial within Australia's earliest Aboriginal people. The Walls of China, Joulni, encompasses a landscape that has contributed to generational change in the way people have viewed Aboriginal Australia. The discoveries of Mungo Woman and Mungo Man vastly expanded our understanding of the ways in which Aboriginal people have lived in Australia for more than 40,000 years.

Joulni is the spiritual heart of ancient Aboriginal Australia and epitomises the ancient past of Aboriginal Australia. It is a key place of symbolic value in affirming Aboriginal self-identity and cultural association with the land, claiming native title, ancestral ownership and occupation of Australia. Joulni is valued by the Aboriginal community as a place with important spiritual associations with the world of their ancestors, a place that provides very strong connection to country, a place that bestows responsibility to look after country, and a place of cultural learning and healing.

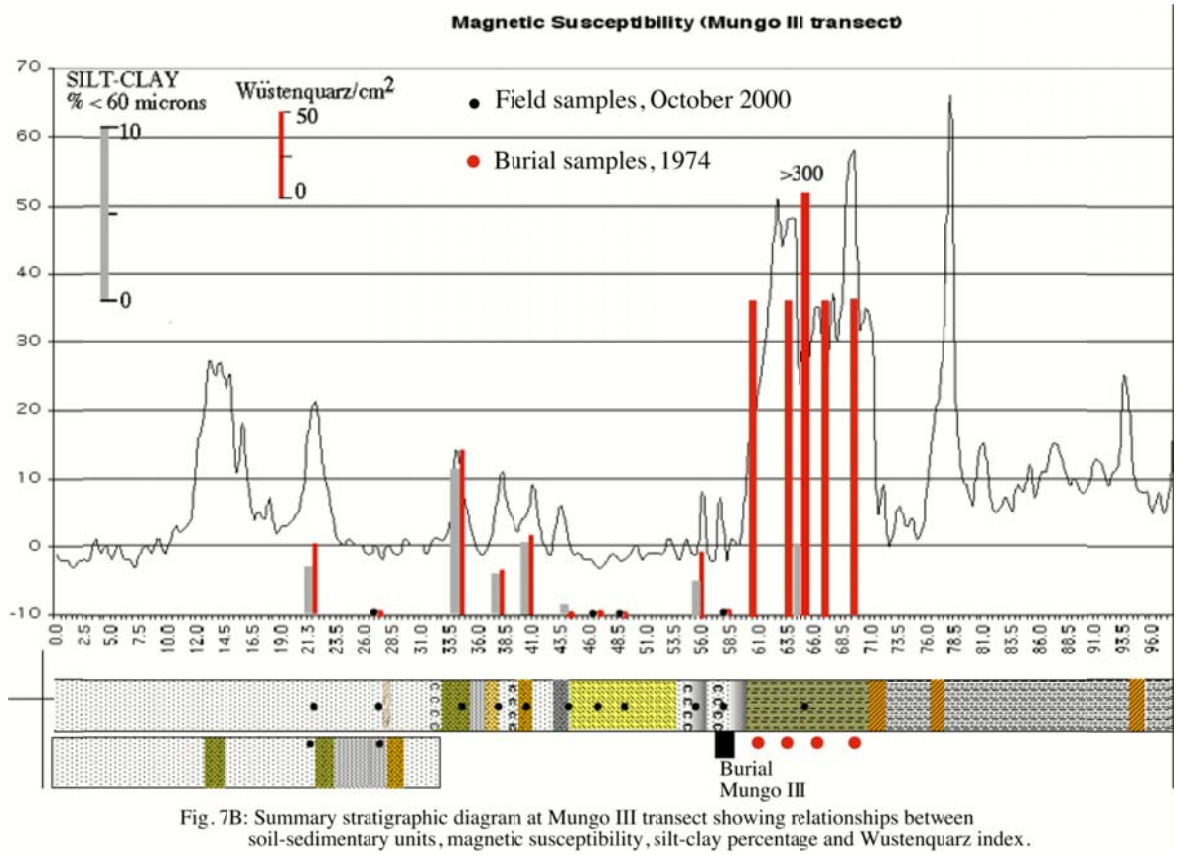
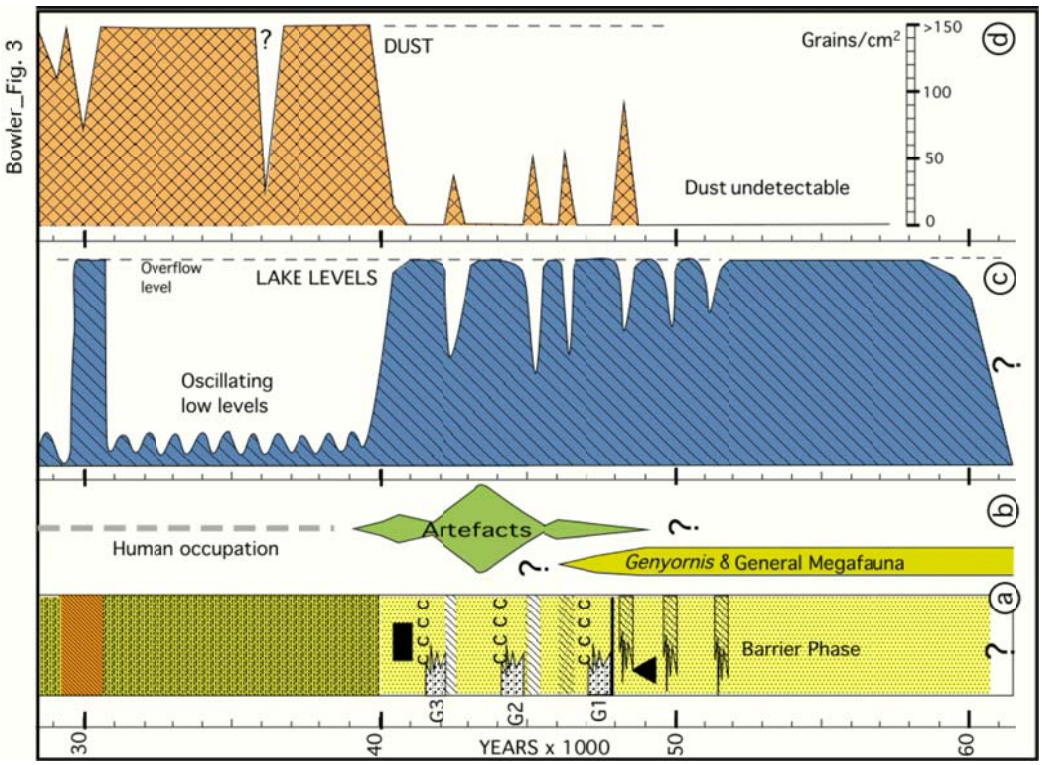


Fig. 7B: Summary stratigraphic diagram at Mungo III transect showing relationships between soil-sedimentary units, magnetic susceptibility, silt-clay percentage and Wustenquarz index.

Stratigraphic cross-section of Mungo Man site. Magnetic susceptibility, clay pellets and desert quartz (Wüstenquarz), dust variability. (source Jim Bowler).



Stratigraphic cross-section in vertical display showing interpretation of lake versus dust components against timescale including human burial (black box) context. Note burial and artefact distribution. (source Bowler et. al. 2003)

Joulni Races

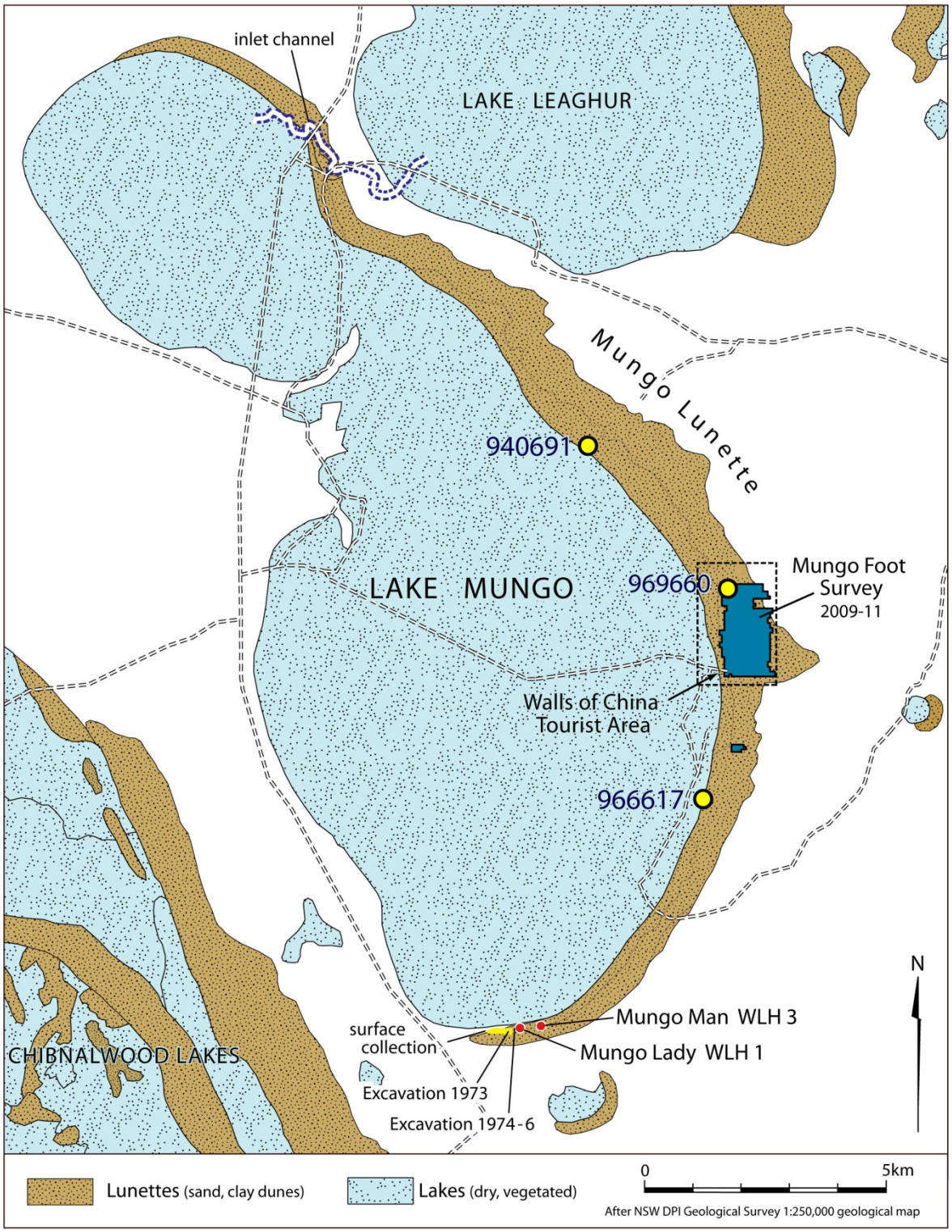
There appears to have been a long standing interest in horse racing at Mungo and Joulni. In November 1922, *Joulni*, the full brother to the Australian Steeplechase winner *Palbi*, ran its maiden race at Narrandera. The owner of *Joulni* is listed as J. H. Patterson (junior), owner of Gol Gol Station from 1911 to 1921. It is likely Patterson named the horse after the Joulni portion of Gol Gol Station. *Joulni* went on to race successfully at numerous locations such Warrnambool, Williamstown (VIC), and Oakbank (SA), and was still competing in 1931.

A race track was established on a clay pan floor of Lake Mungo, in Red Tank Paddock, and picnic races were held on this track in 1940 and 1941. The Mungo Cup in 1941 was awarded to *High Speed,* owned by Harry Richardson of Garnpang Station. Two of the events held on the day are known; The Mungo Cup and the Mungo Bracelet.

The Mungo Cup 1941. The inscription reads *Mungo Cup, Coomealla Hotel Won by H. Richardson's High Speed. 1941.* (source Johnston 2012)

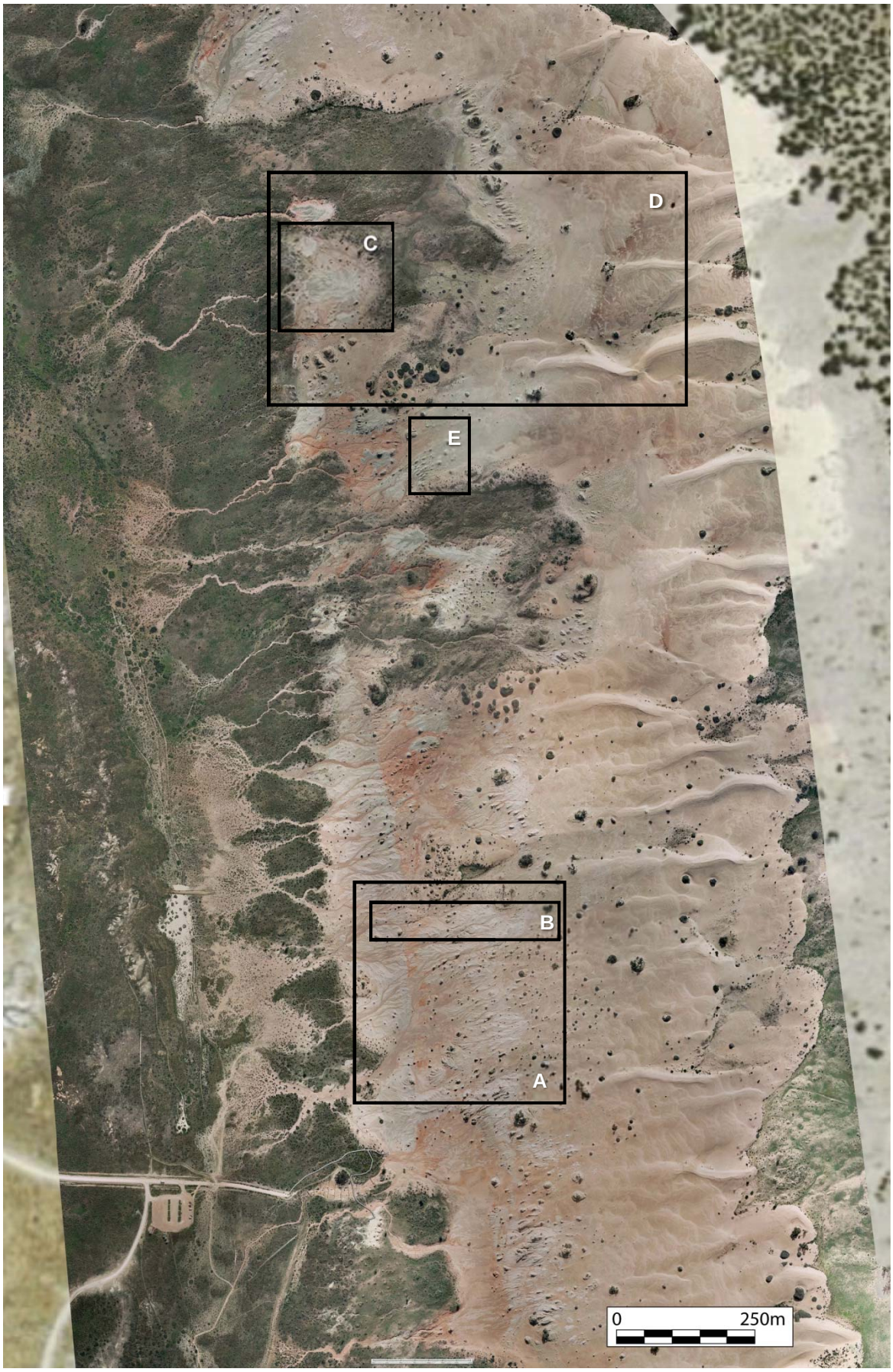
High Speed, winner of the Mungo Cup, 1941, drinking from the Cup, with owner, Harry Richardson, Garnpang Station. Bill Warren (Leaghur Station) on right hand side. The running rail of the race track is partly visible in the background. Photo courtesy Ted Richardson. (source Johnston, 2012)

Recent archaeological and geoarchaeological investigations on the central Mungo lunette

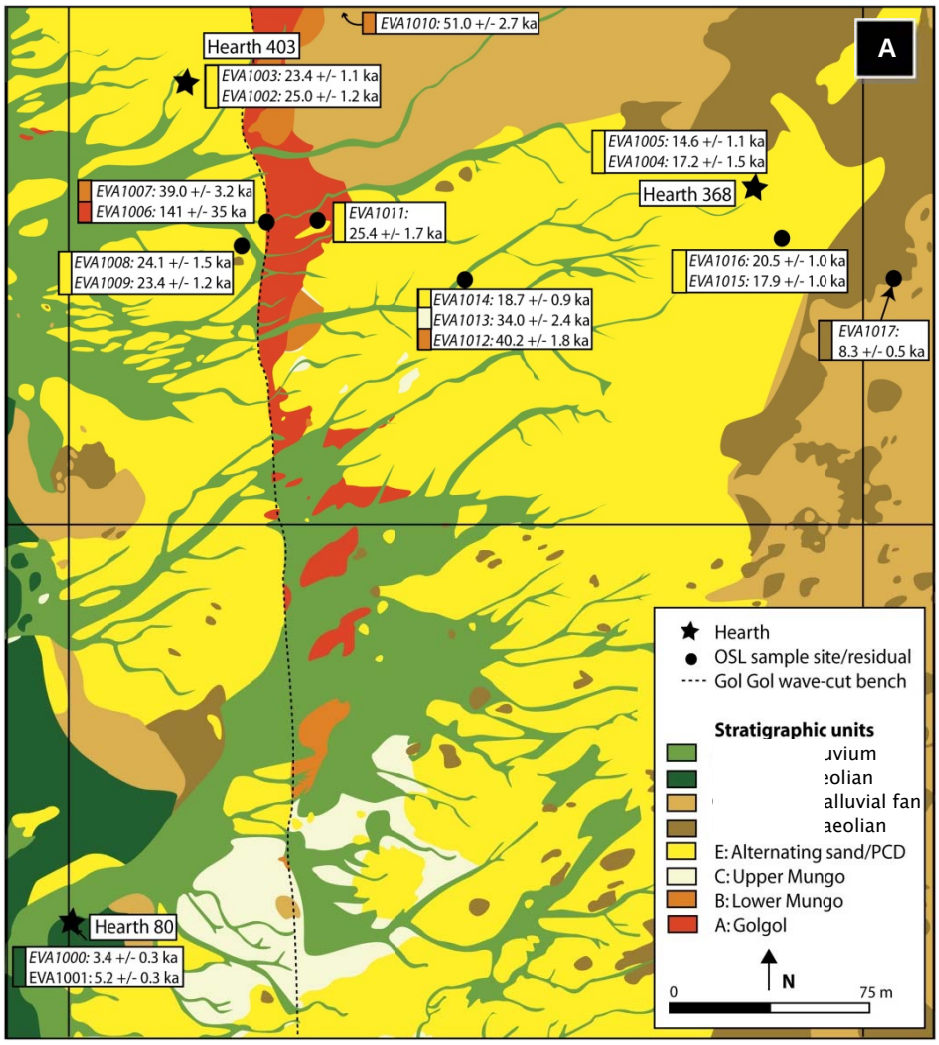


Location of archaeological investigations on the central Mungo lunette since 2007. Yellow dots represent erosion blow-outs that have been subject to detailed study.

(Source: adapted from Stern, N. 2014. In C. Smith (editor), *Encyclopedia of Global Archaeology*. Springer)

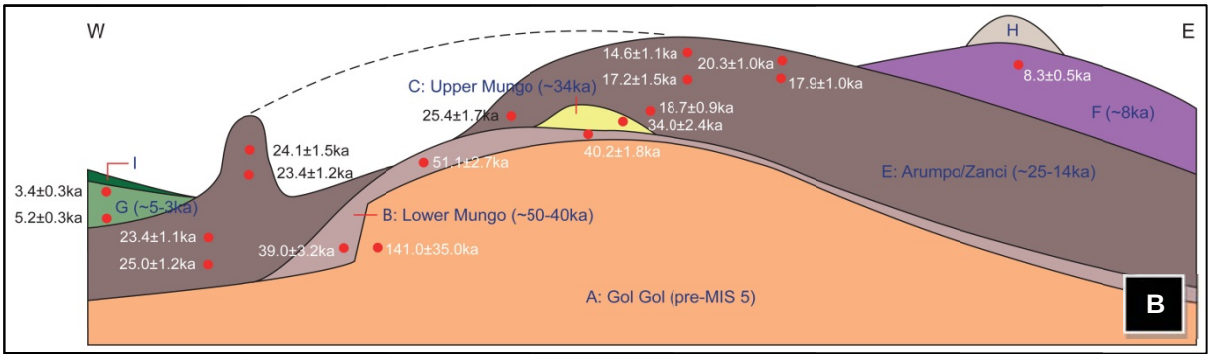


Aerial image showing the location of the following figures. (Source: N. Stern, unpublished)



Geological map of stratigraphical boundaries, showing locations of hearths and OSL sampling locations, with age estimates. As additional geochronological data from individual hearths become available, refinements to the geological map may be possible.

(Source: Fitzsimmons, K.E., Stern, N. and Murray-Wallace, C.V. 2014. Depositional history and archaeology of the central Lake Mungo lunette, Willandra Lakes, southeast Australia. *Journal of Archaeological Science*, 41, 349-364, Fig. 3)



Schematic cross section showing the chronostratigraphy of the transect studied.

(Source: adapted from Fitzsimmons, K.E., Stern, N. and Murray-Wallace, C.V. 2014. Depositional history and archaeology of the central Lake Mungo lunette, Willandra Lakes, southeast Australia. *Journal of Archaeological Science*, 41, 349-364, Fig.5)

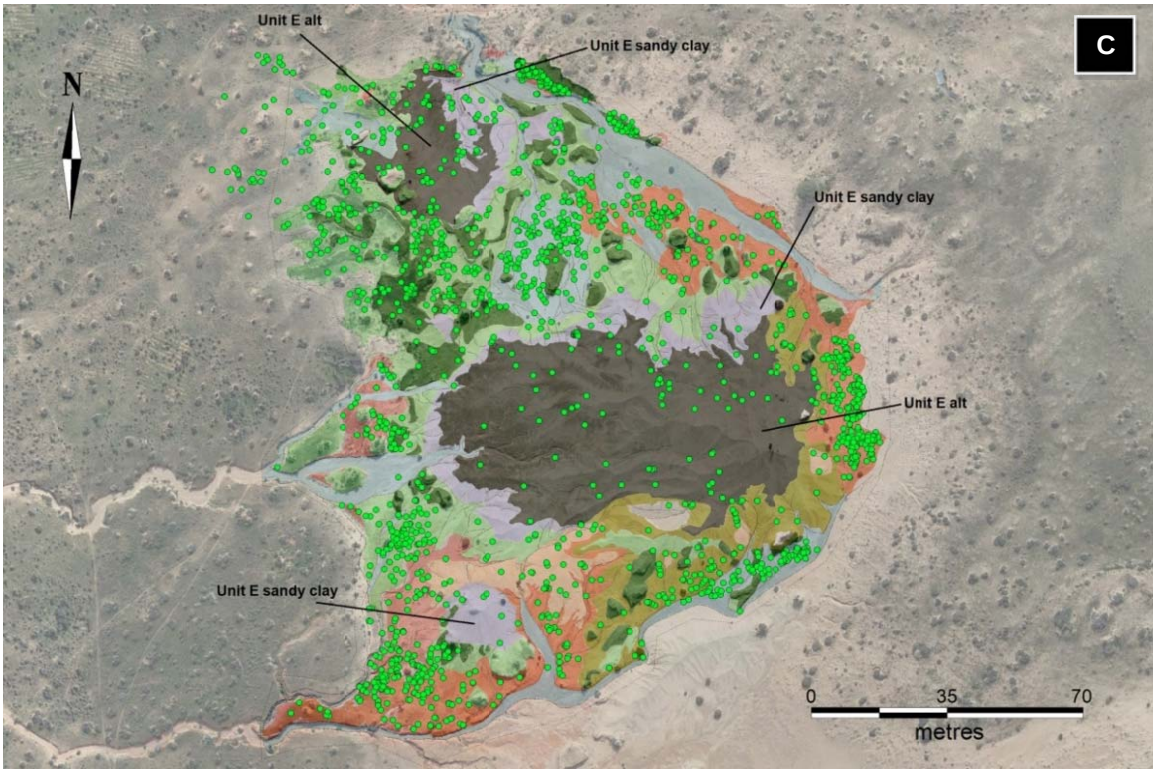


Figure 2.5. Study area 969660 with geology overlay, showing mapping at a more detailed scale. Artefacts (green dots) documented in 2007 and 2008 are also shown. (Source: N. Stern, unpublished)

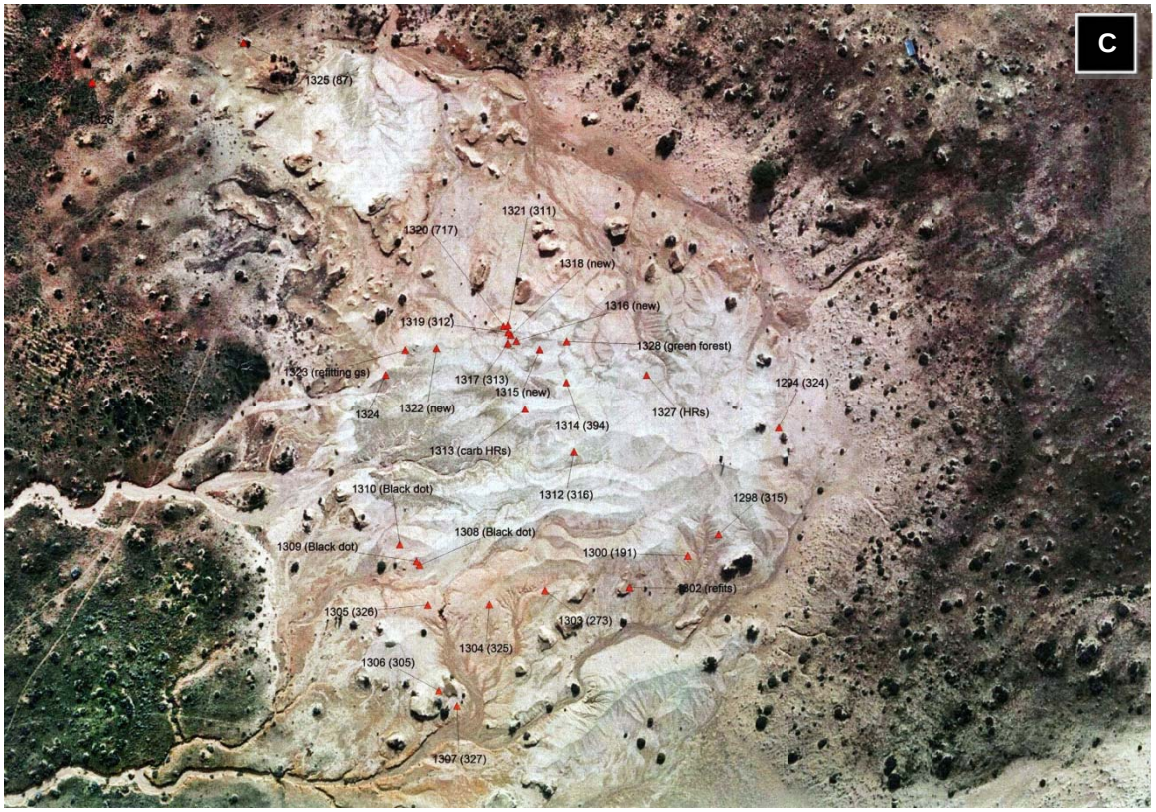


Figure 2.6. Study area 969660 showing hearth locations. (Source: N. Stern, unpublished)

D

(Source: Spry, C. 2014. *Refitting a past: a comparison of late Pleistocene and Terminal Pleistocene/early Holocene stone tool technology at Lake Mungo, southwestern New South Wales, Australia.* PhD Thesis, Department of Archaeology, Environment and Community Planning, La Trobe University)

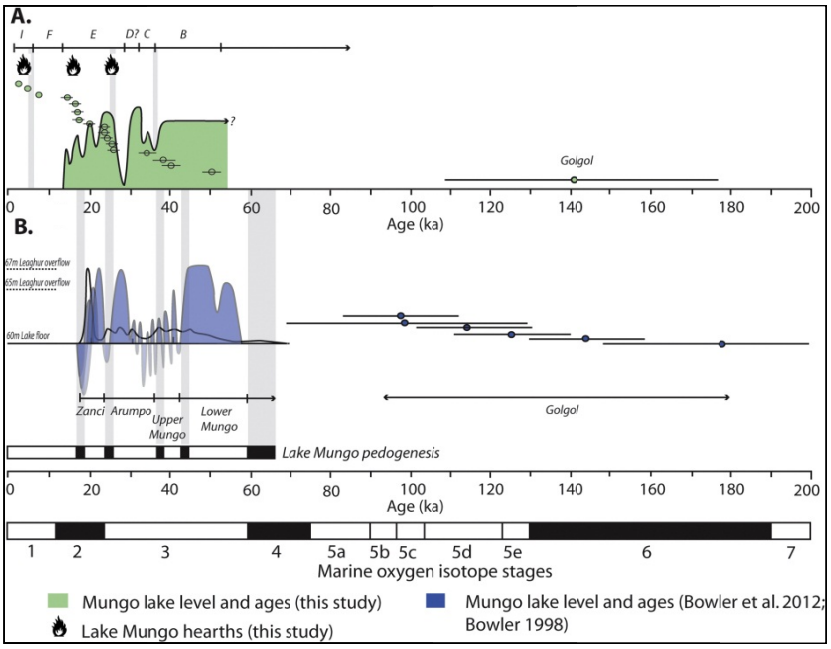


Figure 2.8. A. Lake Mungo palaeohydrology and chronostratigraphy, illustrated as an age-ranked plot and lake-level diagram. The interpreted timing of pedogenesis is indicated by pale grey shading. **B.** Willandra Lakes lake level curve. The published combined ages for the Lake Mungo lunette are also illustrated as a probability density function illustrated with a single black line, with low precision ages for the Golgol unit shown as individual age estimates.

(Source: Fitzsimmons, K.E., Stern, N. and Murray-Wallace, C.V. 2014. Depositional history and archaeology of the central Lake Mungo lunette, Willandra Lakes, southeast Australia. *Journal of Archaeological Science*, 41, 349-364, Fig.6)

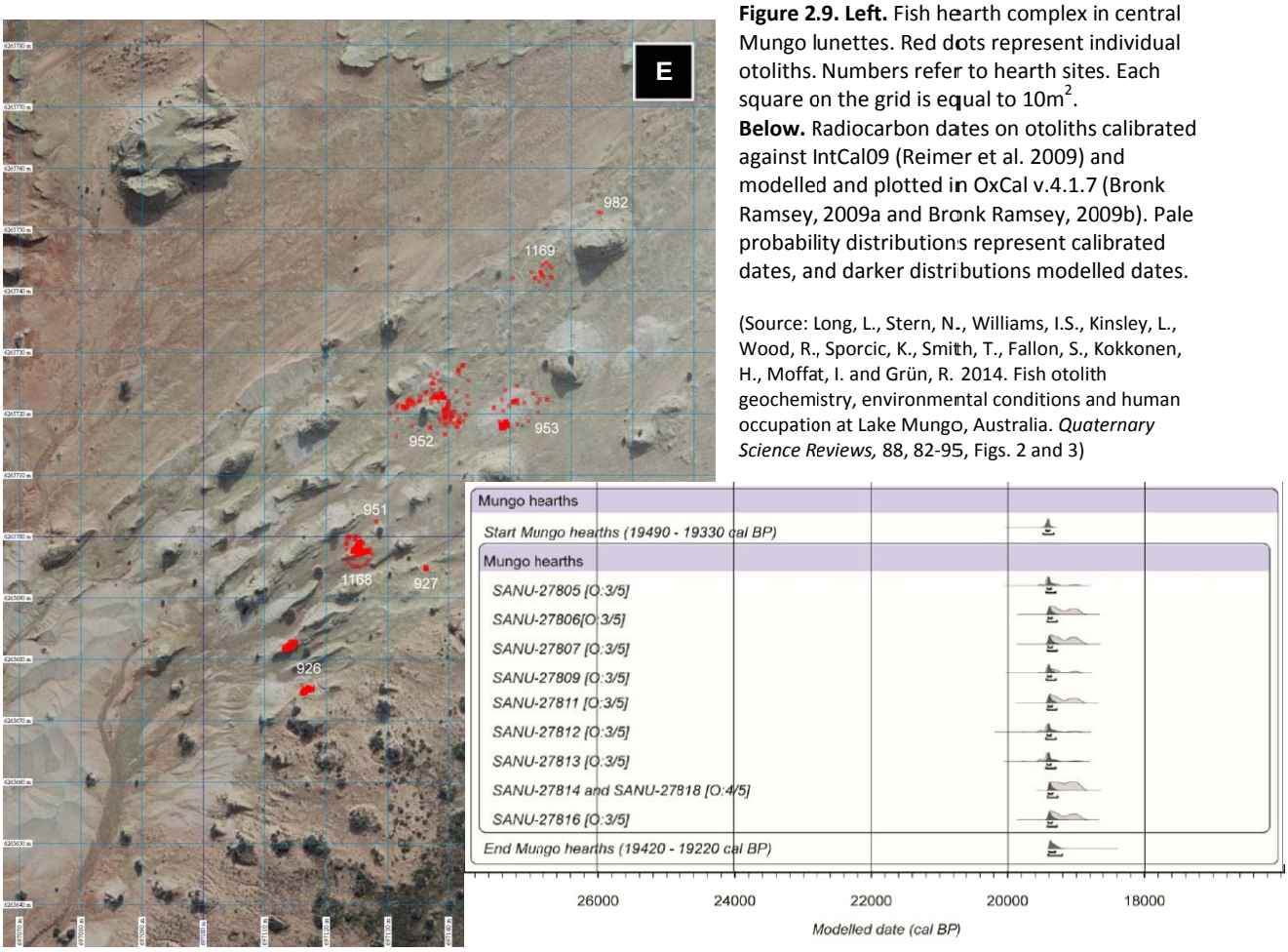


Figure 2.9. Left. Fish hearth complex in central Mungo lunettes. Red dots represent individual otoliths. Numbers refer to hearth sites. Each square on the grid is equal to 10m^2. **Below.** Radiocarbon dates on otoliths calibrated against IntCal09 (Reimer et al. 2009) and modelled and plotted in OxCal v.4.1.7 (Bronk Ramsey, 2009a and Bronk Ramsey, 2009b). Pale probability distributions represent calibrated dates, and darker distributions modelled dates.

(Source: Long, L., Stern, N., Williams, I.S., Kinsley, L., Wood, R., Sporcic, K., Smith, T., Fallon, S., Kokkonen, H., Moffat, I. and Grün, R. 2014. Fish otolith geochemistry, environmental conditions and human occupation at Lake Mungo, Australia. *Quaternary Science Reviews,* 88, 82-95, Figs. 2 and 3)

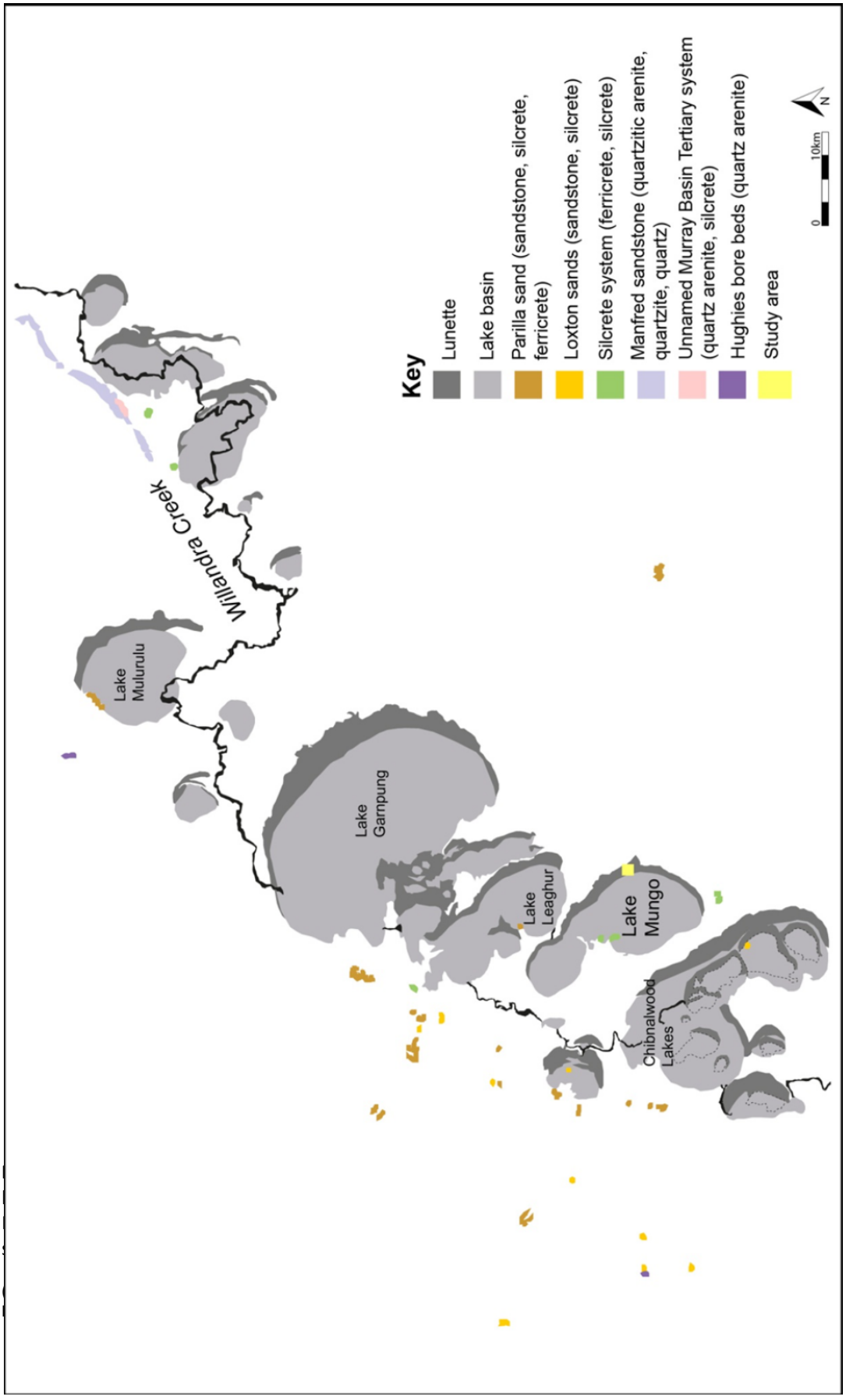


Figure 2.10. Map of the Willandra Lakes region showing potential stone sources.

(Source: Spry, C. 2014. *Refitting a past: a comparison of late Pleistocene and Terminal Pleistocene/early Holocene stone tool technology at Lake Mungo, southwestern New South Wales, Australia*. PhD Thesis, Department of Archaeology, Environment and Community Planning, La Trobe University, Figure 12, includes data courtesy of R. Kurpiel, pers. comm., 2014)

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PhD

Kurpiel, R. In prep. A study of stone sources in the Willandra Lakes Region World Heritage Area.

Spry, C. 2014. Refitting a past: a comparison of late Pleistocene and Terminal Pleistocene/early Holocene stone tool technology at Lake Mungo, southwestern New South Wales. Australia. PhD thesis, Department of Archaeology, Environment and Community Planning, La Trobe University.

Tumney, J. 2011. Environment, Landscape and Stone Technology at Lake Mungo, southwest New South Wales, Australia. PhD thesis, Archaeology Program, La Trobe University.

Honours

Boljkovac, K. 2009. *In situ* SHRIMP δ18O and laser ablation ICP-MS Sr/Ca and 87Sr/86Sr measurements in fossil otoliths for palaeoclimate reconstructions at the Willandra Lakes World Heritage Area. BSc Honours Thesis, Research School of Earth Sciences, Australian National University.

Foley, Elizabeth, 2011. A study of refitting artefacts from surface scatters on the Mungo lunette. BA Honours Thesis, Archaeology Program, La Trobe University.

Kibble, M. 2008. The study of surface faunal assemblages from open sites in the Willandra Lakes: A case study from locality 969660. BA Honours Thesis, Archaeology Program, La Trobe University.

Kurpiel, R. 2010. Notched artefacts from the Willandra Lakes World Heritage Area. BA Honours Thesis, Archaeology Program, La Trobe University.

Long, K. 2012. An ear to the ground: Fish otoliths, chronology and human climate interactions at Lake Mungo. BA Honours Thesis, Department of Archaeology and Anthropology Department, Australian National University.

Lovell, C. In prep. A zooarchaeological study of fish bones from Last Glacial Maximum age hearths at Lake Mungo.

MacManus, T. 2008. Rocks in a box: An assessment of unprovenanced artefact collections from the Willandra Lakes World Heritage Area. BA Honours Thesis, Archaeology Program, La Trobe University.

Roy, L. 2013. A study of tool-design and edge rejuvenation in the scraper assemblages from the Willandra Lakes Region World Heritage Area. BA Honours Thesis, Archaeology Program, La Trobe University.

Stammers, R. 2013. A study of heat-treatment of silcrete from the Willandra Lakes Region World Heritage Area. BA Honours Thesis, Archaeology Program, La Trobe University.

Tovey, Z. In prep. A study of glass artefacts from the Willandra Lakes Region World Heritage Area.

Truscott, W. 2012. Erosion on the Mungo Lunette: The effects of small and large scale weather events on archaeological materials. BA Honours Thesis, Archaeology Program, La Trobe University.

Vick, S. 2012. A technological analysis of the artefacts from the Chibnalwood Beach Quarry Assemblage. BA Honours Thesis, Archaeology Program, La Trobe University.

Weston, E. 2012. A study of shell tools from the Mungo lunette. BA Honours Thesis, Archaeology Program, La Trobe University.

Walls of China "Palaeomagnetic site" sections

The highest elevation area of the Mungo lunette lies in the central east of the dune complex where layers have been successively deposited on each other with little lateral spread. Sections in this region are thick and relatively complete and therefore attractive to study to look at the history of the lake. The area immediately to the south of the Tourist area of the Mungo lunette is one of the most intensively studied where a variety of dating techniques have been used. Barbetti and McElhinny (1972) identified a geomagnetic excursion in fireplaces from an occupation horizon and radiocarbon dated one of the lowest units from 26,000 to 31,000 ^{14}C yr BP. Barbetti and Allen (1972) described the context of early human occupation at Mungo at the same site. At the time, old ages of 32,000 years were considered the earliest times of aboriginal arrival in Australia. Thermoluminescence (TL) dating was subsequently performed at the site by Huxtable and Aitken (1977) and Bell (1991) who noted that the luminescence technique was giving ages older than radiocarbon by 3-5 ka. Readhead (1988) added a further 4 TL ages. Bowler and Price (1998) added an additional 5 TL ages focussing on the oldest Gol Gol units. TL dating of the stratigraphic units is somewhat problematic because of potential incomplete bleaching compared to thermally reset fireplaces but produced ages broadly equivalent to what we expect from the radiocarbon data given the calibration to calendar years.

A new stratigraphic study of the palaeomagnetic site area of the Mungo lunette was initiated as part of an archaeological study by La Trobe University and the Australian National University funded through the ARC (Fig. 1). Three main areas were focussed on: small blowouts at low elevation adjacent to the modern lake floor (S1), the core of lunette which rises up to 22 m above the lake floor (S2-S9), and the rear of the lunette (S10-S11) where mobile dunes are active because of extensive windblown erosion of the lunette (Fig. 2, 3). A dating campaign is being finalised where 33 new optically stimulated luminescence (OSL) ages will provide new constraints on the deposition of the lunette at this site (Barrows et al., in prep). The study is being complemented by a new analysis of the geomorphology and sedimentology at the site.

At the front of the lunette a 2 m high residual lunette pillar was dated at ~16-25 ka indicating deposition centring close to the last glacial maximum. This site records the last filling of Lake Mungo during the terminal Pleistocene. On the main lunette, a 10 m section through the lunette reveals alternating clayey sand and sandy clay pelletal clay units overlying the heavily calcreted top of the Gol Gol unit. Soils through the sequence are weak, making it difficult at this site to differentiate the Arumpo unit identified elsewhere (Bowler, 1998). Ages range from 17-22 ka in the top layers, stratigraphically equivalent to the lower elevation residual. Below this, ages range from 25-30 ka in a unit with multiple pedogenic zones overlying a significant soil at S6. Below this, clayey sands range in age from 32-35 ka overlying the clayey Lower Mungo Unit at 33-37 ka. The lowest units differ at the site studied from those described in Barbetti and Allen (1972) and are more similar, but thicker than those described by Bowler (1998). An ashen-grey clayey sand containing a large number of hearths and laterally equivalent to units containing burials, is dated at close to 50 ka at its base. Below this, a nodule-rich unit records weathering and erosion of the lunette surface during the last interglacial period. Dating of the Gol Gol was not attempted at this site because of intensive pedogenesis of the unit. At the rear of the lunette, reworked sediments overlying the thick modern soil are dated within the last 250 years, recording initiation of widespread erosion of the lunette following European arrival with sheep and rabbits.

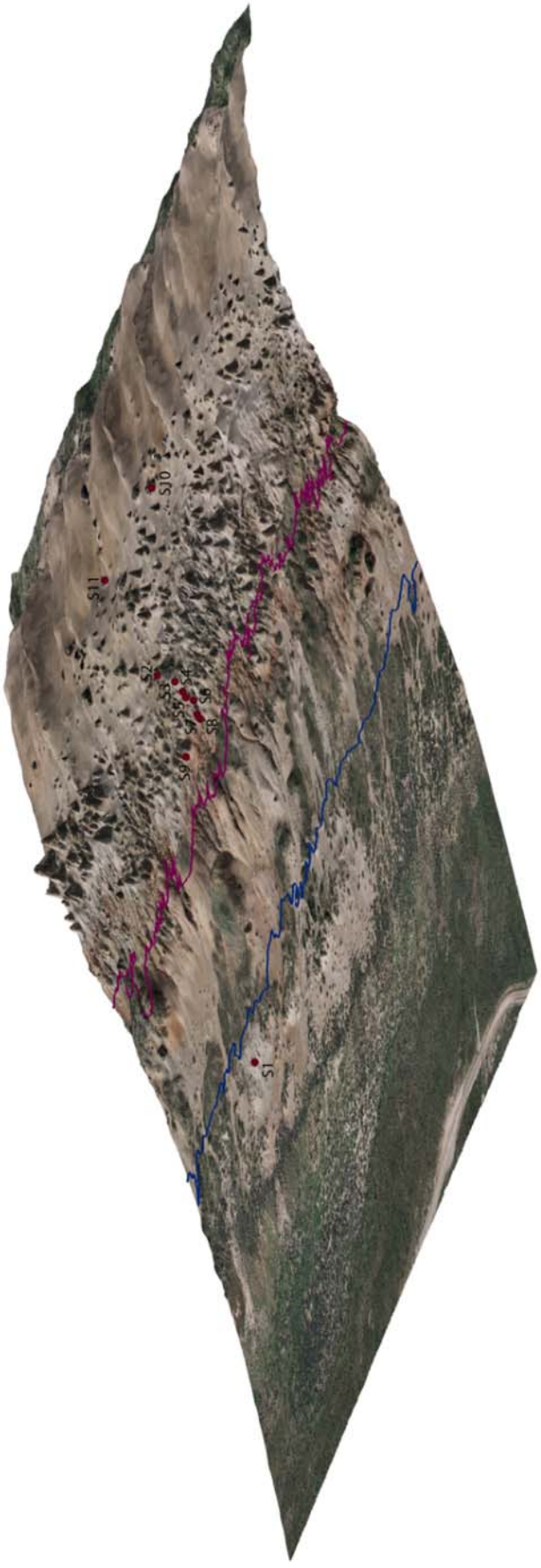


Figure. 1. 3D Aerial image of the Palaeomagnetic site, showing the location of dated sections S1 to S11

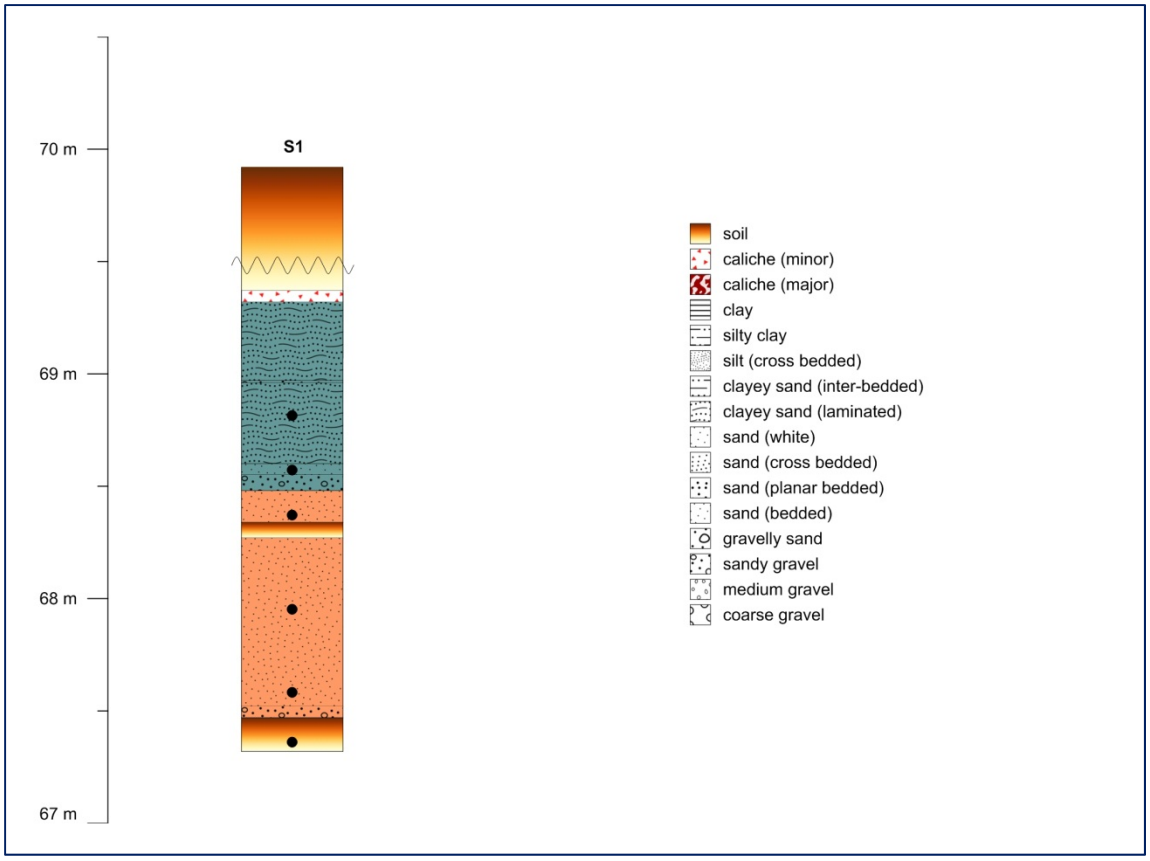


Figure 2 Section of S1

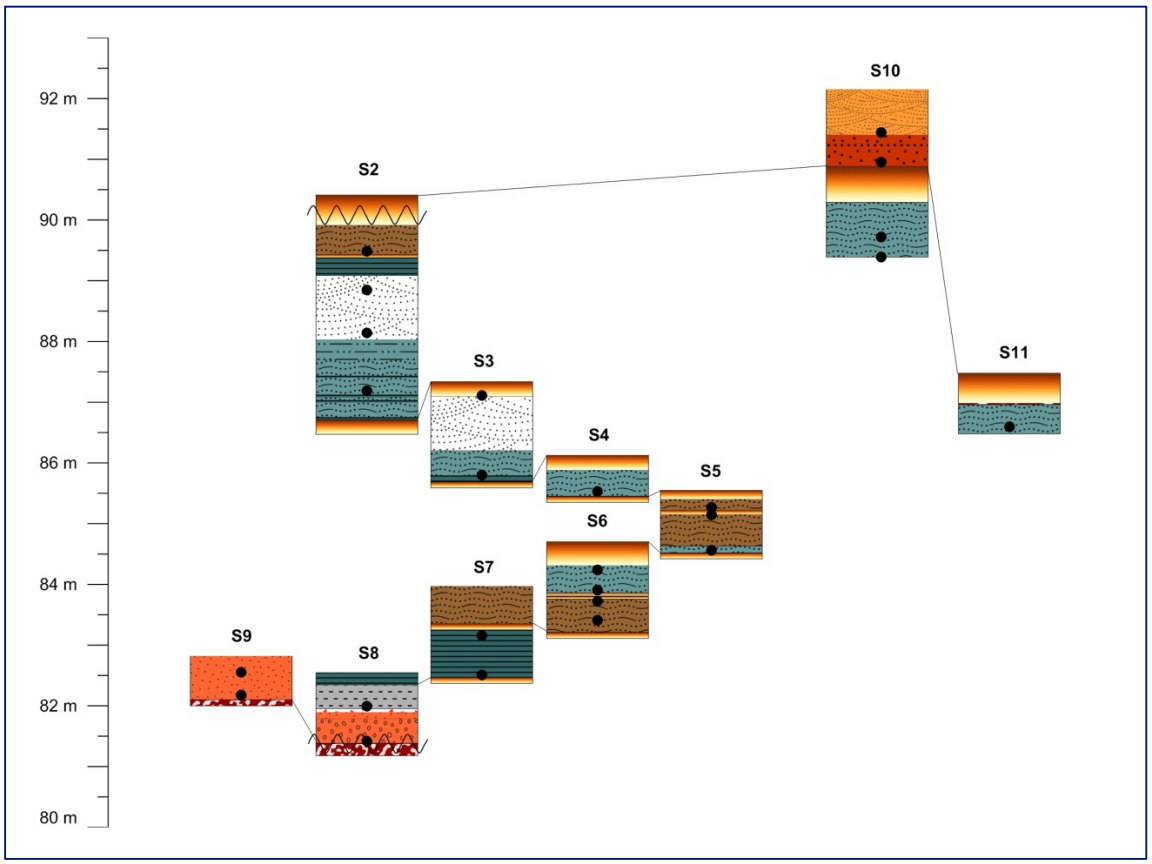


Figure 3 . Sections S2 – S11

Mungo Youth Project

The Outer Arumpo on Top Hut Station. It is the location where the Mungo Youth Project (MYP) is held, most recently in March 2014. Full details are available at http://www.visitmungo.com.au/. The MYP emerged as a key part of the 2006 Mungo Festival, which celebrated 25 years of World Heritage listing and over 45,000 years of indigenous culture in the Willandra Lakes Region World Heritage Area.

The MYP is for schools kids from Years 5 to 11. It is a biennial, ten week, mentored, *research in schools* program that culminates in a three day conference hosted by the Traditional Elder communities (The Paakantji, Ngyiampaa and Mutthi Mutthi) within the Willandra Lakes Region World Heritage Area:

The Mungo Youth Project brings together traditional Aboriginal knowledge and understandings with science and archaeology to focus on *'a deeper understanding of present-day events as well as the enduring significance of earlier ones.'* - Shape of the Australian Curriculum

The project employs the *Kids teaching Kids* model, where students learn so as to teach in an interactive way with other learners. It creates powerful references to contemporary challenges including climate change, community and individual capacity building and respect for Australia's deep cultural heritage.

Critically the project is based on partnerships: students partner with Elders, Traditional Owners, Discovery Rangers, archaeologists, scientists, landholders, educators and National Parks staff as their mentors *before, during and after* the conference.

Study topics in 2014 were:

Language & Identity	the study of local language and cultural identity
Fossil Footprints	what life was like in ancient Mungo
Changing Landscape of Mungo	how climate and people shaped land and biodiversity
World Heritage	understanding and conserving heritage in Australia
Science and the past.What happened when?	what archaeology can tell us about the ancient past. A comparative investigation of global historical change
Initiation, then and now	Rites of passage in society** *note this topic should be done in consultation with an Elder who is a Traditional Owner*

Watpipa, the "Old Man", by Ludwig Becker 1860 (in Tipping 1979). Drawn on the 24th September, 1860. Location was approximately 10 miles southeast of Arumpo Station, i.e. in the vicinity of Willandra Creek just south of Outer Lake Arumpo, some 20km south west of Joulni

Outer Arumpo Lunette

Detailed study has been undertaken in this area by McBryde, Bowler, Westaway, Rhodes, and Magee. The only published section (below) so far comes from 300m south of the east west fenceline.We will not visit this location.

Emu egg shell from Lower Mungo Sands in the site we are at has been dated to 38 ka BP (Bowler 1998: 166).

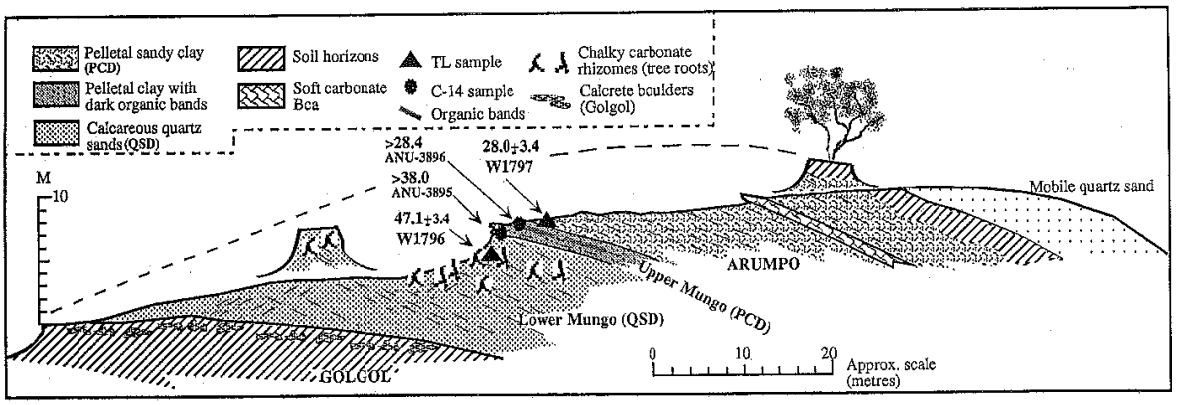
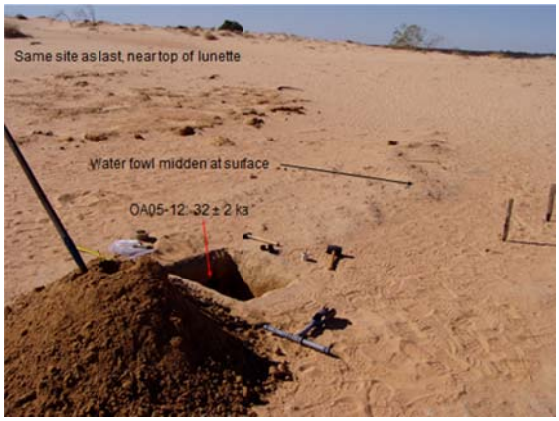
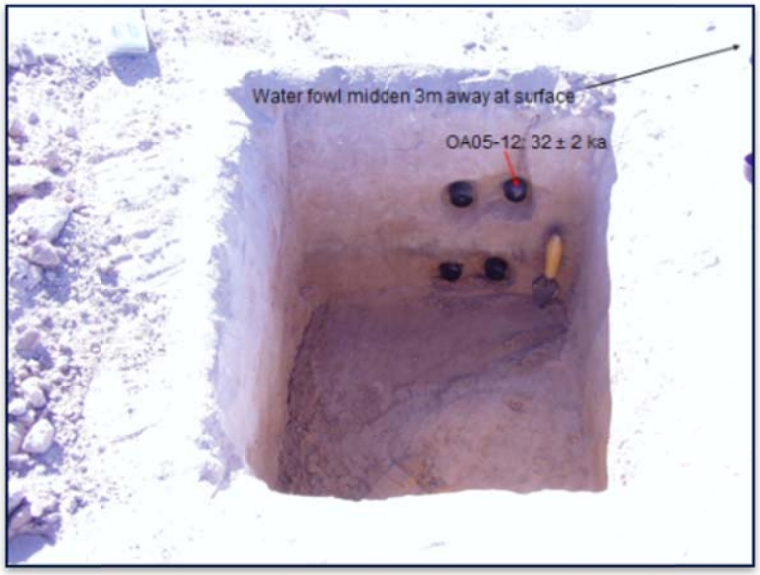


Figure 10. Stratigraphic cross-section through Outer Arumpo lunette (Site 5, Fig. 1). TL samples (Table 4) from levels near Lower to Upper Mungo contact compared with radiocarbon dates as shown.

(Source Bowler 1998).



LEFT: OSL sampling, adjacent to a small cluster of burnt water fowl shell. RIGHT: close up of burnt water fowl shell. OSL Figure produced by Dr Ed Rhodes, using preliminary dates. Not to be used in any way without permission.



Detail of Pit above with OSL dates. Figure produced by Dr Ed Rhodes, using preliminary dates. Not to be used in any way without permission.

Figure produced by Dr Ed Rhodes, using preliminary dates. Not to be used in any way without permission.

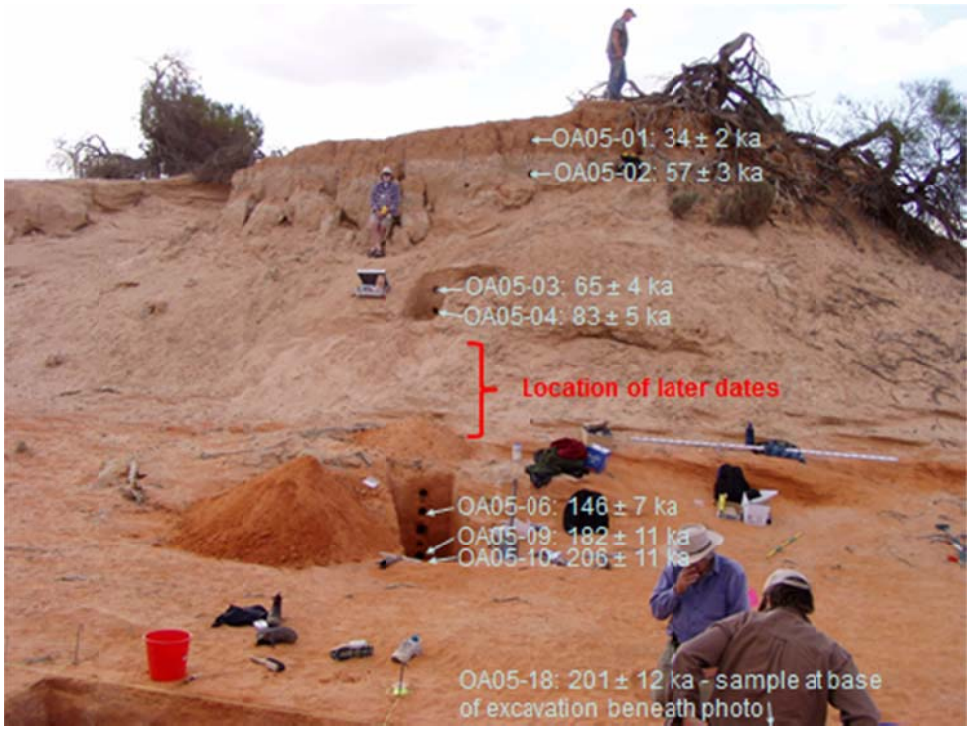
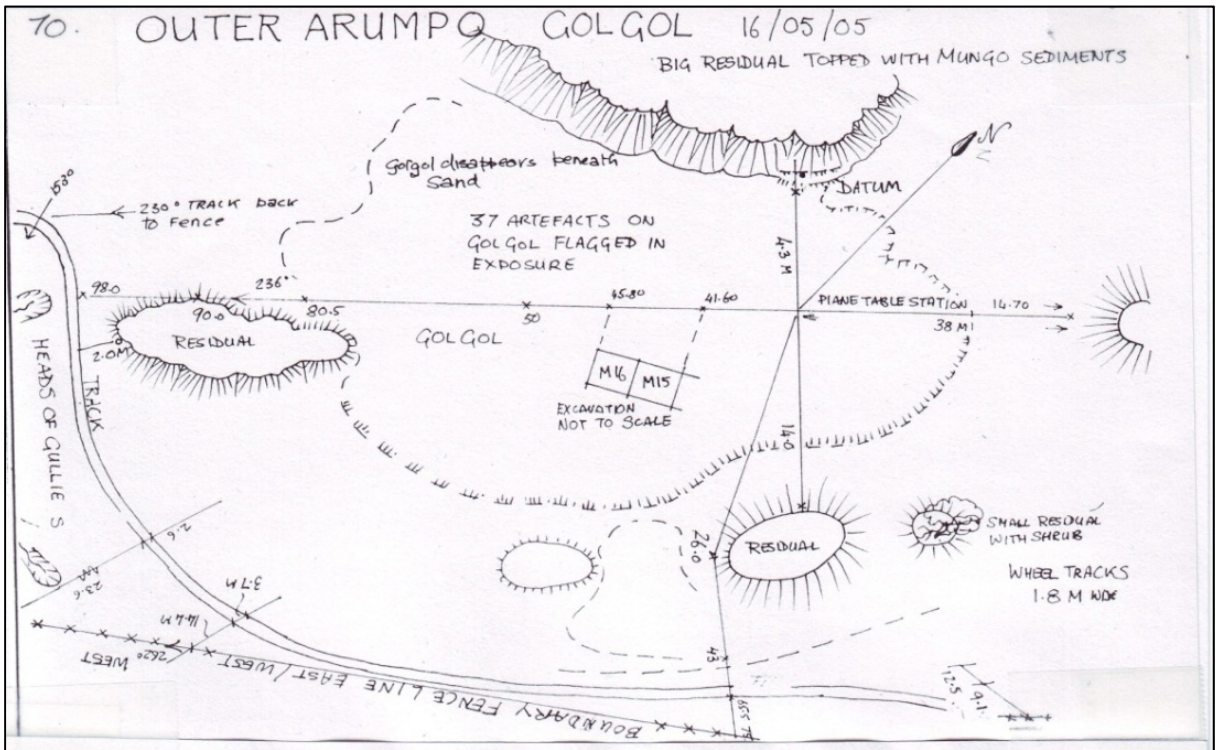


Figure produced by Dr Ed Rhodes, using preliminary dates. Not to be used in any way without permission.



Location of Chronometric and archaeological investigations on Golgol unit at Outer Arumpo. Source, Shawcross field notebook.

Wilfred Shawcross' Plan of excavations into Gol Gol sediments, Outer Arumpo, May 2005.

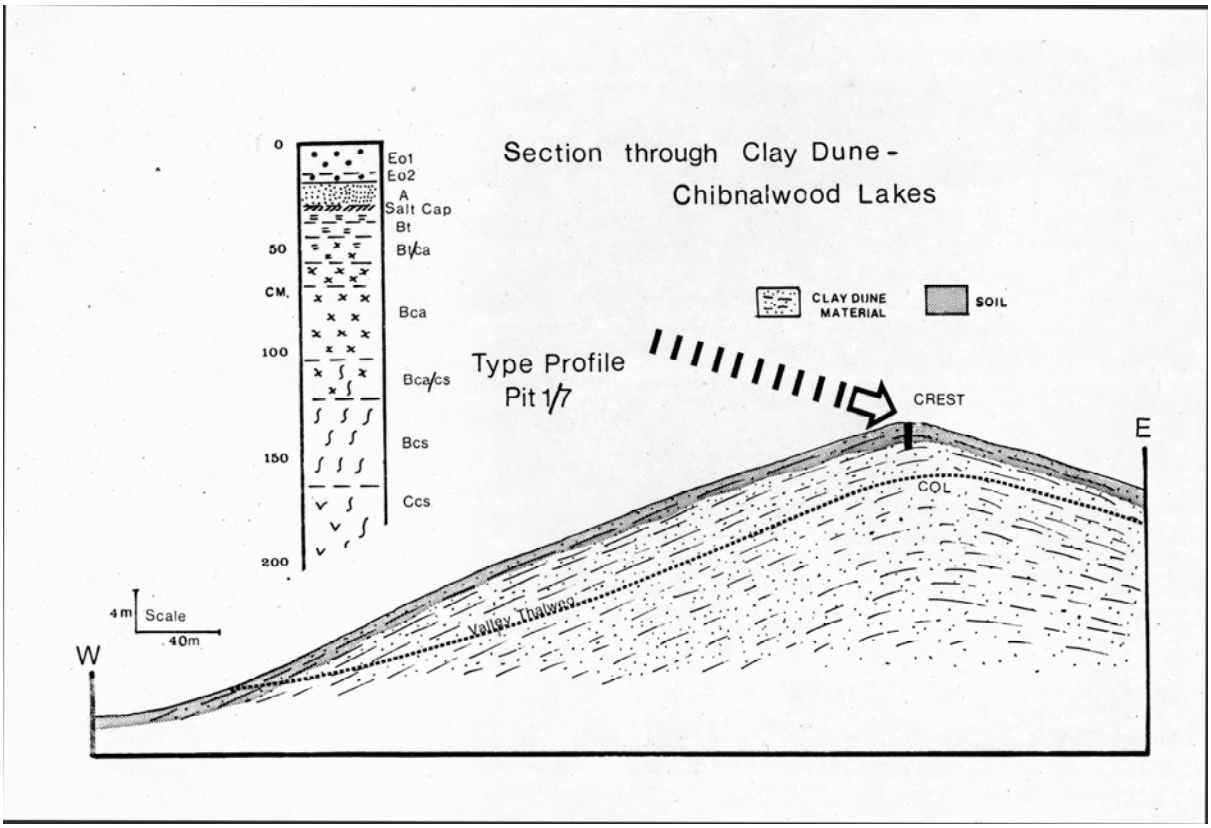
Chibnalwood Dune: Summit Site

The site examines the parent materials and truncated Zanci age soils on the crest of the central lunette of the three basin, Chibnalwood system. Macro- and micro-morphological examination of the soils and sediments supported by mineralogical and chemical analysis was carried out to establish an understanding of soil formation.

Zanci Pedoerm: Clay Dune Sediments.

Origin:

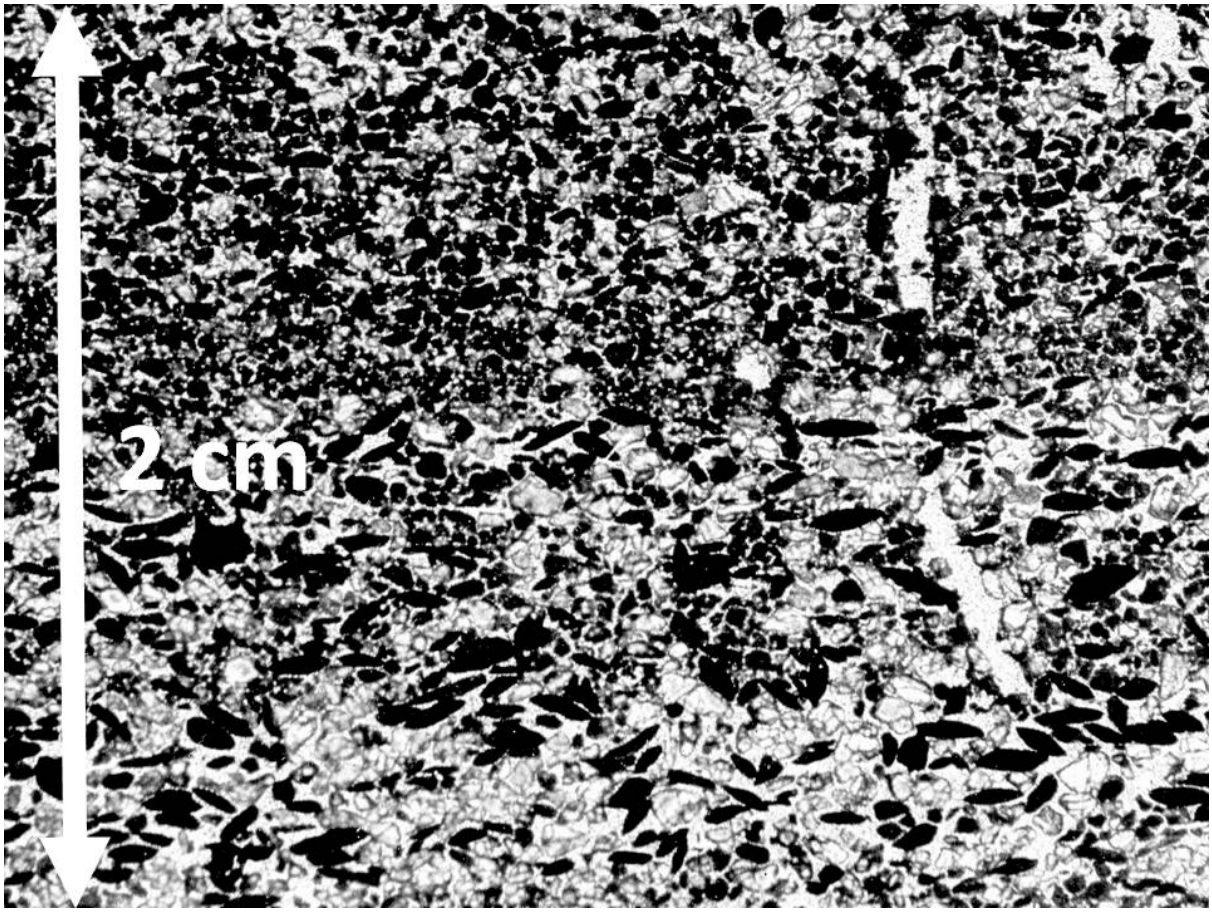
The 28 m high lunette is composed of sediments deflated from the adjacent lake floor during the final drying phase of Lake Arumpo, when lower water volumes filled only a portion of the old lake floor. Oscillating (seasonal?) changes in water level, associated with high, saline groundwater regularly revealed the saline mud of the lake floor and so exposed the drying mud to deflation. In this environment efflorescence of salts in the drying mud produced a range of clay aggregates that were selectively removed as saltation and suspension loads. The saltated clay aggregates accumulated downwind on the developing lunette while the finer suspension load moved eastwards to add to the parna deposits on the Riverine Plain and beyond. (See works of Jim Bowler; Bruce Butler; John Beattie; and others)



Cross-Section through dune at AQUA trip site with type site soil profile added (source Tony Dare_Edwards)

Characteristics:

The dune sediments are composed of a mixture of subplastic clay aggregates, quartz grains, millet seed gypsum, carbonate glaebules, wustenquarz, shell fragments. The average texture, after dispersion, is 40% quartz sand, 6% silt-sized quartz, and 54% clay. Travelling with these carbonaceous, gypseous clay sediments are high levels of soluble salts adsorbed within the clay aggregates.



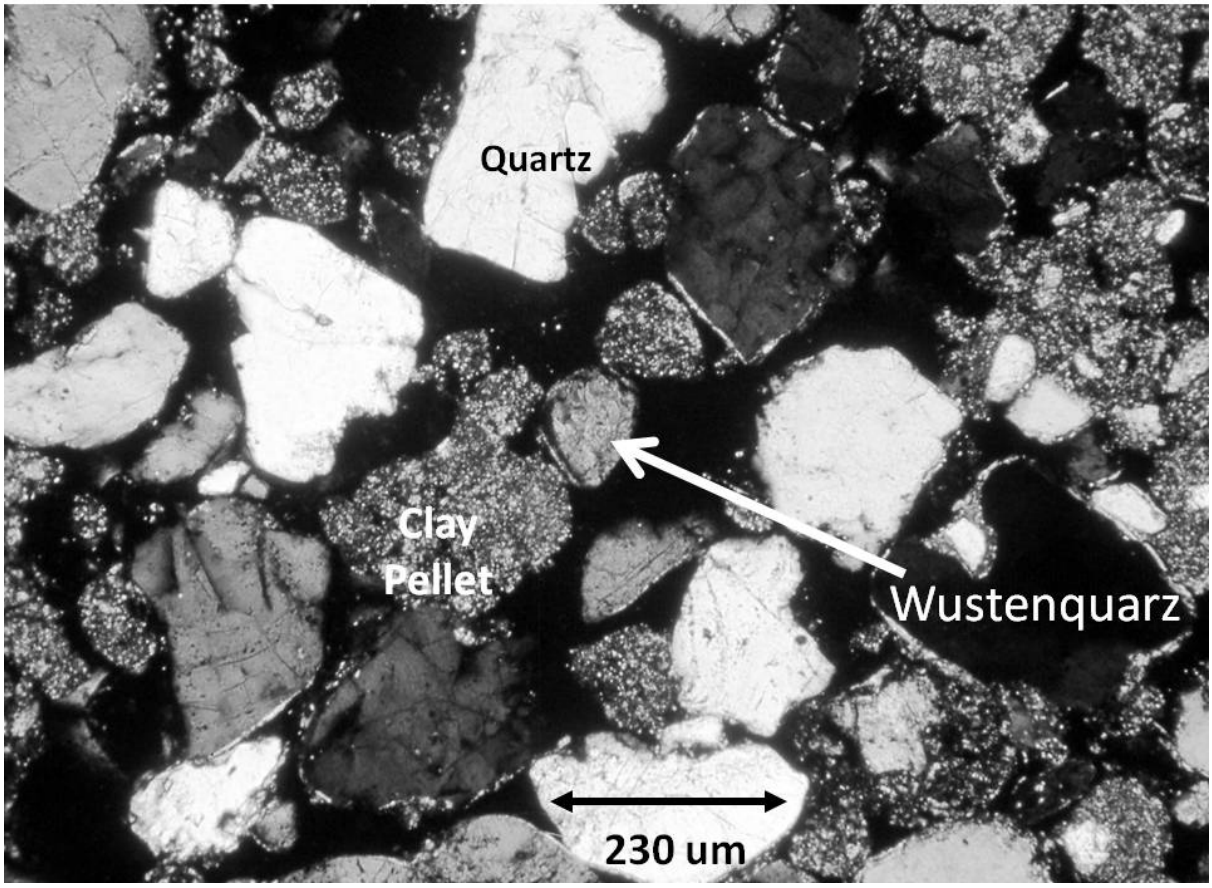
Planar Beds., showing sharp boundary between layers and root channels. (source Tony Dare_Edwards)
Black Grains = Millet Seed Gypsum; Lighter grains=Clay Pellets; and Clear Grains= Quartz

Clay Pellets

The clay aggregates (clay pellets) which are the distinctive feature of these dunes travel as sand- or silt-sized stable grains. Three forms have been recognised in thin section: calicinsepic pellets (dominant) , clay flakes and mixed pellets. The clay mineralogy is uniform across the dune as an Illite-kaolinite suite associated with Hallyosite and minor amounts of amorphous clay. No Palygorskite is identified.

The clay pellets are extremely stable and will not break down to their clay size particles easily. Examination of the pellets show that they are not cemented by carbonate or other salts, rather they are held together by electrostatic forces; salts can be flushed from the pellets without loss of integrity. This stability has led to the pellets being termed subplastic; a term coined by Bruce Butler to describe the way in which parna deposits will change texture grade progressively becoming more clayey upon working between finger and thumb.

Clay pellets (US terminology: dust aggregates) have been suggested as the characteristic sediment type of many Martian dunefields where the thin atmosphere precludes the easy movement of heavier, quartz sand by deflation and saltation. (Bridges, N.T. 2010, Aeolian bedforms, yardangs, and indurated surfaces in the Tharsis Montes as seen by the HiRISE Camera: Evidence for dust aggregates. Icarus 205, 165–182).



Clay Pellet (Calicinsepic) with quartz and wustenquarz (diagnostic ferri-argillan on wustenquarz not visible in panchromatic) (source Tony Dare_Edwards)

Primary Carbonate.

Carbonate glaebules deflated off the lake floor are dominated by dolomite (Mg55Ca45 species) and low magnesium calcite (Mg6Ca94 species). However, Mg/Ca ratios of the soil water extract show a dominance of Mg over Ca (1.6 to 1.9) in all sites on the dune. Calcium is selectively precipitated in the soils as secondary carbonate leaving the Mg salts to predominate and accumulate as Mg-enriched carbonates in the valley floor and on the lake floor.

Primary gypsum

This is saltated onto the dune as distinctive lozenge-shaped, seed-like, gypsum crystals (hence: millet seed gypsum).

Soluble salts

Salt concentrations today vary from >2% (by wt) in the crest to <0.2% in the valley floor. Chemical analysis of the soil extracts show that the salts are dominated by sodium chloride with, in decreasing order, magnesium sulphate, sodium sulphate, calcium sulphate and calcium bicarbonate. X RD results of salt crystals scraped from soil surfaces identify halite as the dominant salt with lesser amounts of Thenardite (Na2SO4), then Gypsum (Ca2SO4 .2H20) with Bloedite, Na2Mg (SO4)2.H2O; Bischofite, MgCl2.6H2O and Vanthofite, Na2Mg(SO4).

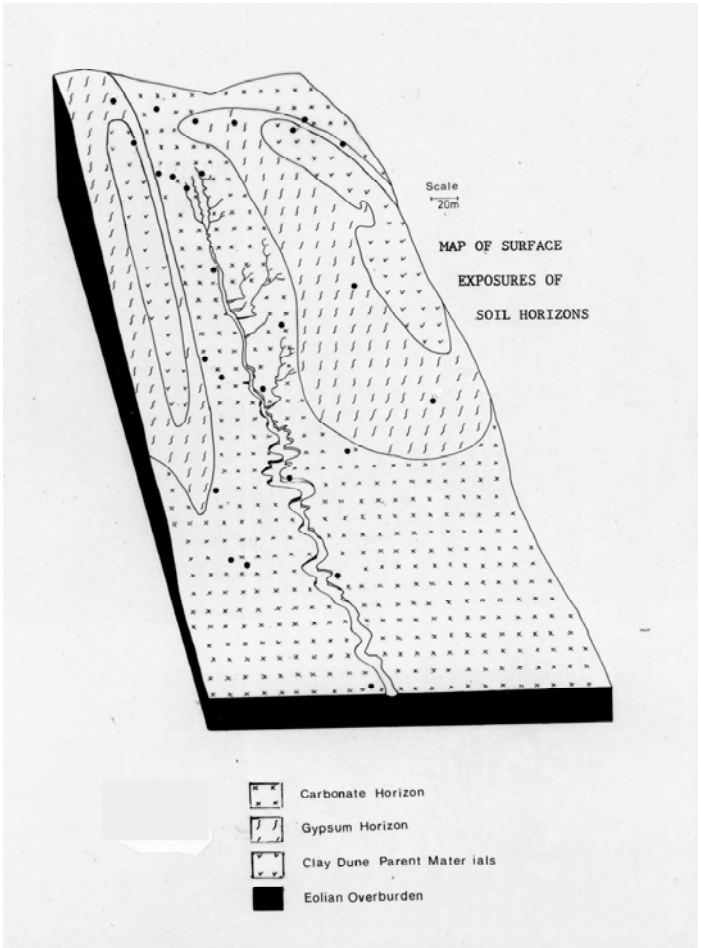
Wustenquarz

Wustenquarz (Gr: “desert sand”; Radczweski, 1939) contents are uniform in the sediments (0.3% by volume though are marginally higher in all upper B horizons and the A horizons of the soil, perhaps due to bioturbation of wustenquarz added to the developing soil surface.

Zanci Soil

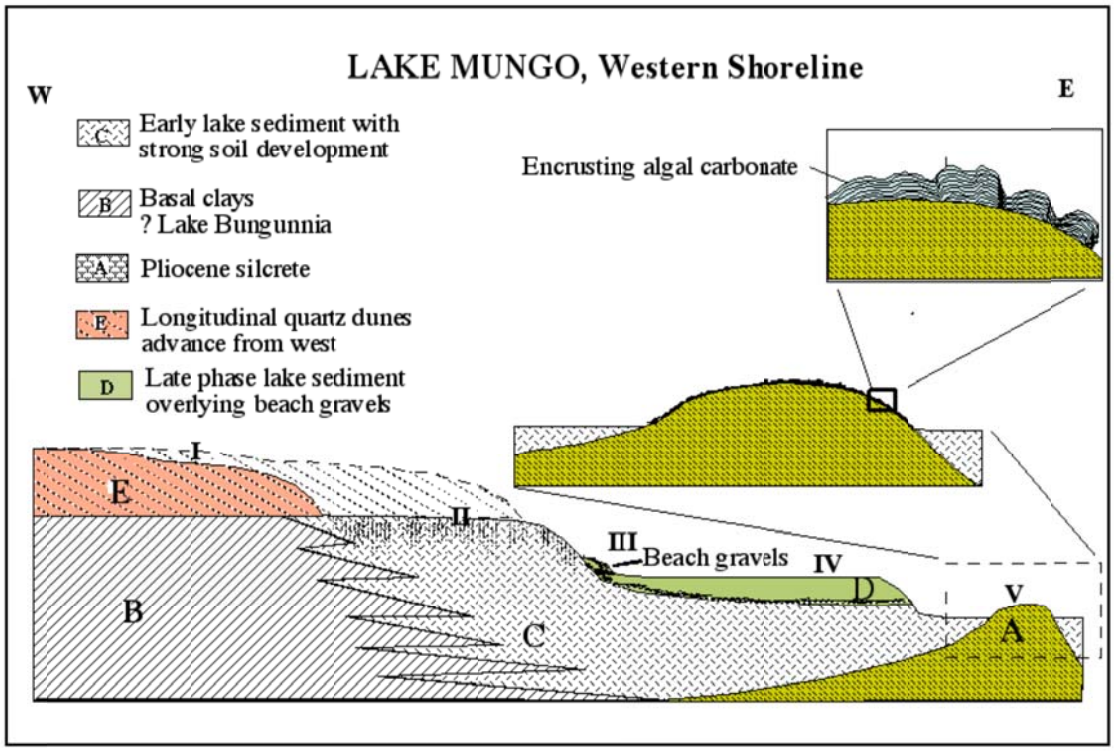
The soil formed on these clay dunes is a deep, well developed sodosol (**Calcic Hypernatric Brown Sodosol**, Isbell 1996; **Db3.13**, Northcote 1974) that is complicated by at least two phases of widespread erosion which truncates the profile and in many sites buries the soil under more recent aeolian units. Ongoing pedogenesis overprints the main profile with materials illuviated from these overlying aeolian units, making the present soil profile polygenetic in character.

The Zanci pedoderm is poorly represented in the Willandra Lakes dating program. The 1970s model, (dependent upon early radiocarbon dating methodology) suggested that the clay dunes of the Zanci unit were deposited between 18000 BP and 15500 BP, meaning the clay dunes have been stable and exposed to pedogenesis since 15500 years. The dates of the two erosion/deposition phases identified at Chibnalwood were suggested to have occurred between 2500 BP and 850 BP and again between 850 BP and present. Recently, Fitzsimmons et al. (2014) have shown that dune building continued at Lake Mungo until close to 15000 BP and that erosion of their Zanci/Arumpo unit occurred around 8000 BP and again more recently.

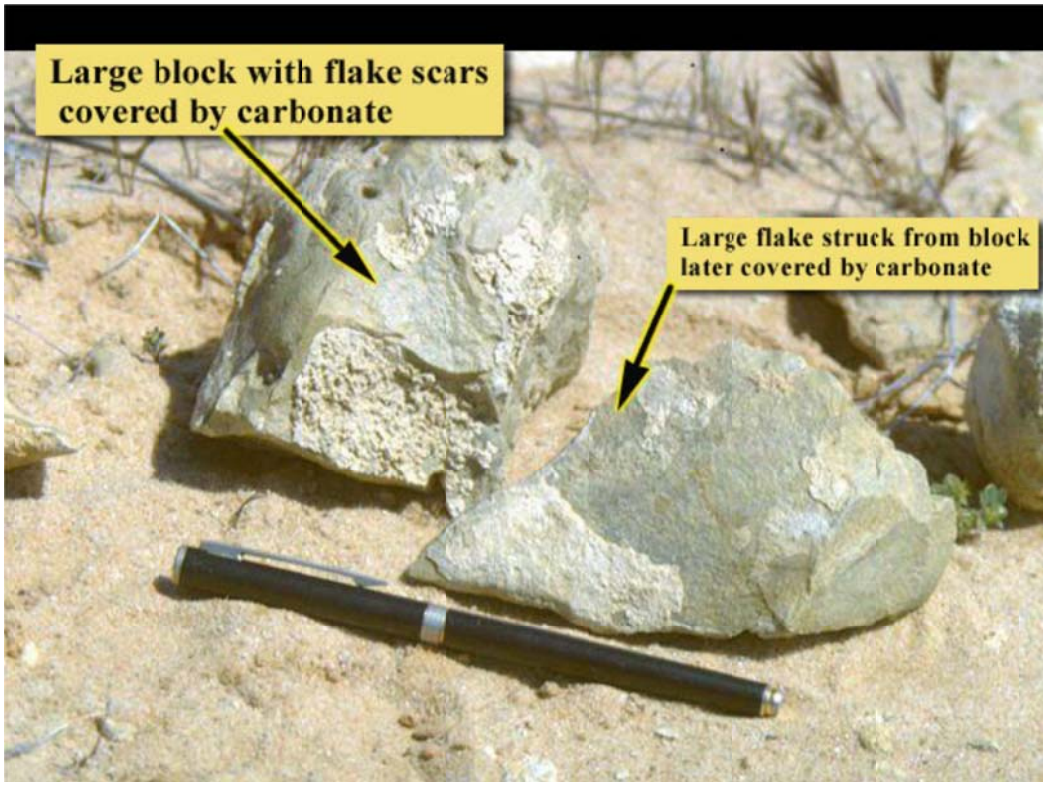


Map of surface exposure of truncated soil horizons. (source Tony Dare_Edwards)

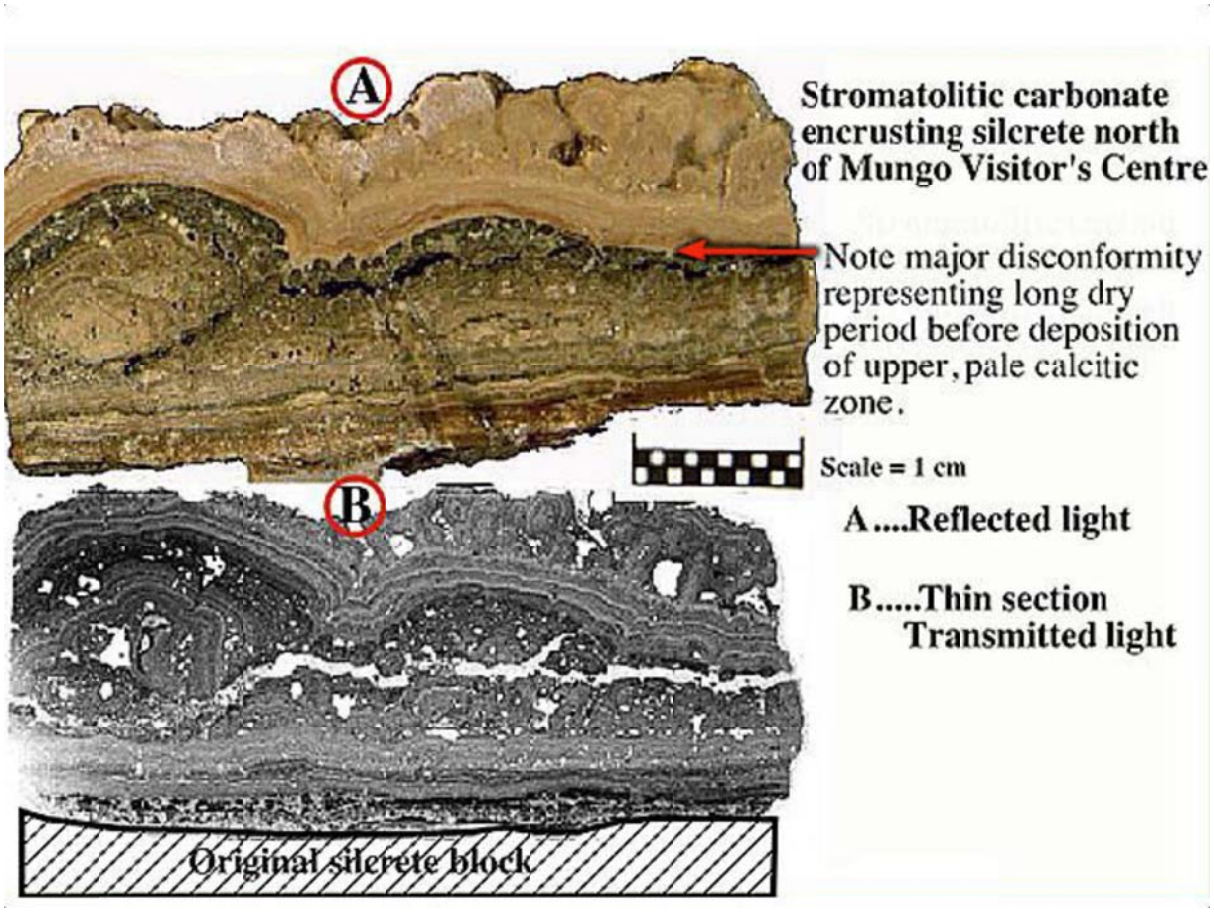
Mungo silcrete and western shore stratigraphy



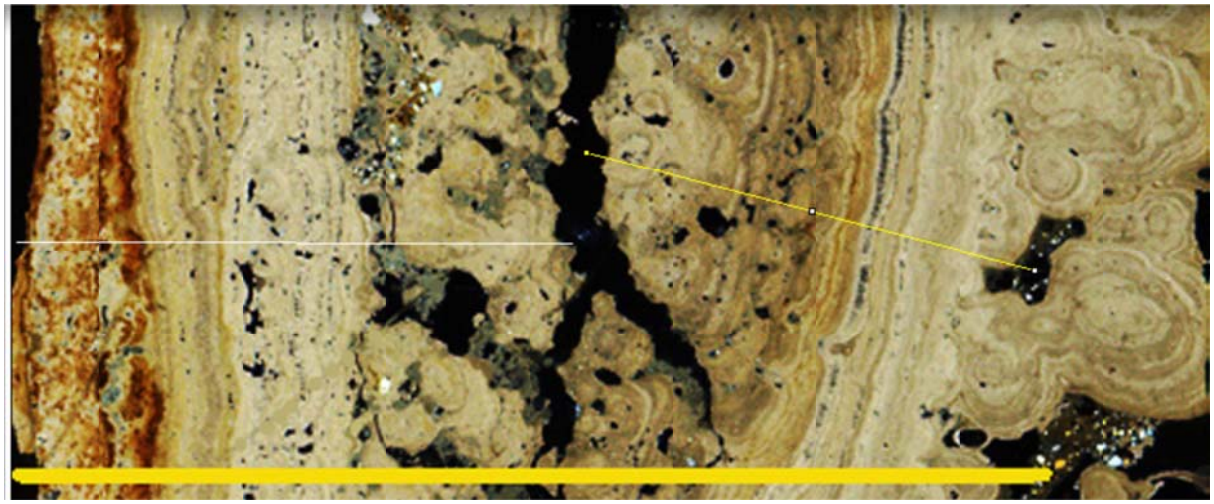
Western shore stratigraphy. Dunes from west, Pliocene silcrete and lake carbonate crusts. (source, Jim Bowler).



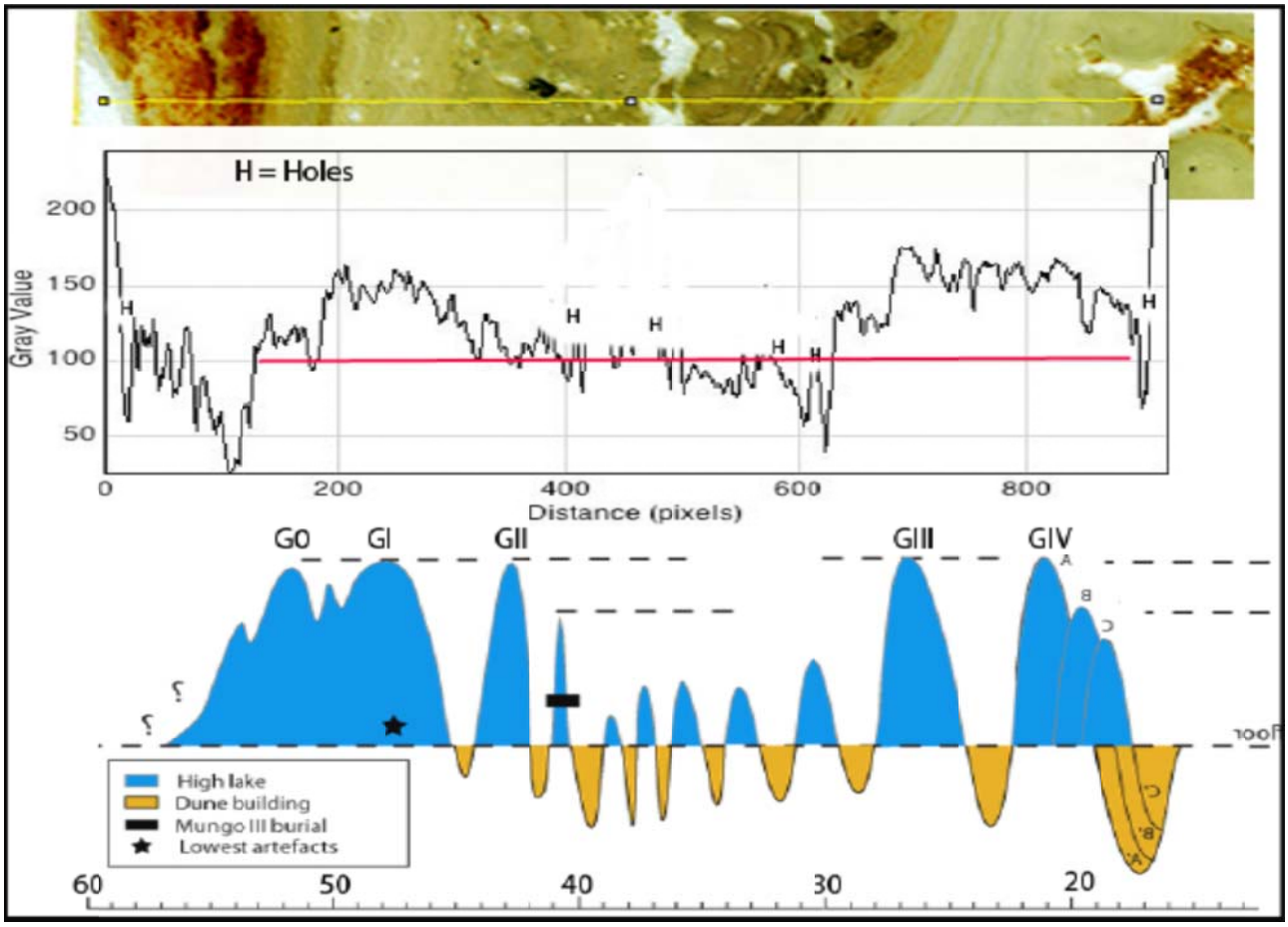
Silcrete blocks, flaked scar (human quarrying) covered by lake carbonate. (source, Jim Bowler).



Cross-section through carbonate crust. (source, Jim Bowler).



Thin-section through carbonate crust in above. See profile in 11. Pale laminae, continuous deposition. Darkening and fractures on drying. Red zone on left, ancient weathered crust. Final drying near 20ka on right. (source, Jim Bowler).



Grey scale scan compared to water level curve. Clean pale carbonate equates with stratigraphic waterlevel curve. G code = gravel, high lake, units. Major lake-full phase 60 to 40ka; major dune building near 20ka, glacial maximum.

Fossil footprints, Lake Garnpung

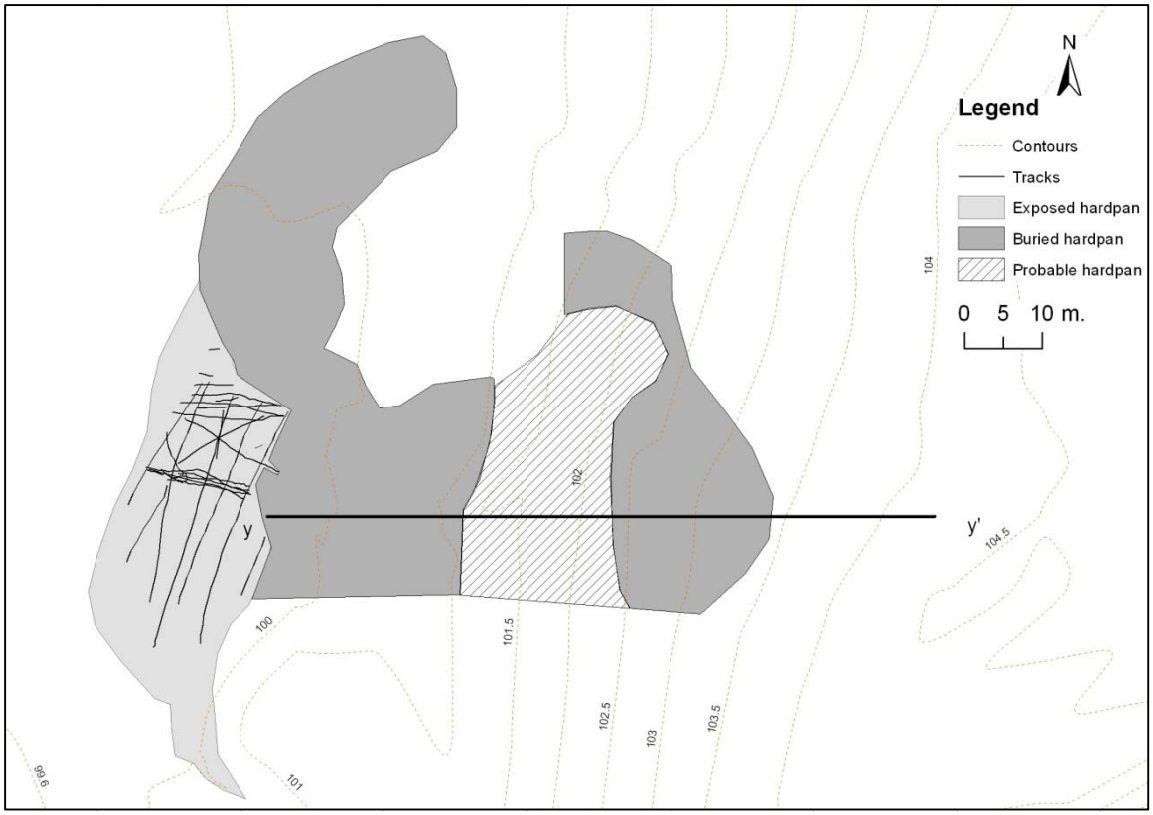
The Garnpang footprints site consists of at least 26 human fossil trackways (individual sets of footprints), numbered T0–T26, as well as individual human footprints not linked to trackways, and the footprints of marsupials and birds. It is the first such fossil trackway site documented in Australia and as such represents a very important record of a rare site type.

A total of 533 footprints have now been mapped and the majority of these have been digitally scanned and the images georectified on to site plans. Of the 533 footprints, 405 have now been matched into 26 trackways. OSL dating above and below the hardpan date the footprints to between 19,000 and 20,000 years ago.

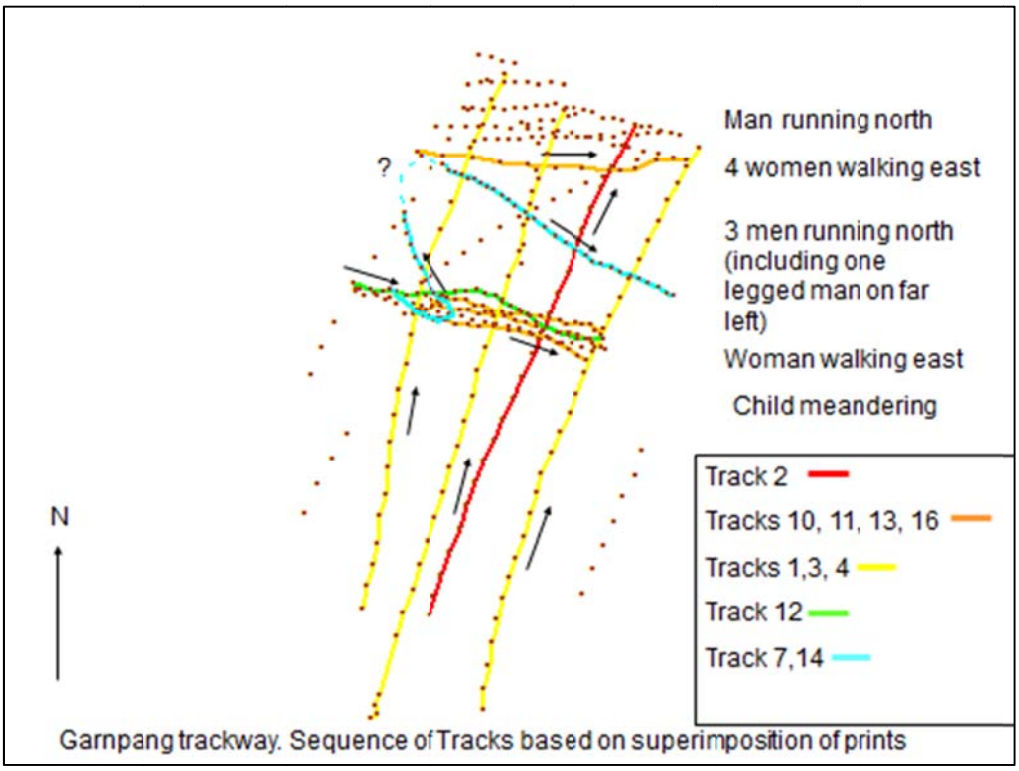
Hardpan Composition

the hardpan is comprised of thin laminae of sandsized magnesitic and silty clay pellets. Those layers near the surface of the unit contain silty clay cemented with magnesite. It is uncertain whether this cementation is primary, due to precipitation from magnesium-rich water ponded at the site, or caused by more recent dissolution and recrystallisation during diagenesis. The footprints of people, marsupials and birds crossing the hardpan could have been impressed during ponding, and the moulds preserved by subsequent magnesite cementation. Alternatively, rain events may have sufficiently moistened a pre-existing magnesitic silty clay layer to enable casting to occur. Mineral composition varies across the hardpan, with abundant quartz, magnesite, ferroan (iron-rich) magnesite and hydromagnesite, and lesser amounts of illite and kaolinite, in the western part. In contrast, the eastern section is dominated by magnesite and ferromagnesite, with minor illite, kaolinite and quartz. As a consequence of the differing mineral composition, the preservation of the footprints differs substantially across thehardpan surface.

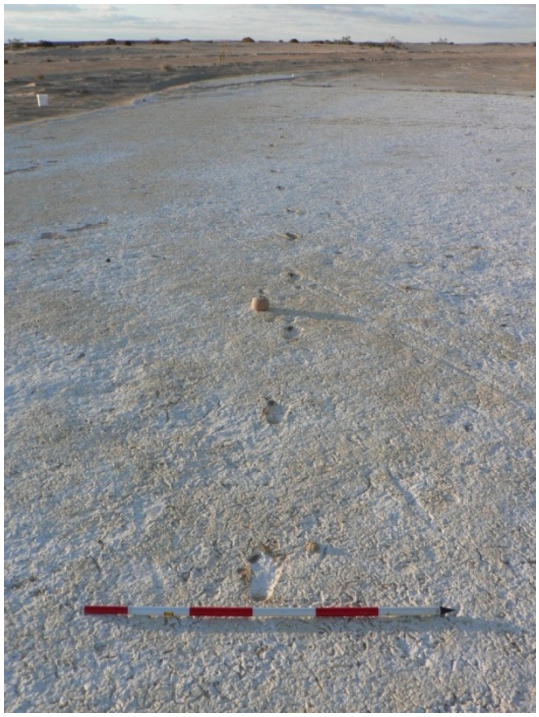
Magnesite, ferromagnesite and hydromagnesite form by precipitation from water in which carbon dioxide has dissolved magnesium-bearing minerals. Such underlying geology has not previously been documented in the Willandra Lakes and magnesitic evaporites have not been reported elsewhere in the region.



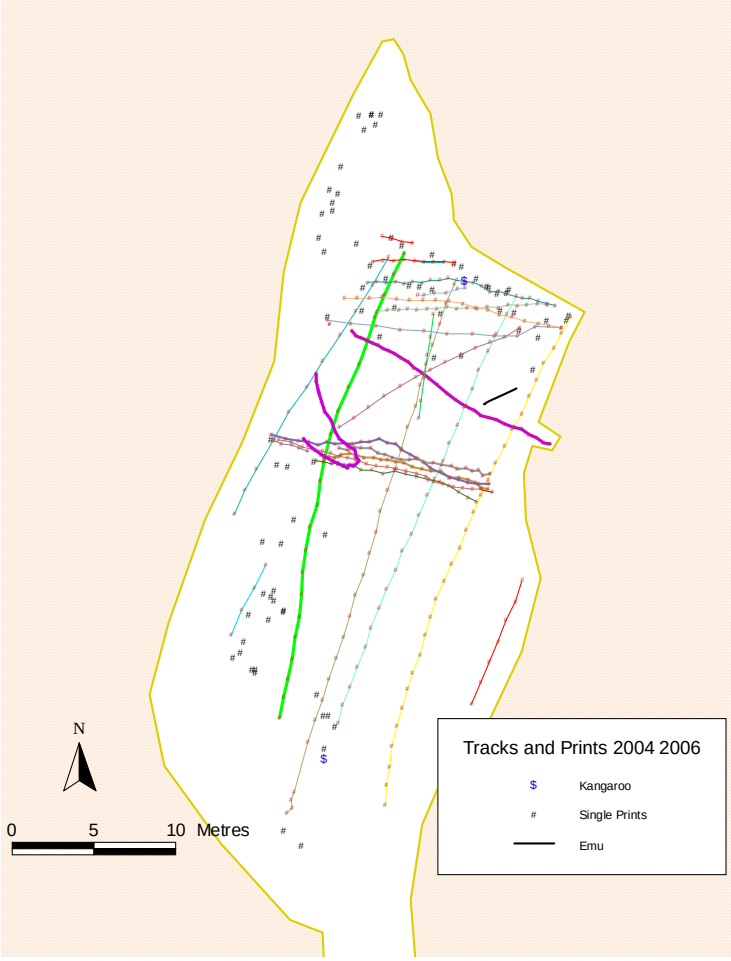
In order to assess the extent of the hardpan beneath the adjacent dune, a GPR survey was commissioned. The survey used 1.5 GHz, 900 MHz and 2200 MHz ground-coupled radar antennae, proving resolution of 0.5 m, 1.8 m and 7.4 m, respectively.



The superimposition of individual tracks at a number of locations indicates the complex sequence of the groups movement.



One legged man's track (Track 4). Right feet only are in this track.



Plan of Gl7 showing all human tracks and isolated prints, as well as kangaroo and emu prints.

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