Paper 2

Lake Gregory - Geomorphology and Palaeohydrology

J.M. Bowler
Museum of Victoria
328 Swanston Street
Melbourne, Victoria 3000

INTRODUCTION

The Lake Gregory system, lying on the northern side of the Australian arid region in the monsoonal summer rainfall zone, provides key sites for elaboration of environmental change. The Australian National University, in its program of semi-arid region studies and the elucidation of Australia's climatic history, sponsored its first expedition to the Gregory lakes in 1978. This was designed to study the geomorphology, to sample the lake sediments and to ascertain whether the lakes could be used to provide a detailed hydrologic history. In 1978 the lakes contained substantial amounts of water. Water samples and some sediments were returned for laboratory analyses; regional observations on the geomorphology and sand dune relationships were obtained.

A second expedition in 1979 visited the lakes under dry-lake conditions. Further field sampling was undertaken but it proved impossible to venture onto the floor of the main lake which had only recently dried, because of soft ground surface conditions unsuitable for vehicle transport. Coring and sediment sampling was therefore restricted to the margins of the basins.

Following the discovery of trace elements of economic interest a third brief visit was made in 1981 to report some findings of the earlier study to the Aboriginal community.

The Gregory lakes provide what is perhaps a unique example of human-land relationships in the anthropological history of Australia. They lie in an area in which the original occupants now have land rights and undertake commercial pastoral activities in the very heartland of their traditional country. Additionally, the water bodies obviously act as a central or focal point, not only in the whole ecology of the region, but also in the cultural and social organisation of the indigenous people. This was brought home to us rather startlingly during the first 1978 visit.

Having provided the Mulan community with a copy of a geomorphic map indicating some areas of interest to us, we requested permission to traverse specific areas. After satisfying the initial inquiries of the elders of the community, we then asked the community elders to identify those areas of special or sacred interest to which we should not travel or in which work was inhibited. At this point, one old man who had been sitting quietly through the early discussions, drew from behind his back a copy of the map we had provided and on it were already marked several areas where excavation activities were specifically forbidden. It was in one sense no surprise to find that the major area of exclusion was exactly the one in which, from the palaeohydrologic evidence, we would have predicted the presence of earlier human occupation, centred on a most favourable lake shore habitat.

As in southern Australia where the lunette dunes preserve the most detailed and exciting components of Aboriginal history, so too here in the modern community the area identified was precisely equivalent to the lunette accumulation zone, in this case on the north-western side of the lake. Named Yadjulano, this encompasses the transverse dune ridge at the point of entry of Sturt Creek into Leira (= Lera) Water-hole and extends to the shoreline on the western side of Malan Lake opposite Pelican Point (Fig. 2.1). We have here an example of continuity of cultural relationships between lakes and lake-shore features. In southern Australia lake-shore occupational evidence extends back some 40 000 years; here in the Gregory lakes apparently similar occupational memory continues to be major social concern of the community to the present day.

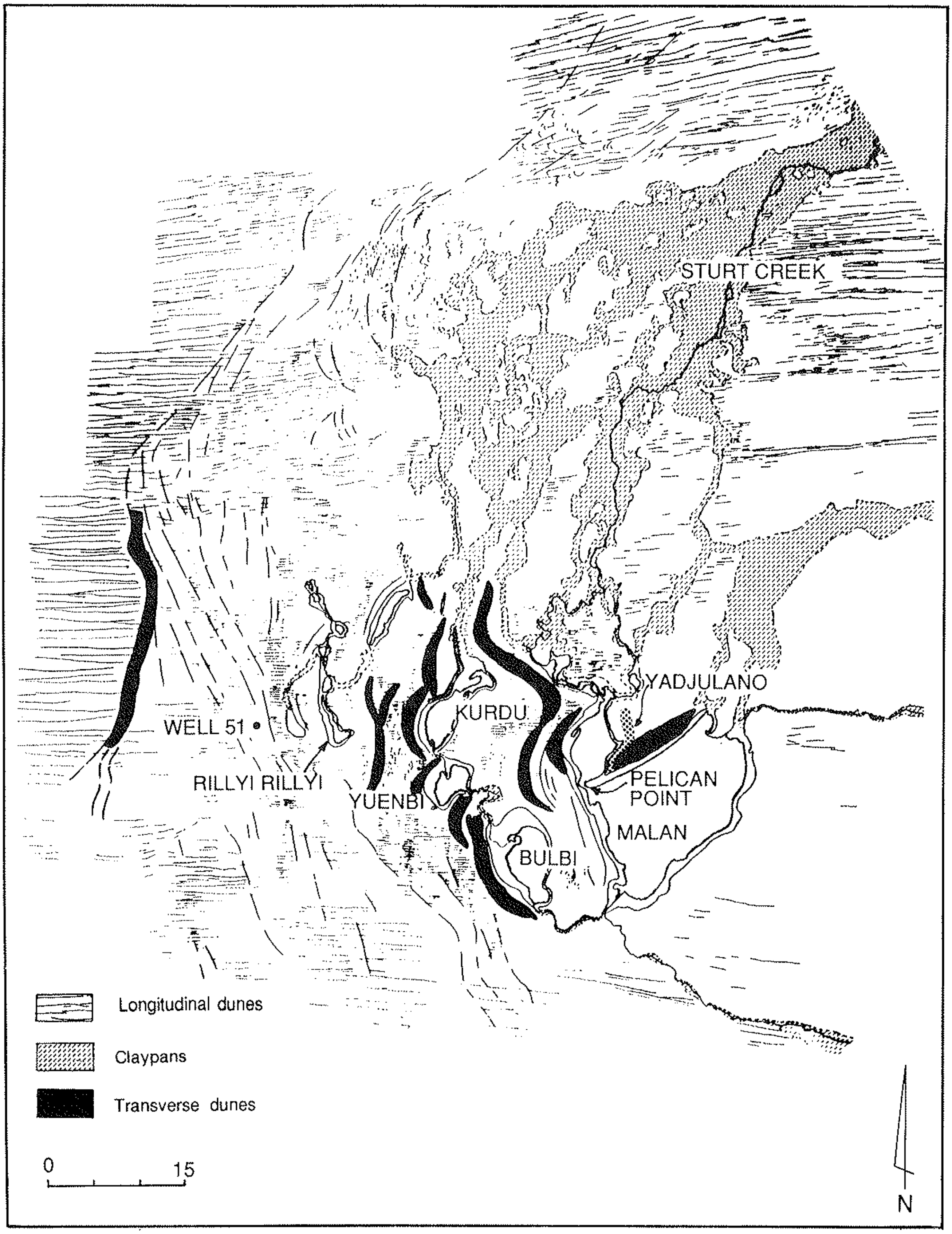

Figure 2.1

Geomorphic map of the Gregory lakes system showing the anastomosing streams of Sturt Creek feeding the interconnected chain of lakes. The lakes set within the east to west regional dune fields of the Great Sandy Desert possess north-south transverse ridges on their western (downwind) side. On the far west of Rillyi Rillyi a north-south ridge represents the western shoreline of a mega-lake, an ancestral phase of the modern Gregory system.

Given the tropical setting and key location the Gregory lakes, in terms of our understanding of Australia's palaeoclimatic history and ethnographic human landscape relationships, represent a unique environment worthy of detailed examination.

GEOMORPHIC SETTING

Sturt Creek, which arises on the eastern margin of the Kimberley, represents one of the few major streams in Australia which terminate within the desert in a relatively freshwater drainage system. This provides a context in which freshwater sits in juxtaposition with arid-land communities of animals and plants. It is a special setting in which waterbirds particularly, and other components of desert ecology, have almost continuous access to fresh water.

The Sturt drainage clearly represents a remnant of a more ancient palaeo-drainage system that once drained through the west of what is today the Great Sandy Desert. Termination or truncation of that drainage was almost certainly due to the development of aridity and blocking by sand dune development. Although the age of such trunk disruption is not identified in northern Australia, by comparison with evidence from southern Australia, such events probably occurred within the last 500 000 years.

LAND UNITS

The Gregory area may be divided into a number of land units characterised by the controlling processes and developed landforms -

(1) *Sturt Creek*

Sturt Creek flows as a single or relatively confined channel in a north-south direction past Halls Creek until, south of Halls Creek, it breaks up into an anastomosing distributory system with a myriad of small channels branching out in a finger-like distributory pattern to feed into the lakes.

(2) *The Lake Gregory Chain*

The Gregory lakes consist of a series of shallow, interconnected basins fed by two main distributories of Sturt Creek. On the western side, the chain of lakes includes Rillyi Rillyi on the far west and three interconnected basins (Kurdu[1], Yuenbi and Bulbi) in the centre (Fig. 2.1).

The eastern arm of Sturt Creek discharges through Leira Water-hole past the Pelican Point peninsula into the main basin (Malan or Barrago). The basin floors are at a slightly different level allowing the lake waters to decant during the evaporative stage with the consequence that salts are transported towards the south into the deepest part of the system which is found in the eastern Malan Lake. Thus, the chemical, sedimentary and landform characteristics affected by salt concentration are, in turn, very different from one basin to the next. This is borne out in the chemical analyses described later.

Lac-Aeolian Units

As in southern Australia, the lake basins have distinctive aeolian transverse ridges developed on the downwind (the western or north-western) margin. In Malan Lake the large ridge near Yadjulano forms a most characteristic feature. On the western side of Bulbi, Yuenbi and Kurdu, equivalent transverse ridges occur (Fig. 2.1). However, unlike the transverse ridges or lunettes in southern Australia which are often clay-rich or gypseous, those in the Gregory area are dominantly composed of quartz sand suggesting an association with full lake rather than dry phases.

In addition to the shoreline ridges which at times define considerably expanded basins, an outer ridge some 25 km west of Rillyi Rillyi defines what is almost certainly the western margin of a greatly expanded, mega-lake phase in the early history of the Gregory basins. The Canning Stock Route running south-west from Well 51 crosses this ridge which in turn provides an important separation in the dune system. Between the outer transverse ridge and Rillyi Rillyi a number of north-south subdued transverse ridges almost certainly represent contractional phases of the mega-lake towards the present smaller basins.

Aeolian-longitudinal dunes

The basins are set within the general framework of the longitudinal dune systems of the Great Sandy Desert. However, in proximity to the lake two distinct longitudinal dune systems are evident.

Beyond the western transverse ridge the high and wide strong red-brown east-west dunes, typical of the Great Sandy Desert, extend westwards towards the Indian Ocean.

On the inner margin of the transverse ridge, in proximity to the basins, a quite different longitudinal dune system has developed. While the east to east-west orientation is identical to that of the larger

1 See Table 2.1 for reconciliation with names used in other papers.

regional dunes the system is composed of dunes which are much smaller in length, lower in amplitude and much more closely spaced. In addition they often possess small, transverse connecting links providing a type of chain armour pattern on aerial photographs.

These clearly relate to a younger development showing a much lower degree of organisation and soil development in terms of their rubefaction. The dunes are much paler in colour than the regional strong red dunes.

AREA RELATIONSHIPS

The areas of the individual basins as defined from their most prominent shorelines are listed in Table 2.1. This amounts to a total of 387 km^2 for the area subject to more frequent flooding.

By comparison the area of the mega-lake defined from the location and orientation of the outer strand line covered in excess of 5000 km^2, more than 15 times the total water surface of the inner basins

Table 2.1

Areas of the Gregory basins measured from the most prominent and therefore the most frequently occupied shoreline levels. Note the total area, approximately 400 km^2, is small by comparison with the ancestral or mega-lake which, measured on the basis of the outer strandline morphology, was more than 12 times the size of the present water bodies. The age of the mega-lake can be estimated only approximately from current data as being more than about 40 000 years BP.

LAKE GREGORY

Main water bodies	*Area (km^2)*
Malan (= Mulan)	267
Bulbi	44
Yeunbi (= Yuinby)	15
Kurdu (= Guda)	30
Rillyi Rillyi (= Rilya)	11
Gillung (= Delivery Camp)	13
Other	7
	387
Outer strand lines	5492

LAKE-AEOLIAN RELATIONSHIPS

In addition to the transverse dunes on the western side of the basins evidence occurs of longitudinal dune encroachment over the lake floors especially in the south-eastern side of Malan Lake. Figure 2.2a shows in diagrammatic form the relationships between east to west longitudinal dunes of the inner system encroaching onto the south-eastern margin of the lake. Evidence of high water levels or strand line deposits can be found along the dune corridor indicating that after the westward advance of those dunes significant periods of high lake levels have in turn encroached upon the dunes themselves.

A cross-section through the dunes south of the lake shown diagrammatically in Figure 2.2b reveals the presence of lacustrine shells extending well beyond the margin of the present basin and underlying the longitudinal dune system. A strongly developed red calcareous soil formed on those lake sediments passes in horizontal fashion below the longitudinal dunes indicating a significant period of pedogenesis between the contraction of the outer lake and the much later development of the inner longitudinal dune system.

Radiocarbon dates from the shells and associated soil carbonate indicate deposition beyond 30 000 before present (BP). Although direct dating is not available for the longitudinal dunes, by comparison with events elsewhere in Australia, we assume an age close to 18 000 BP, which was the period of the last glacial maximum aridity. This needs to be tested by further detailed study.

LACUSTRINE FAUNA

A list of the lacustrine fauna identified during the 1978 visit is provided in Table 2.2. During August 1978 very extensive algal deposits, including possible samples of *Chara* sp. and *Cladophora* sp., formed thick green aquatic growths in the shallow waters (up to 1 m deep) along the shores of Malan Lake. Hosts of ostracods and other aquatic animals were visible in the waters at that time.

Table 2.2

List of fauna from Lake Gregory collected mainly from near Leira Water-hole and the northern margin of Malan Lake in August 1978.

MOLLUSCA

Sermyla sp.	*Corbiculina* sp.
Ameranna sp.	*Velesunio wilsonii*
Plotiopsis sp.	*Helicorbis* sp.
Lymnae sp.	?*Pettancylus* sp.

Identified originally by Leon Barmutta

OSTRACODA - abundant

ALGAE

Chara sp. - abundant
Cladophora sp. - possibly present

CHEMICAL ANALYSES

The chemical analyses listed in Table 2.3 reflect the great variety in evolution of the various waters in the basins. This is largely a reflection of the differing decanting histories as the waters at various stages of evaporation are decanted from one basin to the next. Note the extremely high pH of Malan Lake - up to 11 in 1978. This was associated with the very high algal productivity in the lake.

In the sediments of Malan Lake, traces of trona - a hydrous sodium carbonate - which is a mineral rarely found in Australia, are consistent with a high pH. The mineral, of considerable economic significance as a flux in aluminium smelting, occurred only in minute quantities of no economic value. Its presence is significant as an indicator of the geochemical evolution of the waters. Of additional interest are the very high silica values in the 1978 records. Note also the high carbonate in the Malan 1978 algal depositional phase.

Silica values remain consistently high by comparison with lakes elsewhere in Australia. The occurrence at Yuenbi of silica to 33 ppm almost certainly is associated with the development of authogenic silica (clay) minerals. The turbidity of that water was extremely high (it looked rather like milk) strongly suggesting the presence of colloidal amorphous silicate minerals.

HYDROLOGIC CONTROLS

The Gregory lakes differ from most salt lakes in central and southern Australia in that they do not preserve a salt crust at the surface on drying. This is almost certainly a reflection of the regional and local groundwater relationships. The evidence suggests that the regional groundwater levels lie below the lake floor in such a way as to permit the lakes on drying to lose salts to the groundwater whereas in most other parts of Australia these basins become groundwater discharge systems. In this context, the Gregory basins are almost certainly groundwater recharge systems. The relationships between the lake water and the local and regional groundwater require further elaboration.

Table 2.3

Chemical analyses from the Gregory lake system determined from water samples collected in August 1978 and September 1981. Note that the main basin, alternatively named Gregory, Malan or Barago, contains the largest water volume and at times of drying as in 1978 evolves to a chemical composition substantially different from that of other Australian salt lakes. Results are in ppm.

	pH	TDS	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	$CO3^{2-}$	$HCO3^{-}$	$SO4^{2-}$	CL^{-}	SiO2
AUGUST 1978											
Sturt Creek (Gilwah)	7.33	1710	54.0	37.3	484	29.2	nil	122	260	718	3.9
Malan	11.04	10790	52.0	153	3620	286	31	156	650	5800	2.0
Yeunbi	7.98	n/d	(49.1)	(6.1)	159	31.7	nil	180	(55)	138	(33)
Bulbi	7.30	24170	920	222	7610	288	nil	165	2530	12320	6.9
SEPTEMBER 1981											
Sturt Creek (Gilwah)	9.06	1300	67.0	9.5	344	26.6	5	44	160	560	5.0
Leira	9.38	1400	62.5	9.7	396	31.1	7	35	157	634	4.5
Pelican Point	8.35	2100	74.6	34.8	612	51.6	tr	120	220	1000	5.0
Malan	8.41	2200	87.7	24.2	658	55.6	tr	118	247	1038	5.0

In terms of maximum depths in the absence of detailed topographic levels we estimate from the shoreline position of Malan Lake that the most frequently occupied level would provide a lake of approximately 3-4 m deep in the centre.

In a survey from Rillyi Rillyi west to the transverse dune ridge, beach gravels were identified lying some 10 m above lacustrine shelly carbonates close to Well 51 (Fig. 2.1). Thus the depth of the mega-lake must have been in excess of 10 m. Additional data now available from seismic surveys should permit refinement and more accurate estimates of lake beach and lake depth levels. A summary diagram may be prepared on the basis of the evidence currently available to indicate the pattern of hydrologic change which has led to the evolution of the present lake system. Additional dating is required to refine this pattern and thereby permit accurate correlations with other sequences in Australia and elsewhere in the world. In this context the Gregory lakes provide a unique environment for palaeohydrologic studies.

ACKNOWLEDGEMENTS

This work could not have been undertaken without the closest cooperation with the Mulan Aboriginal Community under the leadership of Mr Rex Johns. Many Aboriginal elders and colleagues assisted in the fieldwork and provided essential and basic information at every level of that operation. The fieldwork was facilitated by the generosity and hospitality of the Community at Balgo Mission to whom our great debt is acknowledged.

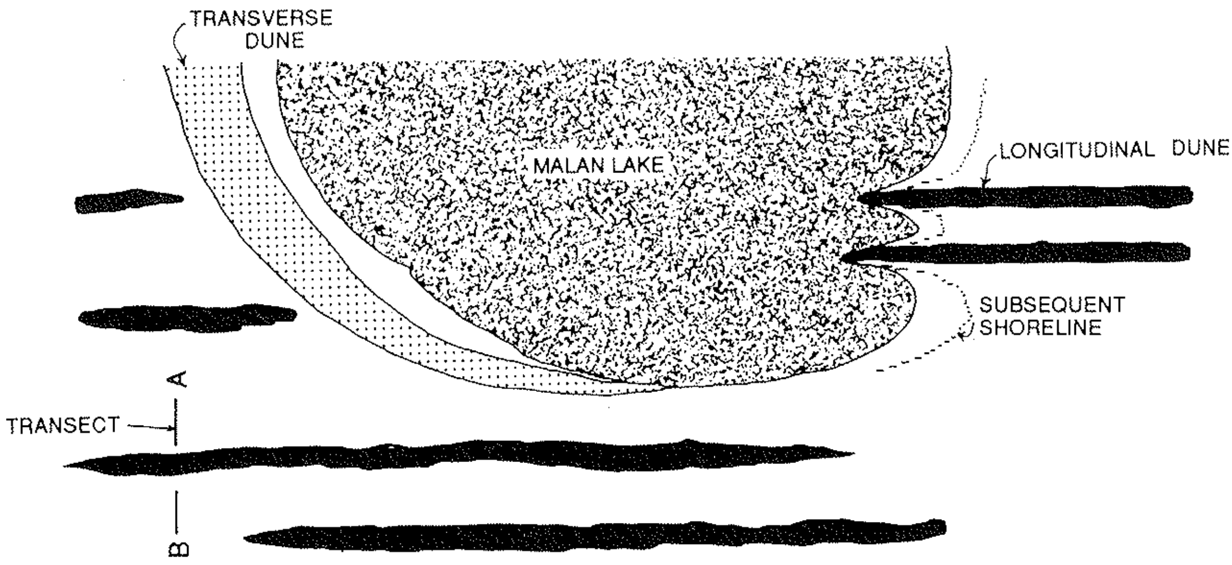

Figure 2.2a
Diagramatic relationships between the lake features such as those in the Malan basin, the transverse (western) lake-shore dune, and the west to east longitudinal dunes which on the south-eastern corner of the Malan Lake have transgressed across the lake floor. A later shoreline (dotted curve) has developed with inundation down the swales of the longitudinal dunes. This type of relationship allows us to establish a relative evolutionary sequence in which lake activity was followed by a drying phase when the east to west dunes transgressed across the dry lake floor; this was in turn followed by a return of water to the lakes with flooding of the earlier dune system.

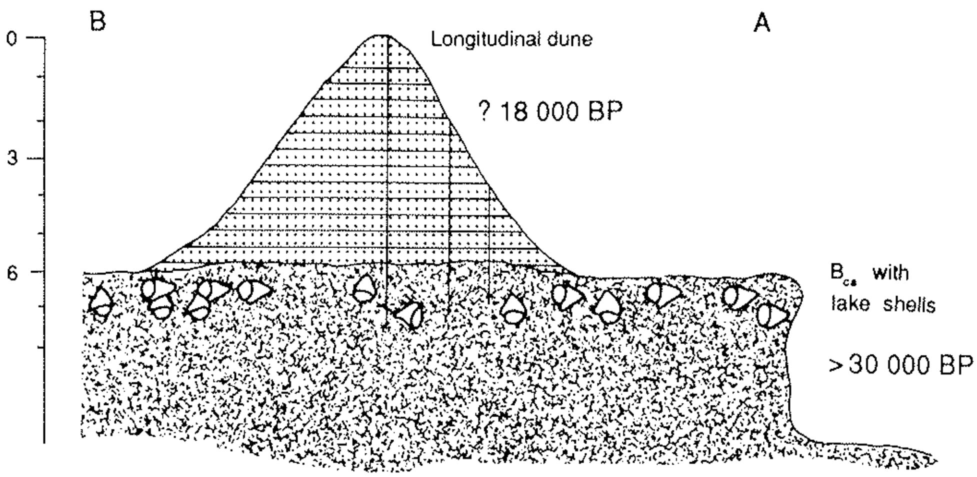

Figure 2.2b
A diagramatic north-south cross-section through a longitudinal dune (see Fig. 2.2a). The dunes have developed on a series of older lake deposits in which limnaeid shells are now cemented into a red calcareous soil. The soil horizon passes horizontally beneath the longitudinal dune emphasising that a substantial time period separates deposition of the lake sediments followed by soil formation and later dune building. By analogy with other areas, the longitudinal dunes are tentatively correlated with the last glacial maximum about 18 000 BP. Radiocarbon dates from the underlying carbonate and shell deposits establish the age of soil and lake sediments as being 30 000 BP.