Australian-New Zealand Geomorphology Group, Second Conference
Barrier Range Field Excursion Notes, 11 July 1984

by R.J. Wasson

The Barrier Range is a low set of hills which stand at most only a few hundred metres above the sedimentary plains to the south, east and west. The western, southeastern and part of the northeastern borders of the Range are fault-controlled, and the dominant Cainozoic movements have been vertical. The southern Range is underlain by high grade metamorphic rocks of the Precambrian Willyama Complex, and these rocks lie beneath Precambrian (Adelaidean) sedimentary rocks in the northern part of the Range.

The excursion will travel first across the area of lowest relief in the southern Barrier Range (Fig. 1), then cross the western faulted margin (Mundi Mundi Scarp), traverse the alluvial fans on the western side of the Range (Mundi Mundi Plain), cross another fault scarp (Kantappa Lineament) and enter the northern Range near Corona Station. From here to Yanco Glen the route lies within the Adelaidean rocks and then re-enters the low-relief terrain of the Willyama Complex.

Fault-cut pediments

Broken Hill to Umberumberka Reservoir

The road to Silverton is largely within the catchment of Umberumberka Creek in the southern Barrier Range. Here the bedrock is the Willyama Complex consisting of high grade metamorphic rocks, subordinate igneous intrusions and rich sulphide mineralization. The Willyama Metamorphism is dated to about 1700 m.y. (Hobbs et alia 1968) while a retrograde metamorphism occurred in local shear zones about 500 m.y. ago. The main rock types are sillimanite gneiss, andalusite schist, chiastolite schist, mica schist, amphibolite, granite gneiss, granite and pegmatite.

Transverse drainage

The fine-grained regolith in Umberumberka catchment is largely confined to the valley bottoms and footslopes. The regolith consists of shallow loamy and clay-rich soils which are stony near outcrops and on mid-slopes, overlying deeply weathered rocks. Chartres (1982a, b; 1983) has shown that clay mantles on slopes at Fowlers Gap, 110km to the north of Broken Hill, are at least partially of aeolian origin. Comparable material has been found both to the east and west of the Barrier Range so it is highly likely that there is a significant aeolian component in the soils of the Umberumberka catchment.

At the time of European settlement, in the 1850's, hillslopes carried mulga (Acacia aneura) scrub but this was largely cleared in the 19th century, except on the steep country to the northwest. On steep, rocky country there is a very open cover of acacias, shrubs and herbs. On non-rocky lower slopes and alluvial flats there is up to 50% cover of chenopod shrubs and herbs, particularly in wet years. River red gums (Eucalyptus camaldulenies) line the main stream channels. Most of the vegetation has been extensively altered by grazing and mine-related activities since the second half of the 19th century.

Umberumberka Reservoir

The catchment upstream of this water body is about $420km^2$ receiving an average annual rainfall of about 220mm. The average annual pan evaporation at the Dam is 2270mm.

Sediment has been trapped in the reservoir since it was completed in 1915 (Wasson and Galloway, 1984). Comparison of contour plans and cross-sections surveyed at various times shows that by 1982 the original capacity of the reservoir $(1.3 \times 10^7 m^3)$ had been reduced by sedimentation to $6 \times 10^6 m^3$. For comparability, erosion rates are calculated as average lowering of the regolith of the whole catchment in mm/thousand years (see Table 1). The rate of sedimentation, and therefore sediment transport by Umberumberka Creek, was 3 times higher between 1915 and 1941 than thereafter.

Very rapid erosion since 1850 is ascribable to grazing, rabbits, clearing and mining. Much of the sediment eroded during the 19th century may have been stored temporally on footslopes and alluvial flats. Despite lags such as these, there has clearly been a remarkable decline in the amount of material reaching the reservoir since the early 1940's. Better management is thought to have reduced both the area affected by erosion and its intensity from about the 1940's. Records of the NSW Soil Conservation Servce testify to extensive erosion by water and wind during the 1930's and 1940's with very few references to serious problems in later years. However, sheep numbers fell dramatically about the turn of the century some 40 years before sedimentation rates fell. The lag between erosion and deposition in the reservoir could be an explanation but it seems that climate is involved. Rainfall during the period 1915 to 1945 was lower in the Broken Hill district than afterwards. At Stephens Creek reservoir, just to the east of Broken Hill, a decline in sedimentation rate from the 1940's has been detected. At 4 other reservoirs in NSW, S.A. and Victoria the same pattern emerges: higher rainfall is accompanied by reduced sedimentation rates since the 1940's.

Umberumberka Fan

Umberumberka Dam is near the edge of the Mundi Mundi Scarp and to the west is the Mundi Mundi Plain. The plain consists of coalescing alluvial fans of low angle extending up to 20km to the west. Beyond this point an alluvial plain extends to the sump of the Frome Embayment, the salina of Lake Frome.

The stratigraphy of the Mundi Mundi alluvial fans (Wasson, 1979), when combined with sedimentation rates calculated for Umberumberka reservoir, allows comparison of erosion rates from Umberumberka catchment for periods both before and after European settlement.

Well-defined stratigraphic units in Umberumberka fan have been identified in creek banks and auger holes and some of the sediments have been dated by carbon-14. Similar sequences of sediments are exposed in valley floor fills upstream and are believed to be of the same age although, unfortunately, no dateable material was found.

The stratigraphic units are as follows:

1. Mundi Mundi sediments

Mundi Mundi sediments consist of the bedload of braided channels and slurry flows. They are generally 1-2m thick and occupy 80% of the area of Umberumberka fan. Older sedimentary units are exposed beyond their feather edge so their extent can be determined. They accumulated between 6000 and 3000 B.P. According to calculations by Nanninga and Wasson (in press) the volume of this unit is $9.95 \times 10^7 m^3$.

2. Fan entrenchment

Shortly after 3000 B.P. Umberumberka Creek cut a trench into its fan. The depth of the trench decreases from a few m at the head of the fan to virtually zero at the toe 14km to the west and its original volume was $4 \times 10^5 m^3$. It was certainly completed before 830 B.P. Presumably alluvium in the catchment upstream was also incised at this time.

3. Floodout

A small floodout was deposited at the toe of the main Umberumberka fan. It must have included material derived from the entrenchment and so is partly contemporaneous with the latter. It consists mainly of fine-texture material and its volume is about $1 \times 10^6 m^3$. During the early stages of its development, before the fan entrenchment was very deep, it is quite likely that a thin blanket of sediment was spread over the lower part of the main Umberumberka fan. Such a blanket with an average thickness of 10cm and covering 20% of the fan would have had a volume of $4 \times 10^6 m^3$ but would be too thin to detect now. Anything substantially thicker would probably be detected and so this estimated volume is regarded as an upper limit. The floodout would continue to receive sediment until the dam was completed in 1915 and cut off the supply.

4. Thackaringa sediments

A low terrace of sand and gravel formed within the fan trench 500-830 years ago. Presumably the finer fraction was carried further and contributed to the floodout. The volume of the low terrace is about $1 \times 10^5 m^3$.

5. Slight incision

Shortly after 500 B.P. the stream began to incise once more to form the modern channel which is mainly sand and gravel.

Erosion rates (Table 1) were high over the period 6000-3000 B.P. but very low in the succeeding interval 3000 B.P. to 1850 A.D. during which channel incision occurred. Recent research summarized by CLIMANZ (1983) indicates that warm and wet conditions in southeastern Australia were present by 8000 B.P. and continued until 4000 B.P. whereupon drier conditions set in until c.1000 B.P. Then rainfall increased slightly to its present level. Erosion was therefore high during both a wet phase and the transition to the following dry phase when erosion was minimal. The

Thackaringa sediments were deposited during a subsequent slightly wetter phase. Thus the major controls of erosion and sedimentation prior to European impact were climatic. However, there is an apparent difference between climatic controls operating in the Holocene (a wet climate increases erosion and vice versa) and those operating since 1915 when an increase in rainfall led to a decrease in erosion rate.

TABLE 1

Period	Sediments	Erosion Rate (mm/1000 yr)
6000-3000 B.P.	Mundi Mundi sediments	83
3000 B.P. - 1850 A.D.	Half the floodout, Thackaringa sediments, possibly thin blanket on lower Umberumberka fan	0.5 - 4.0
1850 - 1982 A.D.	Young channel sediments, half the floodout, reservoir sediments	232
1850 - 1915 A.D.	Young channel sediments, half the floodout	251
1915 - 1941 A.D.	Pre - 1941 reservoir sediments	290
1942 - 1982 A.D.	Post - 1941 reservoir sediments	109

Mundi Mundi Scarp

From Umberumberka Fan to the Kantappa Lineament (Figure 1) the road traverses coalescing alluvial fans, the apices of which lie at the base of the Mundi Mundi Scarp. The Scarp is almost linear separating the Barrier Range to its east from the Tarkarooloo Basin to its west. Most geologists working in the Broken Hill area accept a fault origin for the Scarp but offer differing interpretations of its type. For example, a monocline in the south and a thrust in the north; a semi-scissor type with the hinge in the south; a normal fault with declining rock strength to the south.

The evidence for the Scarp being fault-controlled is as follows:

1. The abrupt and almost linear plan shape of the Scarp.

2. A hole drilled 3.75km west of the Scarp at a point 5.5km southwest of Umberumberka Dam encountered 177m of Cainozoic sediment before reaching pyroxenite in the Willyama Complex.

3. The Scarp conforms to a major lineament orientation in adjacent areas of S.A., Vic. and N.S.W.

4. The Scarp's orientation can be traced in a linear to the north of the Willyama Complex across the Adelaidean sedimentary rocks north of Wilangee station (Figure 1).

5. Small dissected pediment remnants are preserved along the base of the Scarps. They are rarely greater than 25 x $10^4 m^2$, stand up to 5m above adjacent fan surfaces, are cliffed at their downslope edges, and are incised by streams issuing from the Scarp.

6. Pediment remnants often lie at the mouths of valleys which display well developed nickpoints. Levelling within these valleys has shown that the pediment remnants lie at heights (above the streams) that are roughly the same as the heights of the nickpoints.

7. Above the nickpoints the valleys are broad and also display some valley-in-valley morphology.

In summary, the evidence supports fault-control with valley-in-valley morphology recording an early period of movement of sufficient antiquity for stream junctions to become accordant. The latest movement is recorded in the dissected pediment remnants, nickpoints and discordant stream junctions downstream of the nickpoints. The latest period of significant movement in the Flinders Ranges, on the other side of the Tarkarooloo Basin, was Pliocene. Perhaps this is when the Mundi Mundi Scarp last moved.

The Kantappa Lineament

The Lineament originates in the Barrier Range and extends onto the Mundi Mundi Plain separating poorly outcropping laminated shales and glacigenic conglomerates of Adelaidean (Precambrian) age to the east from Quaternary alluvium and aeolian deposits to the west. In some areas the lineament is expressed as a small steep rise to the east of up to 8m. A gravity survey carried out by the NSW Geological Survey (Paul et al., n.d.) indicated that the lineament represents the western edge of a small block fault of about 50m throw.

To Corona Station and Yanco Glen

From the Kantappa Lineament to Mt Woowoolahra Station the road crosses outcrops of Adelaidean sedimentary rocks that overlie the Willyama Complex and form the northern Barrier Range. Patches of silicified sandstone and shale (called 'silcrete' by some) occur in this area. About 3km west of Mt Woowoolahra homestead is a body of granite exposed in Willowurrawa Creek. Overlying the granite is a sequence of conglomerates (? tillites) containing granite boulders and (?) varved sediments belonging to the Adelaidean series.

Approximately 17km east of Mt Woowoolahra homestead the road passes into the northern Barrier Range. From Corona Station homestead southwards for about 15km the road lies close to the Corona Fault which separates Willyama Complex rocks to the east from Adelaidean rocks to the west. The block of Willyama rocks to the west forms the Euriowie Inlier which is a large basement dome trending north-northwest. The Corona Fault has acted vertically to bring the basement Willyama Complex up against the younger Adelaidean sediments. The inlier is an expression of the dominantly vertical tectonism of the region. The carbonates and fine-grained sediments of the Adelaidean have been folded and have undergone décollement and flowage in some areas. The Adelaidean rocks were largely derived from the Willyama Complex as the latter rose vertically.

The latest probably vertical movements on the Mundi Mundi Fault and Kantappa Lineament are expressions of a very long history of vertical tectonics in the Barrier Range.

At altogether a different scale, further evidence of rapid soil erosion around the turn of the century is provided by a dam on Corona station. The Wool Scour Dam has a catchment of only $15km^2$ (in the Willyama Complex rocks) so that there would have been little or no lag between initial erosion and deposition in the reservoir. $1.2 \times 10^5 m^3$ of sediment accumulated behind this dam during the 20 years before it burst in about 1906, implying a mean soil erosion rate of c.400mm/1000 yrs. This is the highest rate recorded so far in the Range (cf. Table 1).

From a little south of the turnoff to Poolamacca Station homestead the road traverses mantles of red-brown clays lying on Adelaidean rocks. These clays are similar to those described by Chartres (1982a, b; 1983) at Fowlers Gap, some 50km north northeast of Poolamacca. The clays are thought to be of aeolian origin, blown as silt-size pellets during more arid conditions. Pedogenesis has obscured some of the original sedimentary character of these clay mantles while processes of downslope movement, swelling, runoff and runon have produced microtopography and chenopod 'groves' forming patterned ground.

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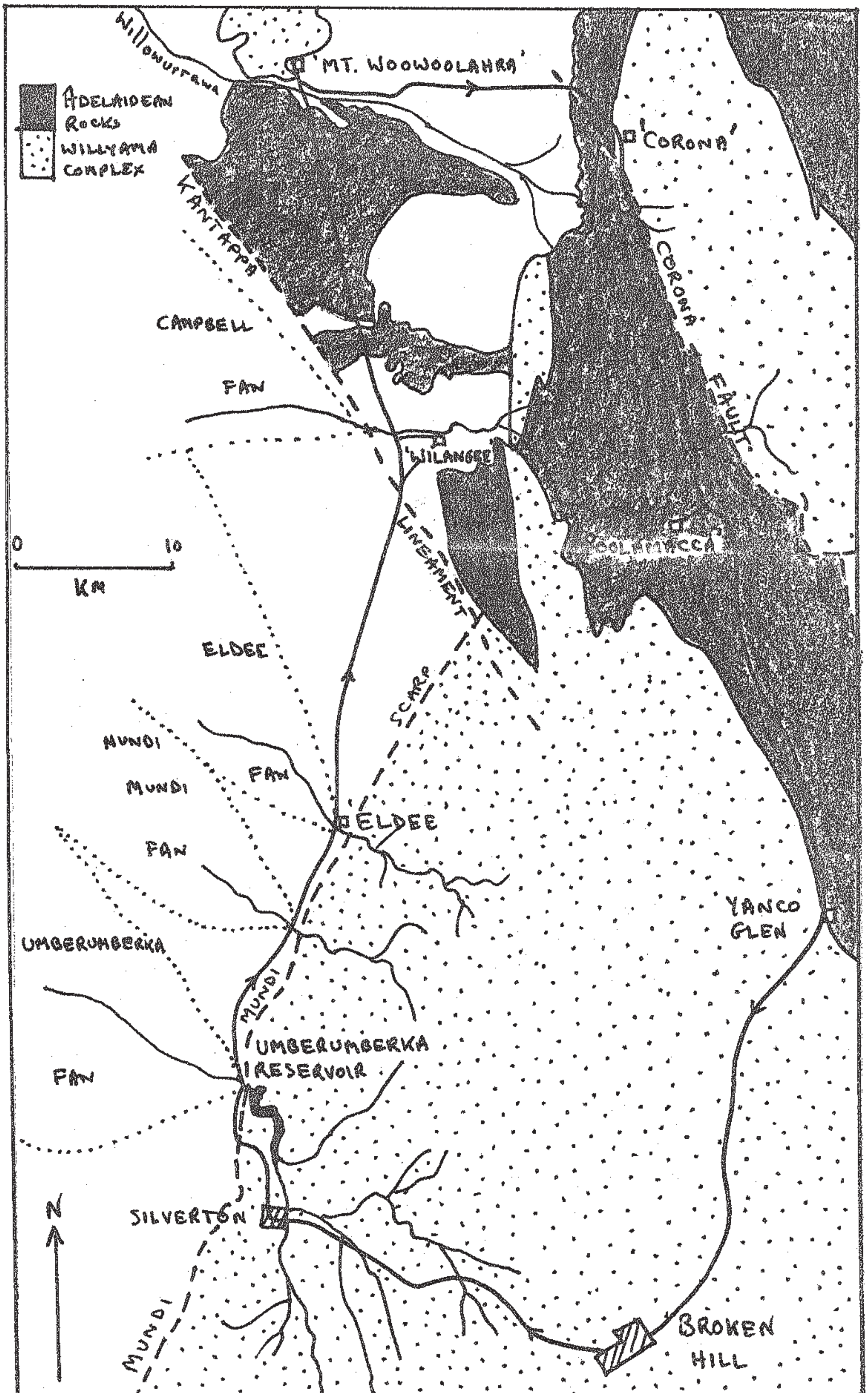
FIG. 1


ADELAIDEAN ROCKS
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AUSTRALIAN - NEW ZEALAND GEOMORPHOLOGY GROUP, 2nd CONFERENCE
POST - CONFERENCE EXCURSION NOTES, STRZELECKI DUNEFIELD

by R.J. Wasson

Broken Hill to Tibooburra (Fig.1).

Between Broken Hill and Tibooburra the route begins by crossing the Barrier Range, with which you will be reasonably familiar after the one-day excursion. At Fowlers Gap Research Station (operated by the University of NSW), some 110 km north of Broken Hill, we will examine a clay rich slope mantle of almost certain aeolian origin. A large research effort is expended at the Research Station, ranging from arid zone hydrology, geomorphology and geology to animal husbandry. Unfortunately, we will not have time to visit the Station.

From Fowlers Gap the view to the east is across the Bancannia Trough, a Mesozoic sedimentary basin with topographic expression maintained by marginal normal faulting. Lake Bancannia and Nucha Lake are two large salt lakes in the Bancannia Trough. The lakes lie near the centre of the basin with alluvial fans upwind and lunettes and longitudinal dunes downwind. This is an arid zone basinal landform assemblage in the 'classical' mould but, as you will see, is atypical of much of the area that you will traverse.

From the 'settlement' of Packsaddle the road crosses many kilometres of alluvium with small areas of low longitudinal dunes with a N50°E orientation. These dunes form the eastern-most part of the 'red dunes' of the Strzelecki Dunefield, stretching from here almost to Lake Frome.

The vegetation on these dunes has been altered from its natural state. Shrub invasion has occurred and has been ascribed to grazing in the first instance and, by some, to a change in fire regime since European settlement.

About 60 km north of Packsaddle the road passes between two lakes. To the west Gnurntah (or Cobham) Lake and to the east The Salt Lake. The road lies on a lunette derived from Gnurntah Lake, and downwind of the lunette longitudinal dunes extend towards The Salt Lake. This arrangement of dunes, i.e. longitudinals extending from transverse features, is common and we will see it often in the Strzelecki Dunefield.

Carbonate from a calcareous palaeosol developed near the top of the Gnurntah Lunette gave an apparent ^{14}C age of c. 12,000 (R. Gillespie, pers.comm). This is almost certainly a minimum age for both the palaeosol and the lunette.

By the time Peak Hill station is reached (the homestead is to the west with a mesa bluff just to the east of the road) the road has entered the "Tibooburra Dome'. This structure is oriented NNE-WSW with Precambrian low-grade metamorphic rocks cropping out in the central part and Cretaceous and Palaeogene rocks forming residuals along both eastern and western flanks. Closure seems to occur to the north. The Precambrian rocks are broadly equivalent to the Willyama Complex and form the easternmost outcrop of the Australian Shield or Craton. Rocks of the Tasman Geosyncline lie a little to the east of Tibooburra. Granite near Tibooburra has a K/Ar age of 399 m.y. and intrudes the Precambrian rocks.

The Cretaceous marine sequence overlies the Precambrian but post-Cretaceous faulting has brought the low-grade metamorphics and marine sediments into lateral contact in a number of places. The Cretaceous Rolling Downs Group is overlain by quartzose sands of the Palaeogene Eyre Formation, cropping out on mesas on the flanks of the Dome. Silicification of the Eyre Formation has produced 'silcrete' over large areas.

At 'Peak Hill' there is an outcrop of silcrete forming the caprock to the mesa with Eyre Formation overlying Rolling Downs Group. At Milparinka, silicified wood is common in lag gravels derived from the Eyre Formation. About 20 km north of Milparinka the road passes the southern end of the Warratta Fault Scarp, a distinctive topographic feature with an estimated throw of 240 m. Both Precambrian and Cretaceous rocks occur to the west of the fault and Cainozoic sediments overlying Cretaceous rocks form the pediment to the east. For the remainder of the journey to Tibooburra, mesas and other residuals are visible 10-15 km to the east. Silcrete is well developed on these residuals, particularly at Mt. Stuart.

The upwarping of the Tibooburra Dome clearly post-dates the Palaeogene and probably was coeval with the Early Oligocene to Early Miocene deformation that produced broad anticlines and synclines in northeastern S.A. and southwestern Qld. (Wopfner, 1974; Wasson, 1983a). The Mid-Miocene Etadunna Formation has never been reported in the Tibooburra area, its absence providing a minimum age for the folding.

The silicification of the Eyre Formation (and Rolling Downs Group to a lesser extent) also predates the folding as there is sympathetic dip of silcrete and Eyre Formation rocks. The origin of the Tibooburra silcrete is a matter of considerable debate but, in summary, two arguments are advanced. Firstly, the silcrete is produced near the ground surface by epigene (pedogenic) processes involving essentially vertical fluctuations of the water table. Secondly, the silcrete is produced in the subsurface by precipitation of silica from laterally-directed groundwater flow. The resolution of this argument is vitally important to the geomorphology of the region because in the first case the silcrete is a reasonably good indicator of a former ground surface while in the latter an unknown thickness of overburden has been eroded.

How is the planation of the Tibooburra Dome being accomplished? While in many instances scarps do not retreat (Twidale, 1983), the mesas around Tibooburra do seem to be suffering backwearing. Short pediments occur at the base of Richter-denudation slopes. The pediments are cut in the Cretaceous argillaceous rocks and are covered by often bouldery silcrete gibber. Away from the pediments the surface is undulating with streams cut into a silcrete gibber surface. If scarp retreat was entirely responsible for planation in this area then the country between the residuals should consist of multiple concave surfaces joining at low but pointed crests. The rolling topography, however, implies modification of the concave slopes so that pedimentation, stream incision and downwearing all play a part in the planation. The antagonism between various ideas of planation (encapsulated in the terms peneplanation and pediplanation) is not warranted in the Tibooburra area (cf. Twidale, 1983).

Tibooburra to Moomba

The first 40 km is across rolling gibber plains and intervening alluvial tracts in the unroofed part of the Tibooburra Dome. A little northwest of Gum Hole Tank we cross a 'jump-up' (or breakaway) of silcrete, one of the low dissected residuals forming the western edge of the Dome. About 2 km west of the 'Waka' and 'Binerah Downs' road junction the drainage is westward and the road lies on the eastern-most edge of the Tarkarooloo Basin. From here to Lake Frome and Strzelecki Creek the surface is one of low relief and gentle declivity.

On the track to 'Waka' homestead, longitudinal dunes of the quartzose red variety begin to appear and gradually the road enters the Strzelecki Dunefield. Between Frome Lake (not Lake Frome) on our path and Lake Pinnaroo (near 'Fort Grey' homestead, also on our path) a section in the upwind end of a dune provides the first dated stratigraphic site (See Fig. 2).

At 'Fort Grey' begins a cross-section of the red dunes of the Strzelecki. During a search for patterns in dune geometry and granulometry, Robert Hyde (Earth Sciences, Macquarie U.) and I measured a number of variables along the road to 'Merty Merty' homestead and beyond for some 40 km to the west of Strzelecki Creek. Every fifth dune was examined, a cross-profile surveyed, a crestal sample taken and the average spacing determined from aerial photographs of the dunes to either side of that surveyed and sampled.

The variables derived were:

H - maximum dune height measured above the swale to the east
D - horizontal distance from base of dune on eastern side to crest
D/H an index of dune shape or 'peakedness'.
D_o - distance from 'Fort Grey' homestead.
S - average dune spacing
M_z - graphic mean grain size of crestal sand
Q_i - inclusive graphic standard deviation of crestal sand.

For the samples from 'Fort Grey' to 'Merty Merty' (T1 on Fig.2) all variables could be approximated by a normal distribution at the 90% confidence level. Trends across the dunefield were looked for by carrying out linear regression between D_o and each of the other variables. Using the significance criterion of $r^2 > 0.5$, the only significant trend is between D/H and D_o. That is, dunes become steeper further west, a trend that is independent of all other variables. The traverse is approximately at right-angles to the gradient of mean annual rainfall, so dunes become steeper as rainfall decreases. Certainly the proportion of bare sand on the dunes increases to the west, presumably indicating more mobility. So we might conclude that the more mobile dunes in the drier area can more often sustain slipfaces and resist slopewash and so are generally steeper under present conditions. In addition, internal stratification of what is thought to be Late Holocene additions to the dunes show low-angle bedding near 'Fort Grey'. It appears that the dunes on the wetter end of the traverse have never been very steep, probably because vegetation has been a significant modulator of sand transport at least during the Holocene.

At the eastern end of the traverse, crestal dune sands are red-brown (dominant hue is 2.5 YR) becoming dominantly 5 YR until the Strzelecki Creek is reached at D_o = 130 km (Fig.3).

This traverse (T1) lies across the eastern side of former lake Dieri (cf. Loffler and Sullivan, 1979; Wasson, 1983a). It is envisaged that a lake of Mid-Miocene age occupied this area, including most of the area of the Strzelecki Dunefield, leaving behind the dolomites of the Namba and Etadunna Formations. Pans between the dunes along T1 are often aligned across the dunes, giving the impression of shorelines. The aligned pans preserve no evidence of lacustrine conditions, the sediments of which have been reworked both by wind and water. Deformation of the former basin of L. Dieri is reflected in the fall from 120 m (AHD) near 'Fort Grey' to 40 m at 'Merty Merty'.

The explorer Captain Charles Sturt set up a stockade near the southern end of Telegraph Swamp (about 10 km west of 'Fort Grey' homestead), which he called the Park, in August 1845. On 14th August Sturt and some of his party set out for the centre of the continent, leaving the Park and travelling N45°W (mag.). He was sufficiently unimpressed by the country that we shall traverse on T1 for him to have made few comments, other than to note the succession of dunes and intervening flats, that spinifex generally covered the sand ridges in an area

80 km north-west of the Park, and that piles of ironstone and quartz pebbles occurred on some of the flats (Sturt, 1849). The vegetation on the red dunes has been altered from that of Sturt's time by grazing. Shrub invasion has occurred and rabbits have caused considerable change.

At Strzelecki Creek we pass from the palimpsest landscape of red quartzone dunes overlying the much altered bed of L. Dieri to the pale (dominantly 7.5 YR/6) dunes of the Cooper Creek flood basin. The traverse T1 was extended west of the Creek (T2). Trends of the previously listed variables were not discerned on T2.

Comparing T1 and T2, for those variables that are normally distributed, only height is significantly different using a t-test. That is, dunes on T2 are higher than on T1. Using the Mann-Whitney u-test, crestal M_z is finer on T2 than on T1. Therefore, T1 and T2 have different populations of H and M_z.

The colour difference between dunes on T1 and T2 is the result of thinner grain coatings on T2 and greater iron content on T1 (Wasson 1983b).

Charles Sturt reached Strzelecki Creek (named after Count Paul Strzelecki, the Polish explorer of southeastern Australia) at 28°3'S latitude, a point about 60 km upstream from where we will first see it. Having left the red dunes he rode across quite different country west of the creek.

"The plains had almost the character of lagoons, since it was evident they were sometimes inundated, from the water mark on the sand hills, by which they were partly separated from one another". Further on Sturt noted: "The plain we next rode across was evidently subject to floods in many parts; the soil was a mixture of sand and clay. There was a good deal of grass here and there upon it, and box trees stunted in their growth were scattered very sparingly round about; but the country was otherwise denuded of timber" (Sturt, 1849, p.358).

Sturt was describing the broad sandy loam flats that separate groups of dunes in the area between Strzelecki Creek and Cooper Creek. On our route from 'Merty Merty' homestead to Moomba Camp the area of these flats gradually increases as the influence of the Cooper becomes more pervasive. The water marks on the sand hills were last seen in 1975 after the largest recorded inundation by the Cooper in the summer of 1974/75. During this flood all of the flats that we will cross on the way to Moomba were flooded and sediment was deposited at least near Moomba.

The dunes in this 'flood basin' are arranged in groups, with a transverse dune at the upwind end of each group of longitudinals. This arrangement was noted at Gnurntah Lake on the way to Tibooburra, and is common throughout the Australian dunefields. The groups become less distinct as distance from Strzelecki and Cooper Creeks increases.

Sturt was searching for an inland sea so when he encountered the many channels of Cooper Creek and its distributaries and waterholes, he was fascinated by the source of the water.

"The whole country indeed over which we had passed from the first creek, was without doubt very low, and must sometimes be almost entirely under water, but what, it may be asked, causes such inundation? (Sturt, 1849, p.362).

Sturt's party was in good condition by comparison with the remnants of the Burke and Wills expedition some 15 years later. Having crossed the continent, only to discover that their companions had left Cooper Creek, Burke and Wills went down the Cooper in search of a route to the south to reach the non-existant settlers near Mt. Hopeless. From a point somewhere north of Moomba, William John Wills (1863) reconnoitred to the south describing "earthy plains" between the sand hills "apparently clothed with chrysanthemums" (p.281). From a dune he described the scene on Sunday 5th May 1861:

"This dreary prospect offering no encouragement to proceed, I returned to Camp 10 by a more direct and better route than I had come, passing over some good salt-bush land which borders on the billabongs to the westward" (p.281).

By the next day: "The present state of things is not calculated to raise our spirits much; the rations are rapidly diminishing; our clothing, especially the boots, are all going to pieces, and we have not the materials for repairing them properly; the camel is completely done up and can scarcely get along, although he has the best of feed and is resting half the time. I suppose this will end in our having to live like the blacks for a few months" (p.281). The real end was more tragic.

Sturt was the first European to offer an explanation of the dunefield. He observed that the orientation of the dunes swung from N6°E (mag.) near the Park to N18°W (mag.) to the north of the Diamantina River, and that they were often very long and straight.

"What, I will ask, was I to conclude from these facts? - that the winds had formed these remarkable accumulations of sand, as straight as an arrow lying on the ground without a break in them for more than ninety miles at a stretch, and which we had already followed up for hundreds of miles, that is to say across six degrees of latitude? No! winds may indeed have assisted in shaping their outlines, but I cannot think that these constituted the originating cause of their formation. They exhibit a regularity that water alone could have given, and to water, I believe, they plainly owe their first existence" (1849, p.381). He goes on to suggest that after uplift from the sea a current of water passed in a direction parallel with the sand hills. The gibber plain to the north of the Cooper flood basin, called now Sturt's Stony Desert, was formed in Sturt's view by the current in this area having greater force, either sweeping the ridges away or not allowing their formation.

It should be remembered that by the 1830's in Britain, the hotbed of geological thought at the time, James Hutton's 'Cyclic Theory of Earth-history' had been largely accepted (Davies, 1968). Implicit in Hutton's theory is that land is periodically created by uplift of the ocean floor, a notion to which Sturt turned. The precise nature of the Huttonian uplift was debated passionately by the catastrophists and uniformitarians. While the endogenetic processes were debated, so too were the exogenetic processes responsible for 'the denudation'. Favoured among several explanations of landforms in the mid nineteenth century were neo-diluvialism (i.e. post Noachian) and marine denudation. The neo-diluvial catastrophic floods offered an explanation of the shelly diluvium (now recognized as glacial drift) that occurs in Britain and Europe.

But without a clearer idea of Sturt's thoughts it is difficult to know if he was convinced by the proponents of the neo-diluvial or the marine denudation theories, or perhaps he had not read anything of the lively debate that raged in his native country and so his thoughts on the dunefield were his own. What is clear is that nobody in Britain had written about the origin of desert dunefields by the time Sturt made his startling discoveries.

By contrast with Sturt, Wills did not mention water in the formation of the dunes: "With regard to the hot winds, the direction of the sand-ridges would seem to indicate a prevalence of east and west winds here rather than of northerly" (1863, p.173).

Both water and wind have played key roles in the origin of the pale dunes west of Strzelecki Creek, for all of the dunes are rich in sand-size clay pellets that testify to deflation from the "earthy plains" that are themselves fed by Cooper Creek. The weighted sand-moving wind resultant at Moomba is oriented at few degrees east of the mean local dune direction, indicating that the strong winds from the southwest and sometimes south are the main forces in dune moulding under modern conditions.

Strzelecki Creek forms the boundary between dunes of different petrographic type: quartzose red-brown dunes and pale brown pellet-rich dunes. These two types occur in both the Strzelecki and Simpson dunefields (see Fig.6 in Wasson, 1983 a,b).

Dune Stratigraphy

Dune sands, both pelletal and quartzose, are separated by calcareous palaeosols of varying degrees of development and by sedimentary discontinuities. As many stratigraphic sites as possible will be visited during the excursion so only a brief summary follows.

In the pale sands, the earliest dune sand recognized so far has a well developed nodular calcareous palaeosol developed at the top, with carbonate segregated along bedding plains at depth. Clay pellets are common in this material but many show signs of destruction by wetting and drying, in the form of fusion. At Swallow Pit (Site 5 Fig.2; Fig.4) the apparent date of 20,000 B.P. is clearly a minimum age for both the palaeosol and the dune sand unit. At Lark Pit (Site 4 Fig.2; Fig.5) the same unit occurs with notional thermoluminescence dates of >80,000 B.P.

The best exposed unit in the area of pale dunes is of approximately Last Glacial Maximum age. At JSN (Site 7 Fig.2; Fig.6) the top of this unit has been dated at 13,000 B.P. while at M1 (Site 2 Fig.2; Fig.7) TL dates range from 20,000 to 12,000. The age of the base of the unit at M1 and at M3 (Site 3 Fig.2; Figs 8,9) is not clear from the dates available but is 20,000 B.P.

The Last Glacial unit is pelletal with well preserved clay pellet and weakly developed pedogenic carbonate nodules that give a ^{14}C age of c. 7,600 B.P. (Fig.8).

The next youngest unit is of mid to late Holocene age. At Dog Bite Lake (Site 10 Fig.2; Fig.10) ^{14}C dates on charcoal place the maximum age for this dune sand unit at 12,500 B.P., while TL dates place it within the last 5,000 years. At Della 5 (Site 9 Fig.2; Fig.11) ^{14}C dates of 2300 B.P. were determined for charcoal from the uppermost layers of the unit, consistent with a TL date of c. 1700 B.P. for the upper part of the unit at Dog Bite (Fig.10).

This mid to late Holocene unit is pelletal with excellently preserved fine-sand size pellets.

The present-day conditions seem to have been initiated within the last 800 years as indicated by ^{14}C dates from Carraweena (Site 8 Fig.2; Fig.12). Most dunes in the area of pale sands have mobile caps which sometimes extend onto the dune flanks (Figs.7, 8, 12), some of which post-date atomic weapons testing (Fig.7). The sands of this modern material include some pellets which are well rounded by contrast with the sub-rounded and sub-angular forms in the mid to late Holocene and Last Glacial units. The pellets in the youngest sands are interpreted as being reworked from the older units, so modern conditions of dune mobility are vastly different from these of only a few thousand years ago.

In the red-brown quartzose dunes fewer dates are available but a stratigraphy exists which is broadly similar to that in the pale dunes. At Merteree (Site 15 Fig.2; Fig.13) a mobile cap overlies a unit which elsewhere has been found to contain microliths of Late Holocene age (P.J. Hughes, pers.comm.). These sands in turn overlie an indurated dune sand in which a weak calcareous palaeosol occurs. Beneath this is much more strongly indurated sand in which the carbonate is much better developed. A ^{14}C date of 19,000 B.P. from the carbonate in what is believed to be an equivalent palaeosol at Dunjeroo (Site 13 Fig.2), while at Frome's Creek (Site 15 Fig.2) another date of c. 14,000 B.P. indicates that this entire unit is > 20,000 B.P. A sequence similar to that at Merteree is seen at the Bore Track (Site 14 Fig.2; Fig.14).

At Lake Merteree (as distinct from Merteree) (Site 11 Fig.2) a number of dunes lie along the boundary between the pale pelletal dunes and the red-brown quartzose dunes. At one site (Fig.15) the mixture of pelletal and quartzose units allows correlation between the dunes east and west of Strzelecki Creek. This correlation is shown in Fig.16.

ALLUVIAL STRATIGRAPHY

The planimetric relationships between meander scroll bars, of now-relict streams, and dunes provides a first step into the alluvial stratigraphy. In most cases the large scroll bars lie well within the 'earthy flats' between the groups of dunes but in others the dunes override the scroll bars. Where only downwind tips of dunes cross the bars than this extension is thought to be of Holocene age for the youngest meandering rivers are of Late Pleistocene age, as we will see later. Where the scroll bars disappear beneath the flanks of dunes at a point a long way upwind of the dune tip, than the scroll bars are probably quite old. Examples occur near Chillimookoo W.H. (Site 16 Fig.2; Fig.17) and near Cooyeeninna W.H. (Site 17 Fig.2; Fig.18).

A few kilometres north of Moomba Camp, at a site known as the Gidgealpa Palaeochannels, the scroll bars are not overrun by dunes and have been dated (Fig.19). The base of the sandy loam to sandy clay loam layer, that forms the upper 80 cm of the floodflat, has been dated at 12020$\pm$150 B.P. Below this layer is a complex set of sandy sediment in the old channel and point bars, grading laterally into sandy clay loam of the overbank facies. The narrow zone of scroll bars suggests that lateral migration was not an important process, and change of channel location was accomplished by avulsion.

At Dog Bite Lake (Site 10 Fig.2; Fig.10) the top of the floodflat veneer was dated to 12460$\pm$160 B.P., a date statistically identical with that for the base of a very similar veneer shown in Fig.19 . This is approximately the time that pelletal dunes of Last Glacial age ceased to accumulate. The source of the clay pellets in this dune unit must have been a mixed sand, silt and clay (loamy) deposit and the floodflat veneers seem to be the only likely candidate. So a major change around 12-13,000 B.P. is reflected in both the aeolian and alluvial stratigraphy.

It seems that widespread accumulation of the floodflat veneer ceased 12-13,000 B.P. and mixed to sandy loads were only carried by some channels (an example being the Gidgealpa Palaeochannels), while at Dog Bite Lake sandy alluvium was no longer deposited after 23,000 B.P. (Fig.10). From this chronology, and the sedimentology of both the floodflats and the dunes, it is concluded that the Last Glacial dune construction phase began 23,000 B.P. In some cases the equivalent of this dune unit has a quartzose base, so in such a case dune construction could have begun prior to 23,000 when sandy alluvium was available for deflation.

Earlier phases of meandering channels are recorded on the floodflats by scroll bars vanishing beneath the flanks of dunes well upwind from dune terminations (as noted above).

CORRELATIONS

The correlations of dune stratigraphy set out in Fig.16 are troubled by the differences in controls on dune formation in the pale pelletal (Moomba) dunes and the red-brown quartzose (Toolachee) dunes. The fall of the water-table that probably terminated pellet production c. 12,000 B.P. may not have been paralleled by climatic changes sufficient to stabilize the red-brown dunes. However, the correlation offered in the diagram is the most secure at the moment.

The correlation of the Cooper alluvial stratigraphy with other sequences (Fig.20) suffers principally from an inadequate radiocarbon control. Despite this, there are certain broad trends and similarities that can be discerned. The change from high sinuosity sand-rich channels prior to 20,000 B.P. in the Goulburn, Darling and Cooper, to low sinuosity mud-rich channels in the Holocene is remarkably consistent in catchments so climatically diverse. Moreover, with the available chronologies, the change from the earliest recorded channels to the Holocene passes through a transitional phase that occurs around the Last Glacial Maximum. There appear to be a number of fundamental changes recorded in these three big catchments, and we might pause to discuss their meaning while in the Strzelecki Desert.

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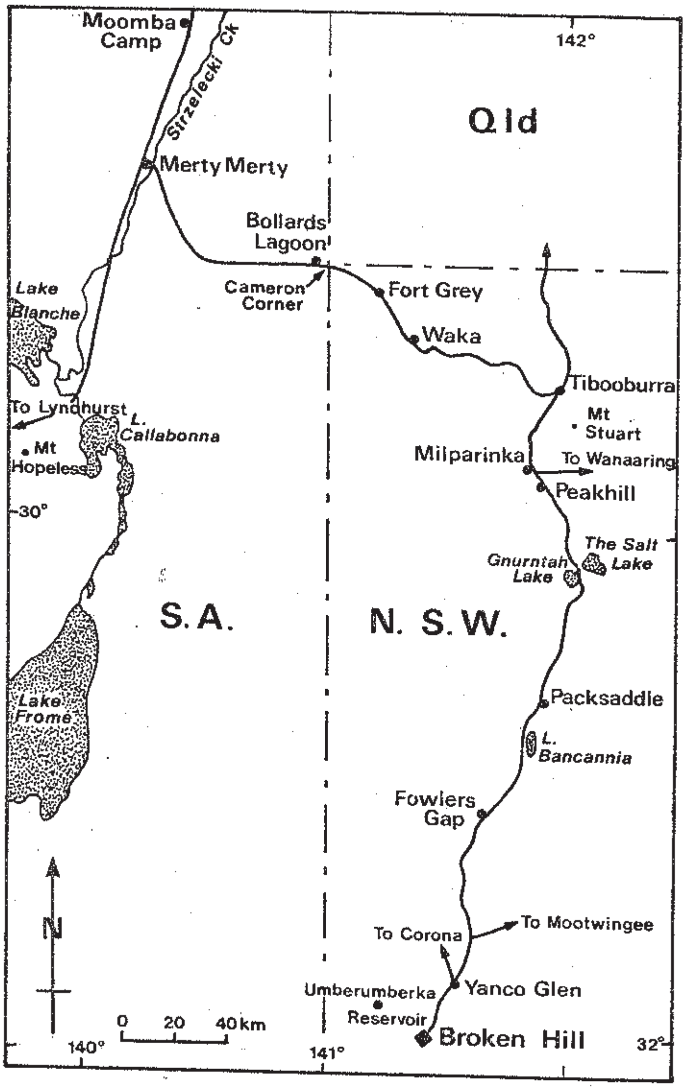


FIG. 1. Route map for the post-conference excursion.

FIG. 2. Northern Strzelecki Dunefield showing major landscape features, traverses T1 and T2, and stratigraphic sites as follows: 1, Moomba; 2, Moomba M1; 3, Moomba M3; 4, Lark Pit; 5, Swallow Pit; 6(a), Gidgealpa palaeochannels and 6(b), transverse dune; 7, JSN; 8, Carraweena; 9, Della 5; 10, Dog Bite Lake; 11, L. Merteree; 12, Merteree; 13, Dunjeroo waterhole; 14, Bore track site 1; 15, Frome's Ck.; 16, Chillimookoo waterhole; 17, Cooyeeninna waterhole; 18, Della 4; 19, Scrubby waterhole; 20, Maggot flats.

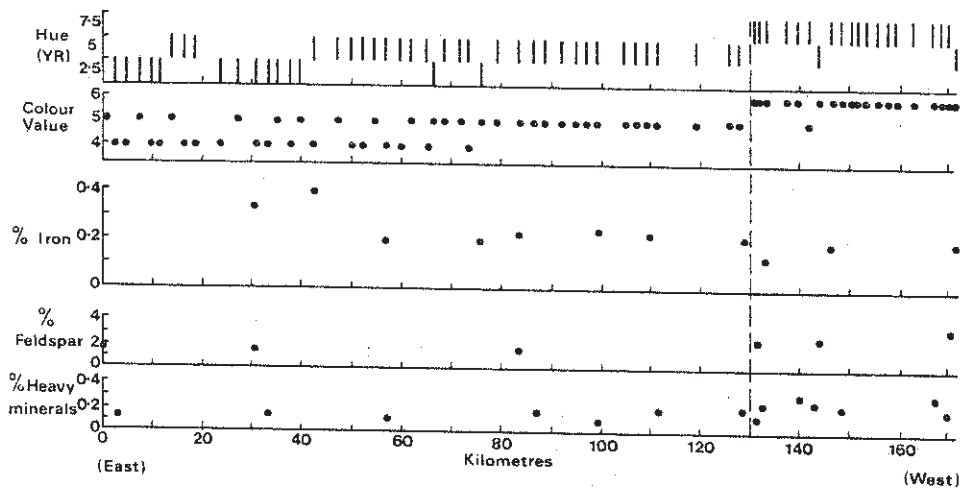


FIG. 3. Crestal sand colour, % Fe, % Feldspar and % Heavy Minerals on T1 (0–130 km) and T2 (130–172 km), Strzelecki Dunefield.

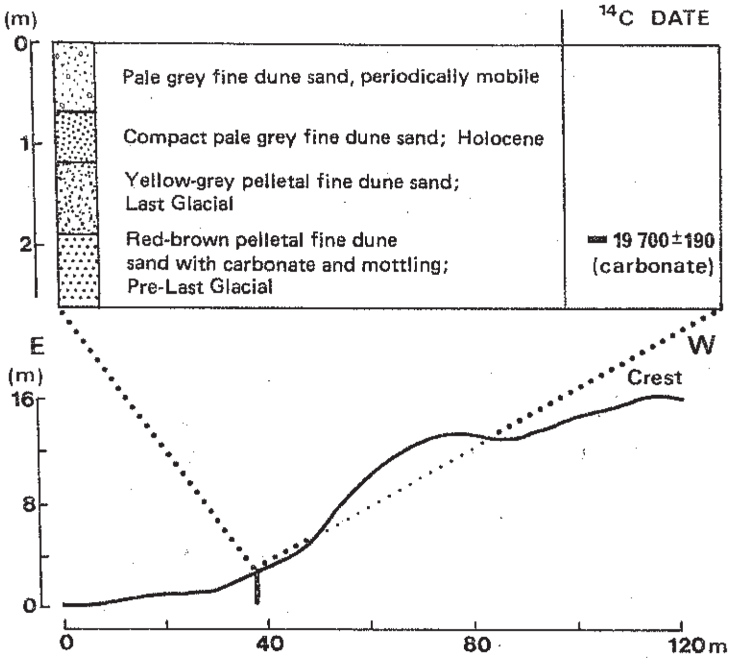


FIG. 4. Swallow Pit; strat. site 5.

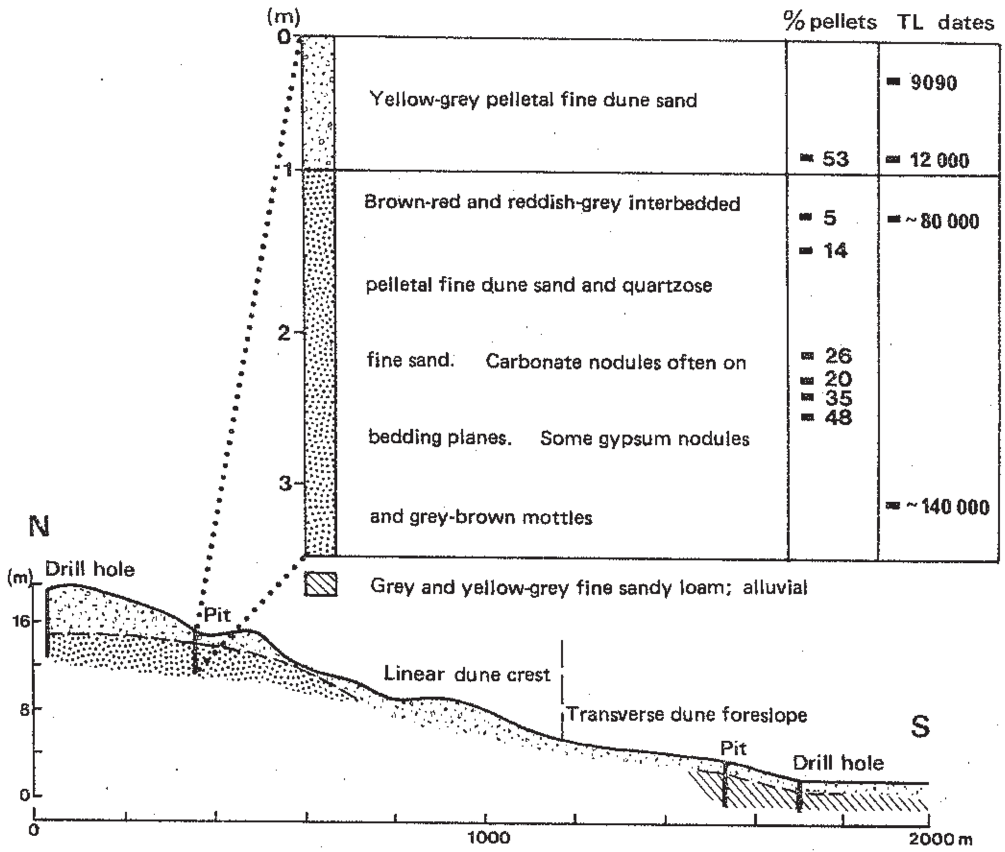
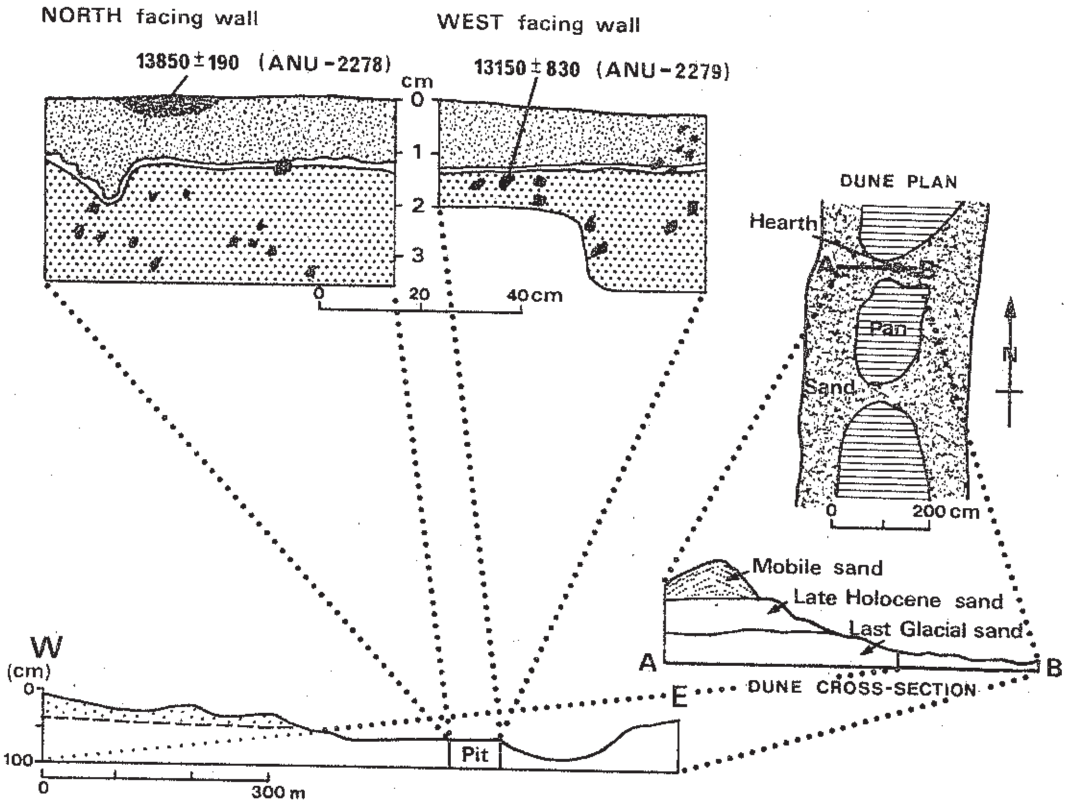


FIG. 5. Lark Pit; strat. site 4.



▨ Yellow-grey fine sand, sub-horizontal laminae, fissile, soft carbonate, charcoal, clay pellets; hearth containing burnt clay, fragments of mussel shell, diffuse organic matter, and charcoal

▭ Bleach developed in above

▨ Very tough, pale yellow-grey fine sand, small hard and soft carbonate nodules, large charcoal pieces, clay pellets

▨ Yellow-grey fine sand, low-angle laminae, no visible carbonate, no charcoal

FIG. 6. JSN; strat. site 4.

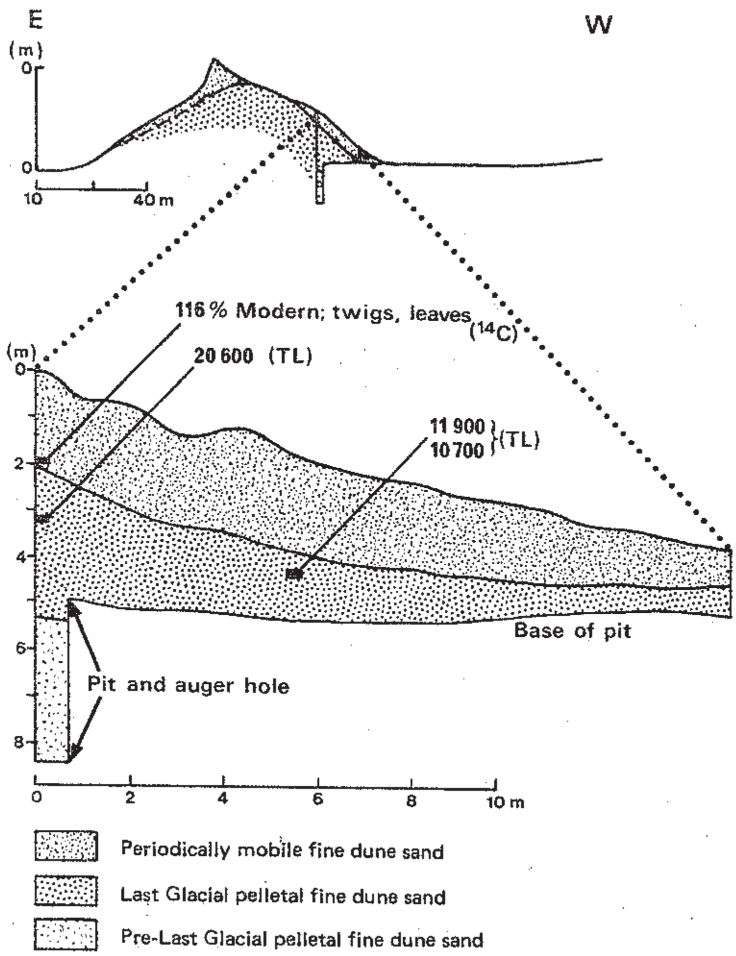


FIG. 7. Moomba M1; strat. site 2.

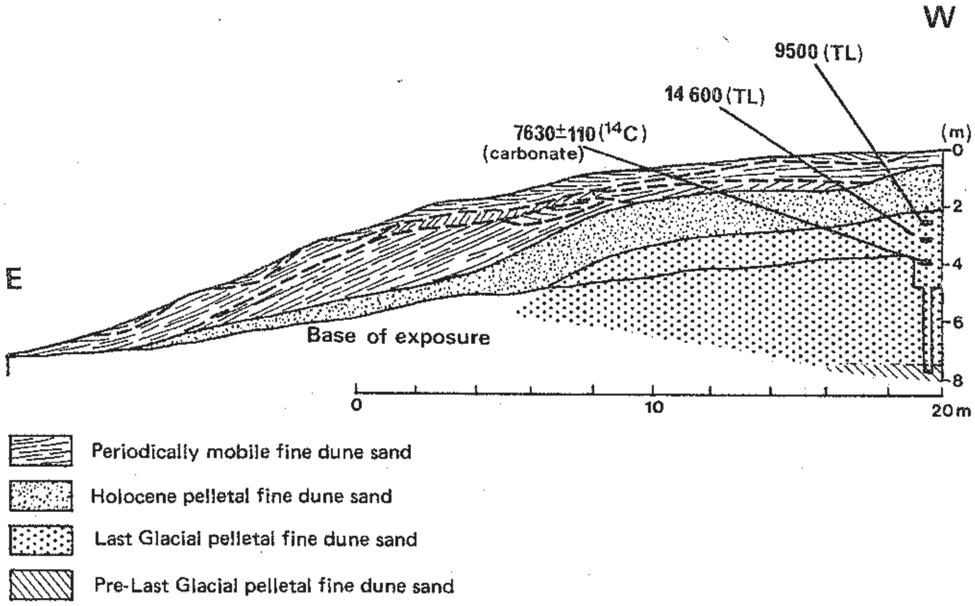


FIG. 8. Moomba M3; strat. site 3. Gully section on eastern dune flank.

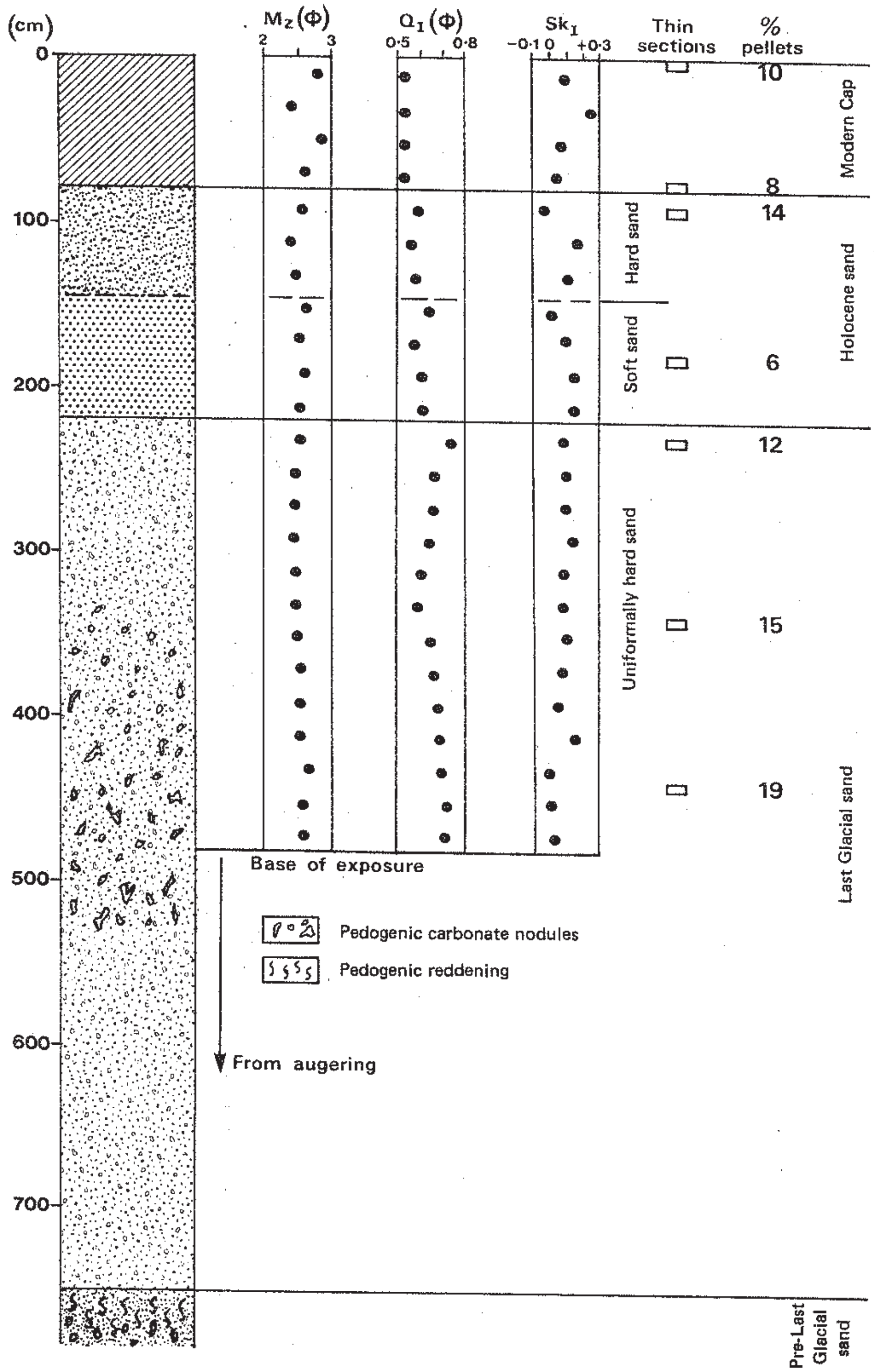


FIG. 9. Moomba M3; strat. site 3. Detail of westernmost part of Fig. 8.

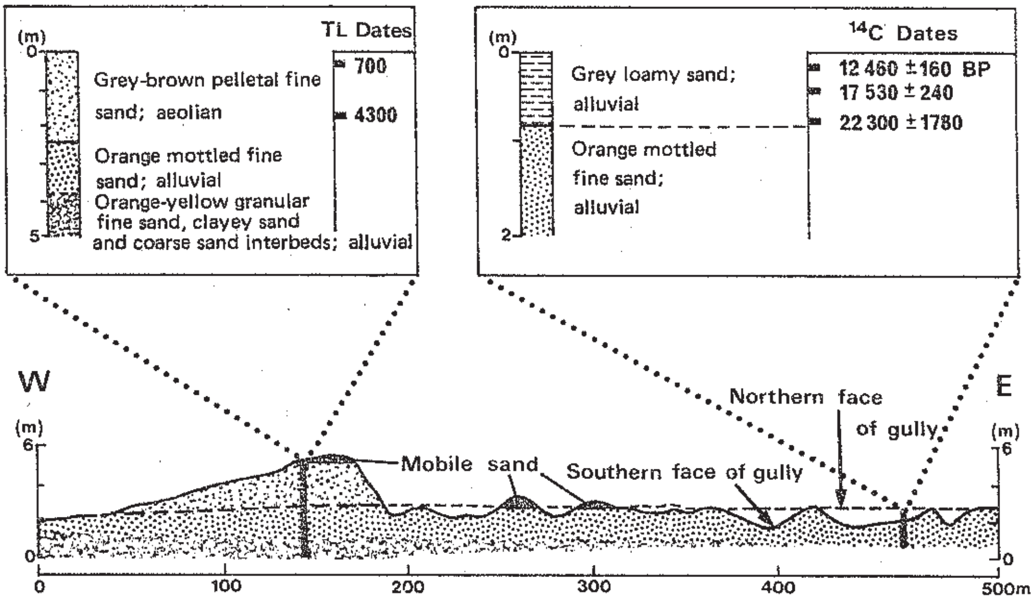
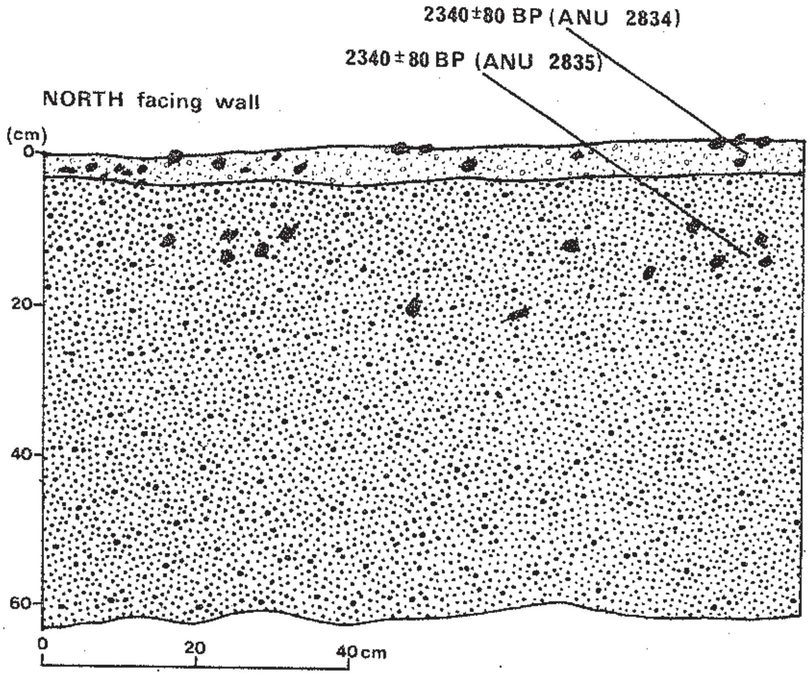


FIG. 10. Dog Bite Lake; strat. site 10.



Tough platy yellow-grey pelletal sediment of fine sand-size, vesicular in upper 0.5 cm; charcoal

Tough greyish-yellow pelletal sediments of fine sand-size, flecks of $CaCO_3$ and charcoal pieces, rude blocky structure

FIG. 11. Della 5; strat. site 9.

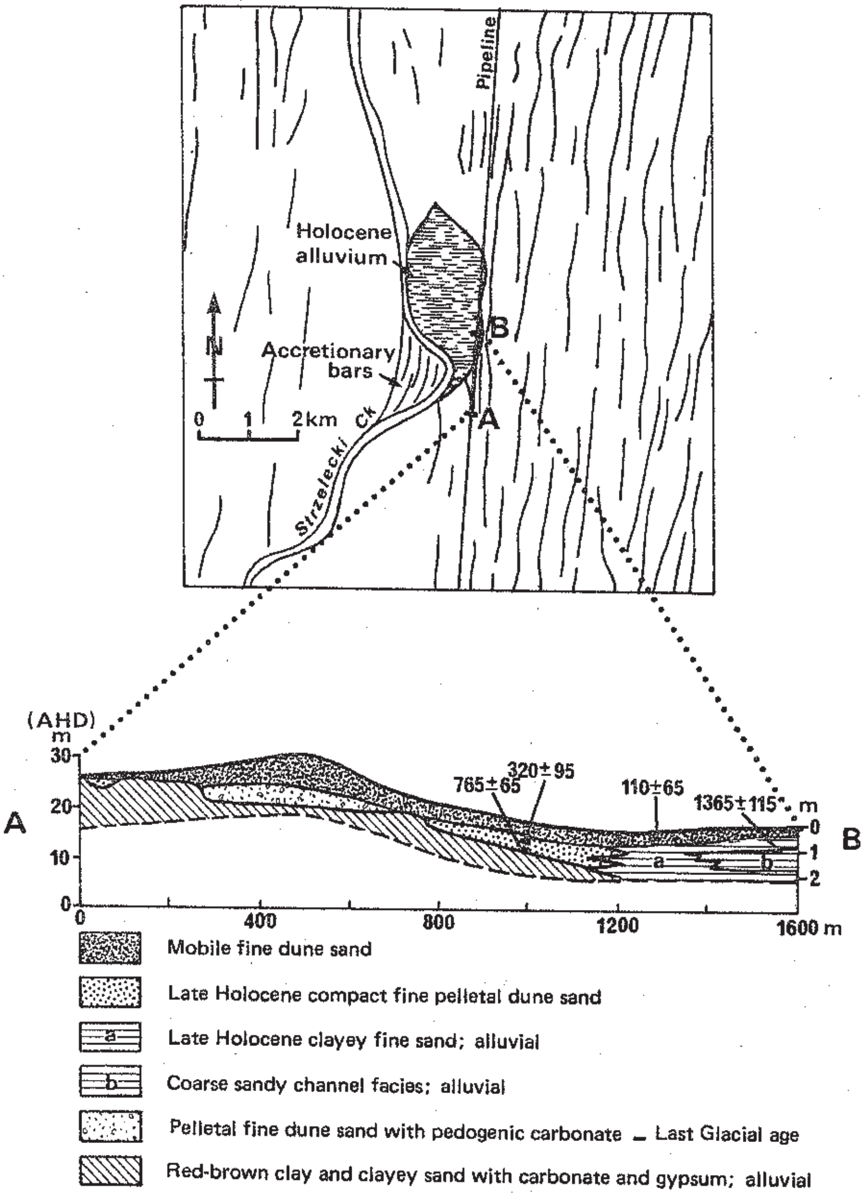


FIG. 12. Carraweena; strat. site 8.

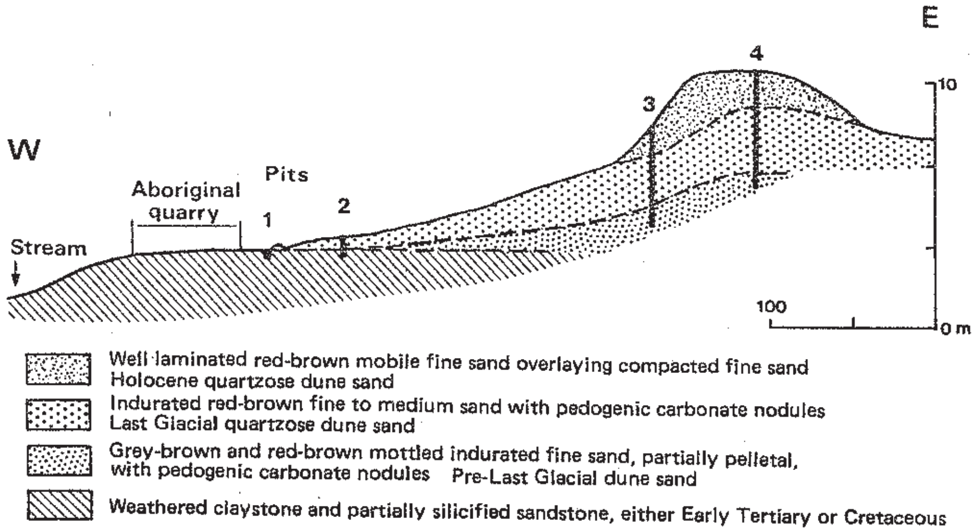


FIG. 13. Merteree; strat. site 12.

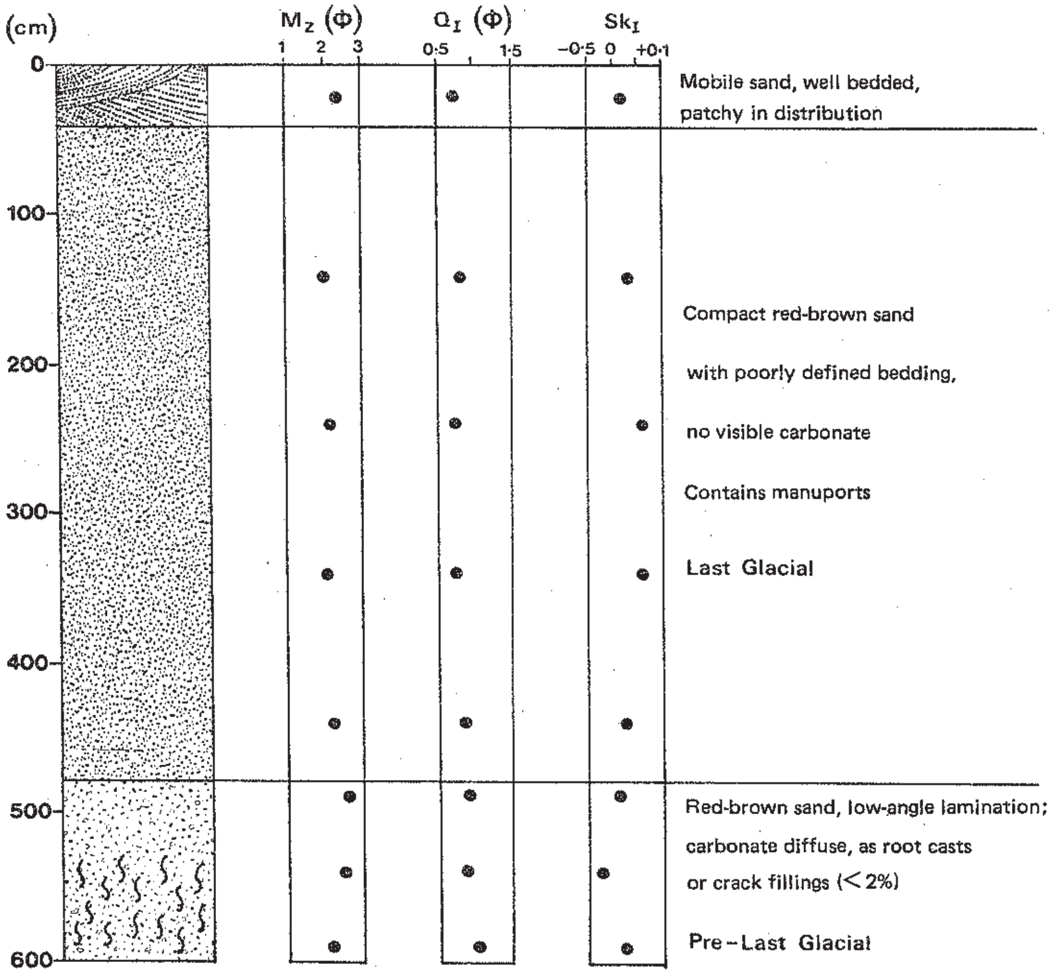


FIG. 14. Bore Track Site 1; strat. site 14.

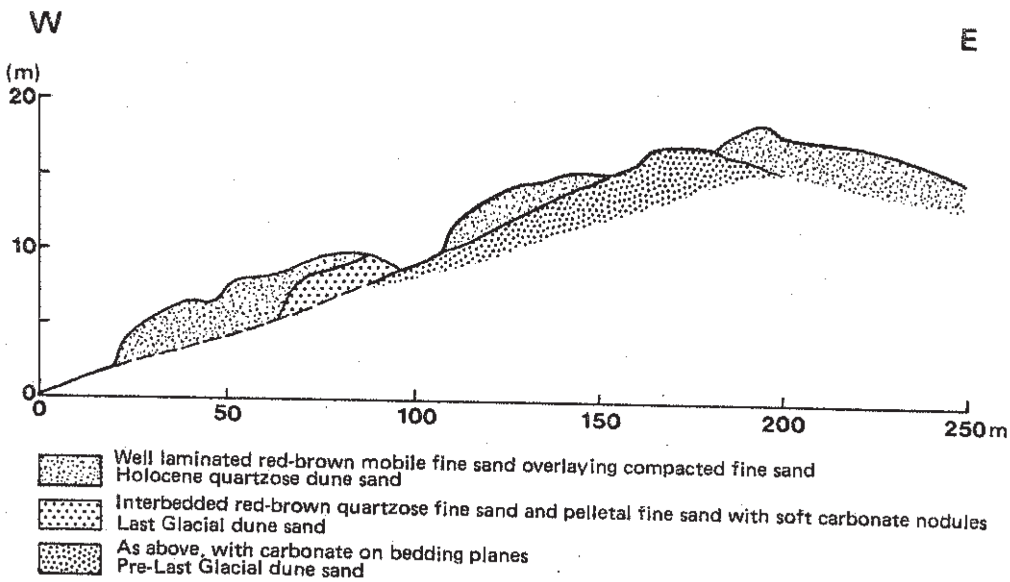


FIG. 15. L. Merteree; strat. site 11.

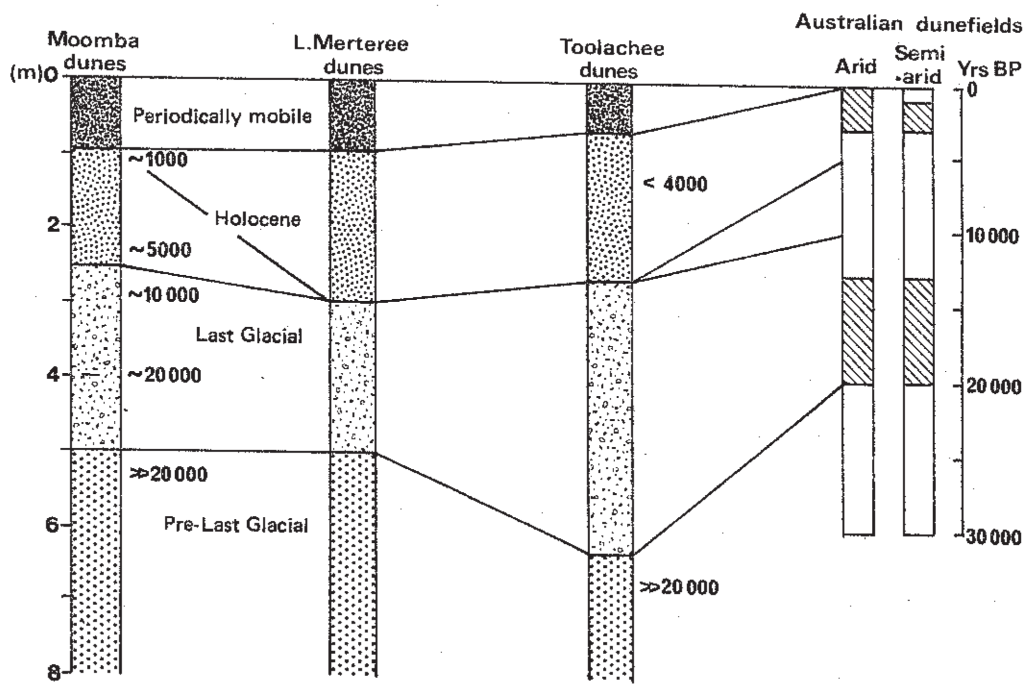


FIG. 16. Correlation between pale pelletal dunes (Moomba dunes), red-brown quartzose dunes (Toolachee dunes) and the intermediate type (L. Merteree dunes), with the general L. Quaternary stratigraphy from other parts of the Australian continental dunefields.

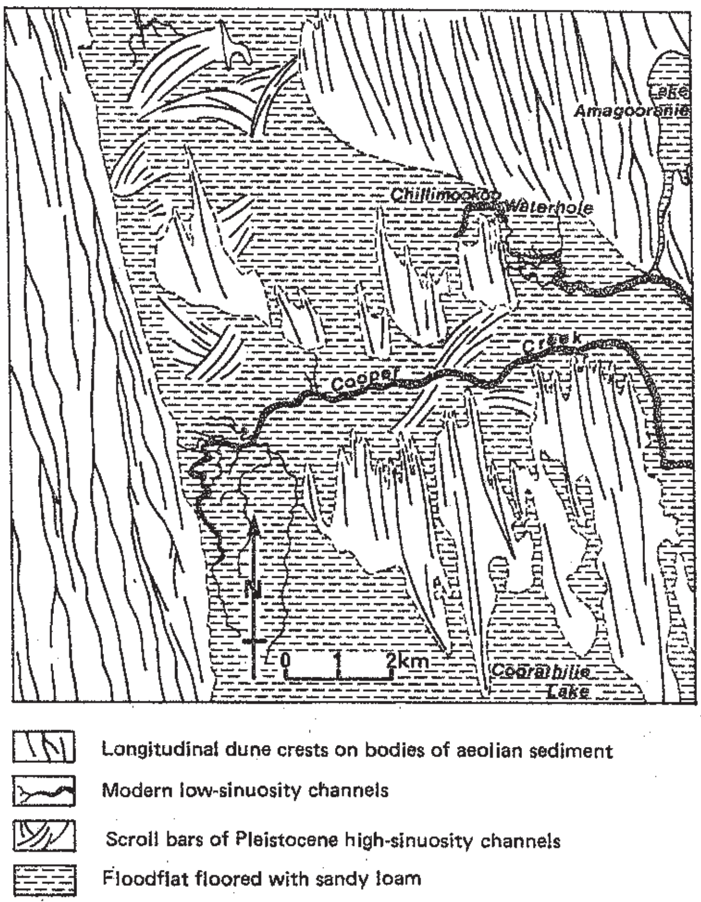


FIG. 17. Area surrounding Chillimookoo waterhole; strat. site 16. Shows relationships between dunes and scroll bars of Pleistocene channels.

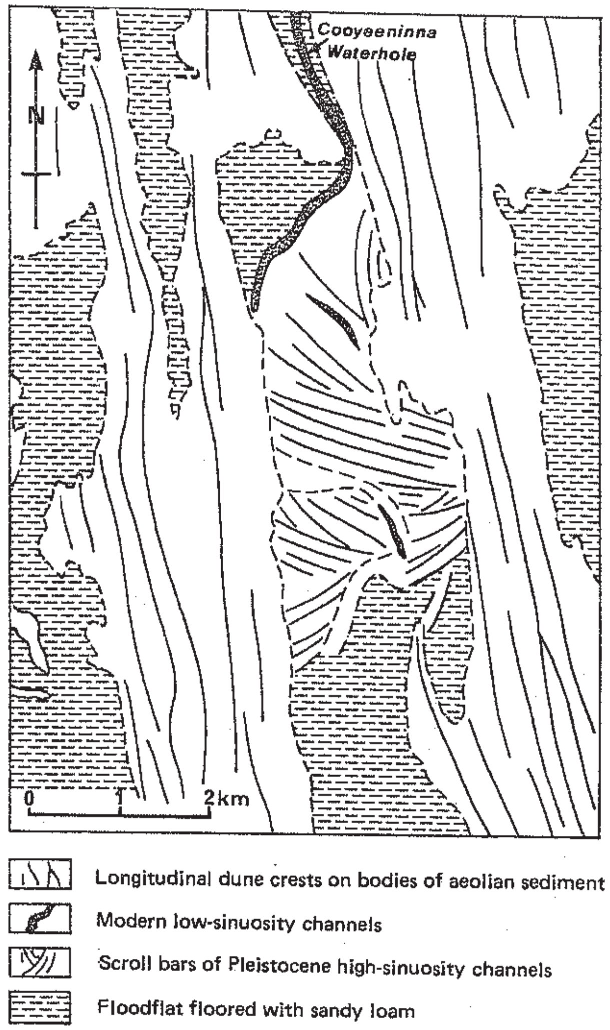


FIG. 18. Cooyeeninna waterhole; strat. site 17. As for Fig. 17.

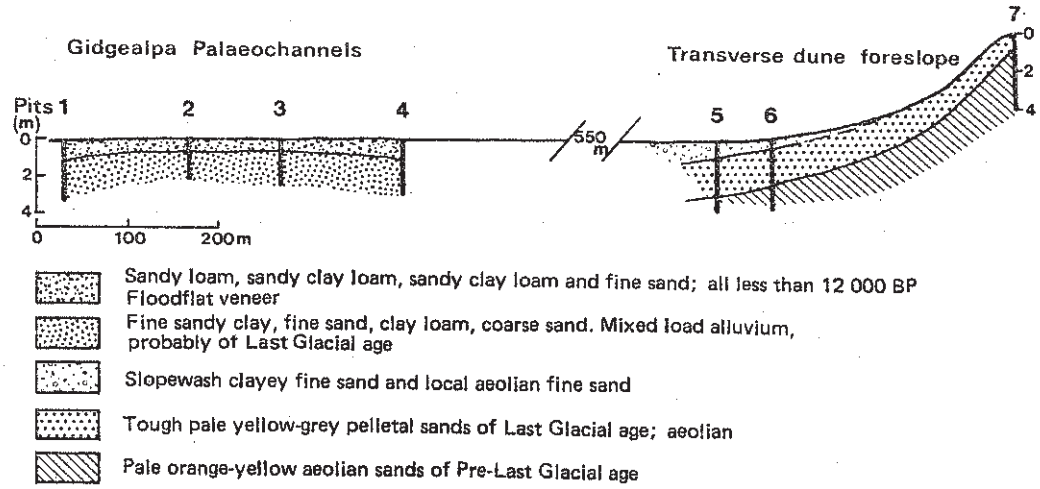


FIG. 19. Gidgealpa palaeochannels (strat. site 6a) and transverse dune (strat. site 6b).

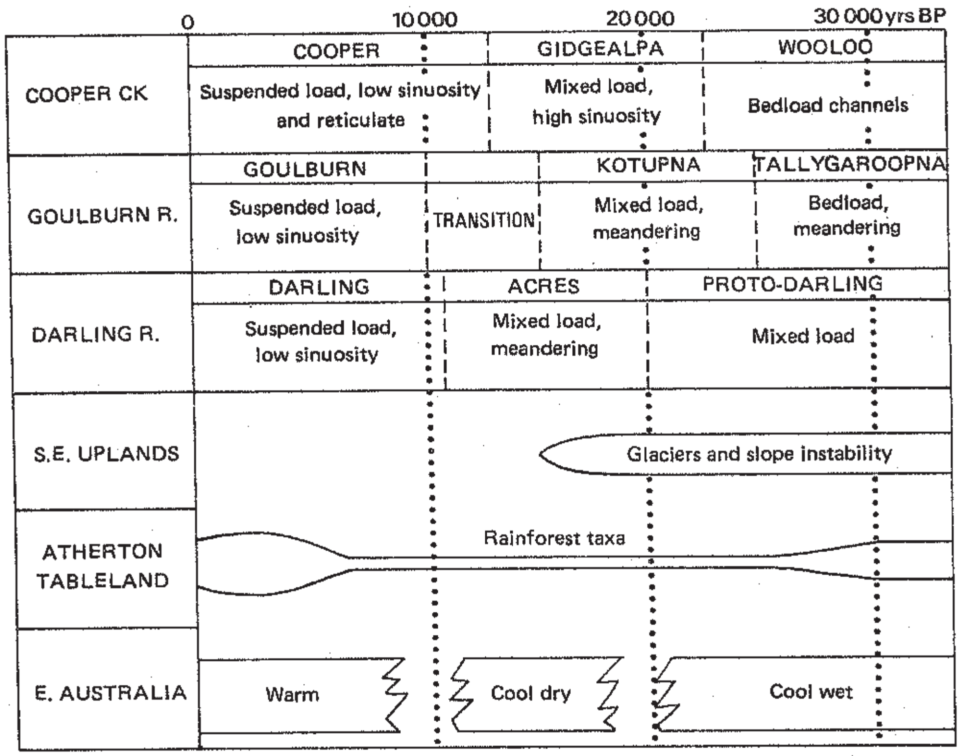
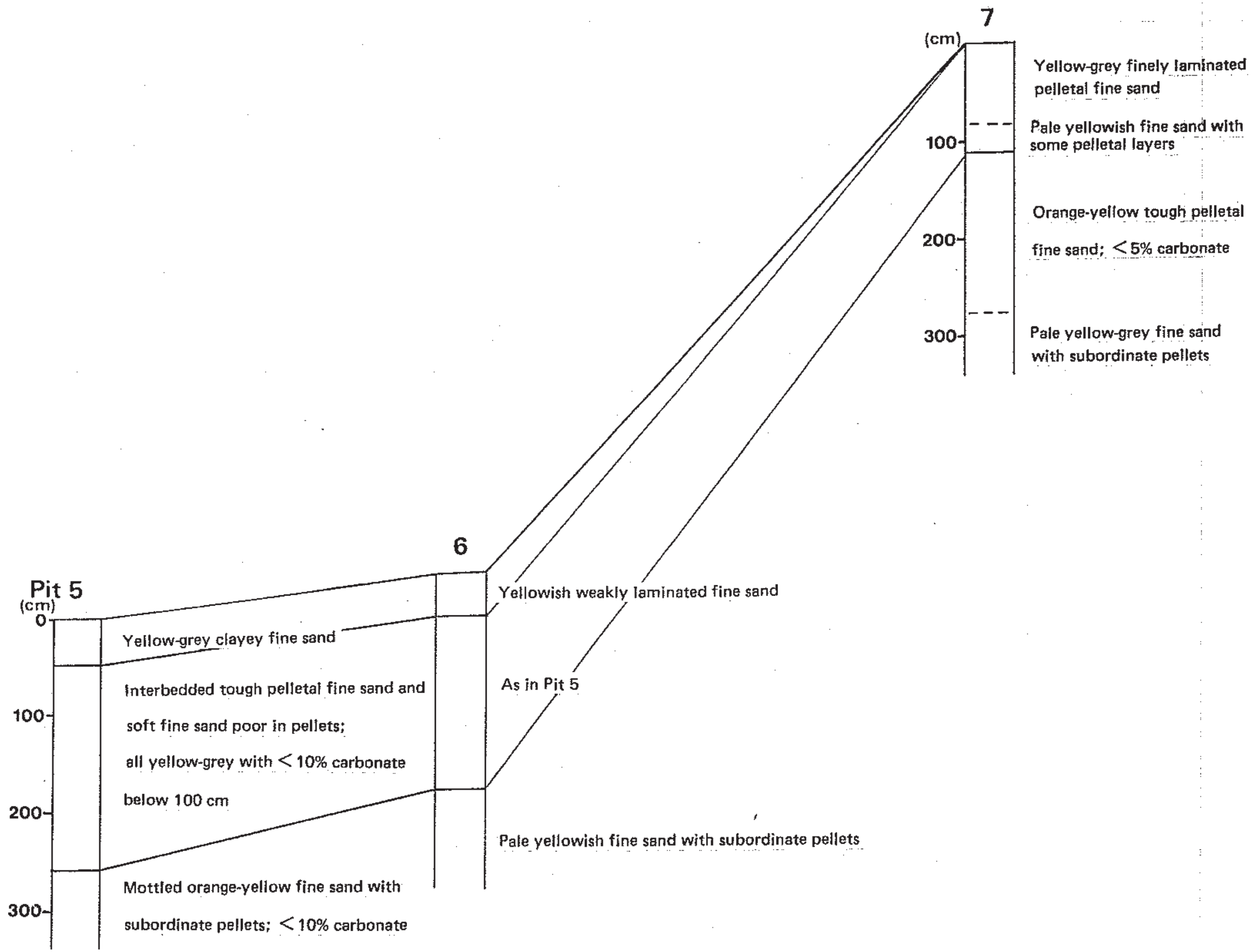
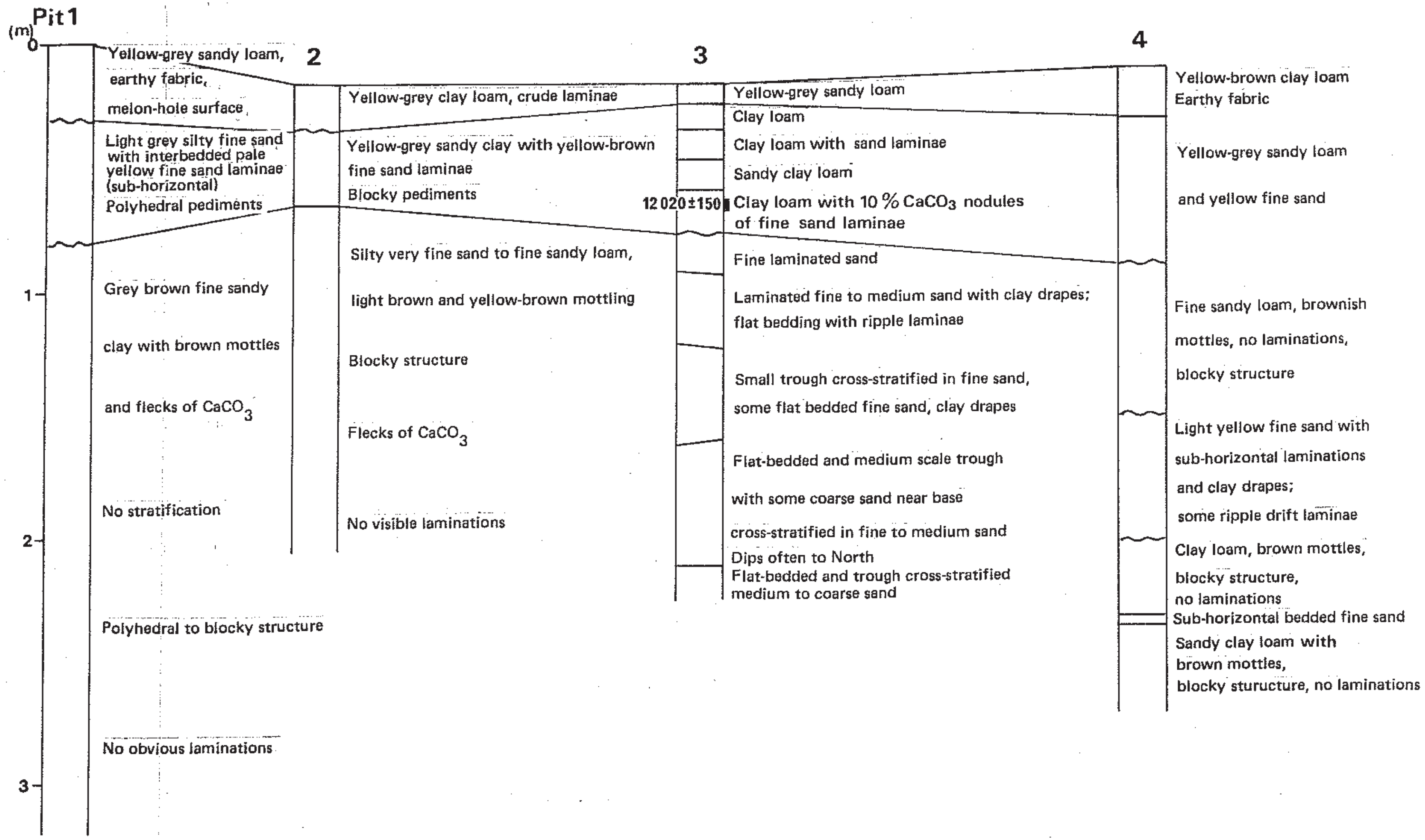


FIG. 20. Correlation between alluvial stratigraphy of Cooper Creek in the Strzelecki Dunefield, Goulburn R. in northern Victoria, and the Darling R. near Tilpa in N.S.W., with the chronology of glaciation and slope instability in the southeastern Uplands, rainforest abundance on the Atherton Tableland, and a general description of palaeoclimate in eastern Australia distilled from CLIMANZ.


Pit 5
(cm)
0
100
200
300
Yellow-grey clayey fine sand
Interbedded tough pelletal fine sand and
soft fine sand poor in pellets;
all yellow-grey with < 10% carbonate
below 100 cm
Mottled orange-yellow fine sand with
subordinate pellets; < 10% carbonate
6
Yellowish weakly laminated fine sand
As in Pit 5
Pale yellowish fine sand with subordinate pellets
7
(cm)
100
200
300
Yellow-grey finely laminated
pelletal fine sand
Pale yellowish fine sand with
some pelletal layers
Orange-yellow tough pelletal
fine sand; < 5% carbonate
Pale yellow-grey fine sand
with subordinate pellets



Pit 1
(m)
0
1
2
3
Yellow-grey sandy loam, earthy fabric, melon-hole surface
Light grey silty fine sand with interbedded pale yellow fine sand laminae (sub-horizontal)
Polyhedral pediments
Grey brown fine sandy clay with brown mottles and flecks of $CaCO_3$
No stratification
Polyhedral to blocky structure
No obvious laminations
2
Yellow-grey clay loam, crude laminae
Yellow-grey sandy clay with yellow-brown fine sand laminae
Blocky pediments
Silty very fine sand to fine sandy loam, light brown and yellow-brown mottling
Blocky structure
Flecks of $CaCO_3$
No visible laminations
3
Yellow-grey sandy loam
Clay loam
Clay loam with sand laminae
Sandy clay loam
12 020±150
Clay loam with 10 % $CaCO_3$ nodules of fine sand laminae
Fine laminated sand
Laminated fine to medium sand with clay drapes; flat bedding with ripple laminae
Small trough cross-stratified in fine sand, some flat bedded fine sand, clay drapes
Flat-bedded and medium scale trough with some coarse sand near base cross-stratified in fine to medium sand
Dips often to North
Flat-bedded and trough cross-stratified medium to coarse sand
4
Yellow-brown clay loam
Earthy fabric
Yellow-grey sandy loam and yellow fine sand
Fine sandy loam, brownish mottles, no laminations, blocky structure
Light yellow fine sand with sub-horizontal laminations and clay drapes; some ripple drift laminae
Clay loam, brown mottles, blocky structure, no laminations
Sub-horizontal bedded fine sand
Sandy clay loam with brown mottles, blocky sturucture, no laminations