# CHAPTER 4

# CHARACTERISTICS OF THE SAND BODIES

## 4.1 INTRODUCTION

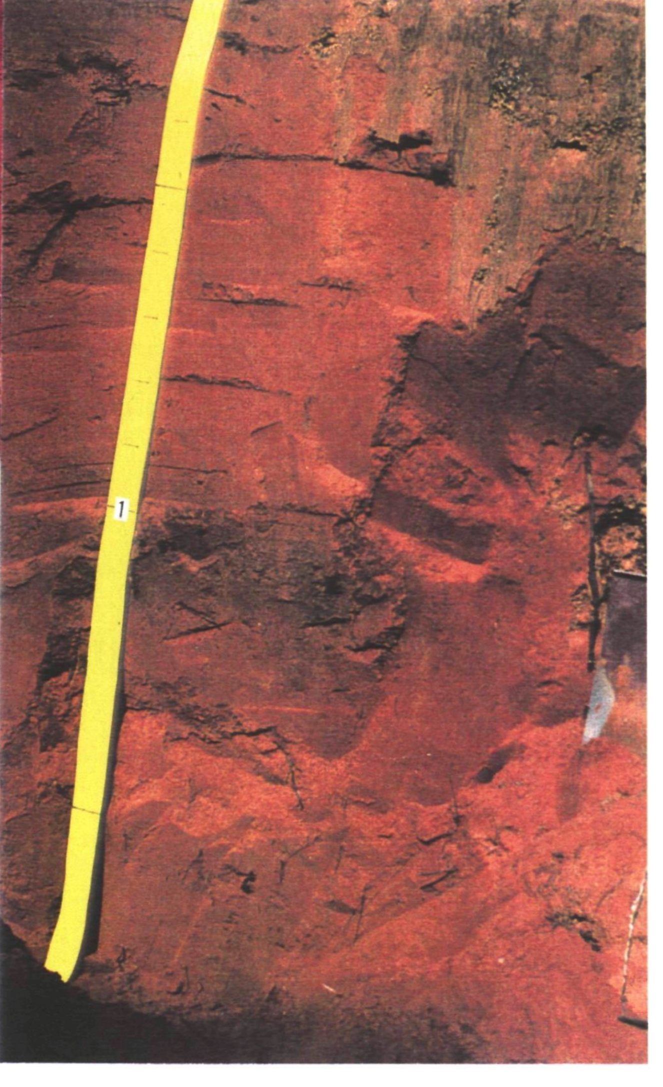
As described in the previous chapters, field reconnaissance revealed four types of sand body (Fig. 10) which were mapped and described on the basis of simple field criteria. However, some uncertainty remained concerning the actual fundamental differences between the sand bodies and their relationship to one another. In particular it was uncertain whether or not a real difference existed between the red sand monkey and the yellow sand monkey. In order to resolve this issue and also to substantiate field observations, a more detailed examination of their sedimentological character was undertaken.

It may be expected that an investigation of sedimentary structures would prove instructive in this regard. In particular alluvial bedforms and/or aeolian cross-bedding might be expected in some of the sand bodies. However an examination of approximately 20 pits and quarry faces revealed no such structures. This concurs with previous research that makes no reference to any sedimentary structures in the Pilliga sand bodies, though earlier investigations were primarily concerned with pedological issues and hence may not have sought out these features for investigation. This lack of sedimentary structures contrasts with work on the Riverine Plain where structures such as trough cosets and concave up foresets are commonly described (e.g. Pels 1964; Bowler, 1976; Page 1994). Assuming that the sedimentary structures were

**Fig. 10.** Four types of sand body identified in the study area. (a) Red sand monkey (RSM) on Pine Rd., (b) yellow sand monkey (YSM) on Dunwerian Rd., (c) source bordering dune (SBD) on Pine Rd., and (d) current deposits, Talluba Creek, near Schwagers Bore Rd.

(a)

(b)



(c)

(d)

formed during primary deposition, it would seem that they have been subsequently destroyed by pedogenic processes.

In the absence of sedimentary structures, attention was directed to particle size analysis. The intention was to assign a 'particle-size signature' to each sand body type, in terms of proportions of gravel, sand and mud and other statistical measures on the sand size fraction. This signature provides a marker to determine the degree of difference between the sand bodies and, hopefully, to provide a clue as to their origin and mode of deposition. Given the absence of sedimentary structures, this exercise has assumed greater importance than might otherwise be applied, as the integrity of the project relies to some extent on the ability to distinguish between the sand bodies.

## 4.2 METHODS

### 4.2.1 Overview

In order to resolve the questions posed above, the collection, treatment and analysis of various samples was necessary. The methods are described below in the order in which they were carried out. It was also necessary to evaluate site integrity, to ensure that any differences observed between sand body types were not the result of internal downstream variation.

### 4.2.2 Selection of sample sites

The process of sample selection took a two-pronged approach, with intensive sampling centred on the main sand monkey near its intersection with Dunwerian Rd. and more general sampling over the rest of the study area. The Dunwerian Rd. site was chosen because it is here that the main sand monkey is most clearly defined on the air photos and previous work provided background data that were of assistance to the study.

Further sample locations were determined during and consequent to the mapping process outlined in the previous chapter. Several red sand monkeys were identified and sampled to provide comparison with the yellow and samples were taken from the SBD to assess its character. Sediments from current creeks were also analysed to compare with other sand bodies, especially the sand monkeys. In order to assess particle size changes over a longer distance, Baradine Creek was sampled along about 80 km, starting from its source area (Fig. 9). Baradine Creek parallels Etoo Creek but drains a considerably larger catchment. The locations of all the sample sites are presented on Figs. 7 and 9.

### 4.2.3. Sample Depths

For the purposes of inter-site comparison depths were standardised at 0.25-0.5m and 1.5-2.0m. These depths were chosen because the upper depth gives a representation of bioturbated surface material but without containing large amounts of organic matter that can affect particle size analysis. The lower sample was taken to gain a summary appreciation of the sand character at depth, in a zone thought to be outside the influence of bioturbation. Further samples were taken at selected sites, usually at close intervals from the near-surface to the clay basement to more fully describe particle size trends in the vertical plain.

### 4.2.4 Sampling

Samples were obtained primarily from sand auger holes, with measured extensions so depth could be accurately gauged. All sample sites were at least 10 m from the side of the road to reduce any possible edge effects. In the case of sites sampled to the base of sand monkeys, this level was dictated by the presence of an impenetrable clay layer. Pits were dug at some sites, including the base of some burrows that had been excavated for road-making materials. Where samples were taken from burrows, a fresh face was exposed so a complete profile description could be made. Creek samples were collected from mid-channel bars on the upstream side of road crossings, from typical surface material down to a depth of approximately 0.25m. All samples were sealed in plastic bags, marked with a unique code, and transported back to the laboratory.

### 4.2.5 Sample Treatment

From each of the 116 samples taken, 10 grams was weighed out, oven-dried at 110°C until dehydrated and reweighed, allowing calculation of a 'moisture factor' for each sample. A 100 gram sub-sample was then weighed and placed in a solution of sodium hexametaphosphate in deionised water for 24 hours to disperse the fine grained aggregates and remove any clay coatings from sand grains. The dispersed sample was then wet sieved through a 63 micron mesh, removing all material smaller than sand size. The >63 micron fraction was oven-dried and reweighed. The mud (i.e. silt plus clay) fraction was calculated by difference (see Appendix 7). The gravel portion was then isolated in a dry sieve (2 mm mesh diameter), shaken for 10 minutes on an Endecott sieve shaker. This portion was weighed, thus allowing the percentages of gravel, sand and mud in each sample to be calculated. These results are presented in Appendix 2.

In 86 selected samples the sand fraction was sieved to 1/2 phi intervals (shaken for 10 minutes on an Endecott sieve shaker) to further characterise individual samples and elucidate trends. It was hoped to make use of the settling tube to provide more sensitive analysis but various operational problems rendered it unusable during the period of study.

### 4.2.6 Data Analysis

Having sieved the sand fraction, the data were entered into a grain size statistical package Marsed, within QBASIC. This calculated standard statistical measures (Folk and Ward 1957) of the sand populations including mean sand size, standard deviation (a measure of sorting), skewness (symmetry of the population) and kurtosis (how peaked the distribution is). The results are presented in Appendix 3. These statistical measures together with the proportion of gravel/sand/mud calculations, were calculated to show trends and provide a basis for comparison within and between various sand bodies.

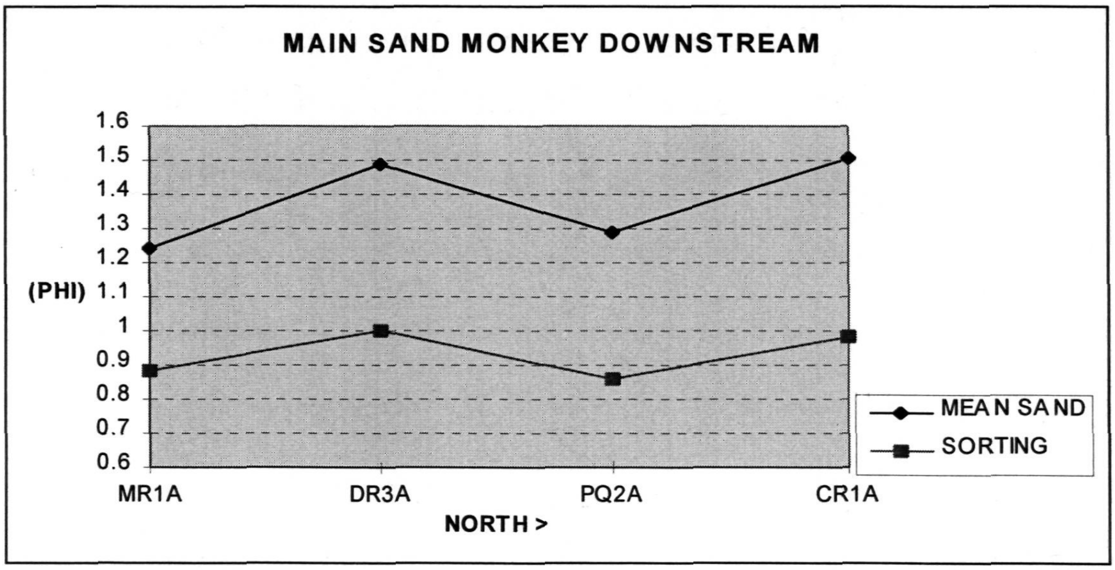
## 4.3 RESULTS

### 4.3.1 Site Integrity

It was important that the samples selected showed up real differences between the sand bodies and were not affected by intrinsic downstream variation. To test this, the main sand monkey was sampled at various points at M Rd., Dunwerian Rd., Pickaxe

Rd. and Camerons Rd., over a length of approximately 15 km to check for downstream variation in particle size or character. No coherent trend in mean sand size, sorting or gravel/sand/mud proportion was observed (Fig. 11), suggesting that over this distance, downstream variation is insignificant. Similarly, Baradine Creek was sampled about 80 km of its length, but failed to show any consistent downstream change. Hence, it is assumed that any differences between the various sand bodies within the study area reflect actual differences in their character.

**Fig. 11.** Downstream variation in the main sand monkey




### 4.3.2 Gravel, sand and mud percentages

Determining the gravel/sand/mud proportions of the different sand bodies provides the basis for testing and refining the simple field descriptions given in Table 4. It was also anticipated that these additional data would assist in identifying geomorphic processes involved in deposition and perhaps provenance. The initial aim was to test whether the materials making up the red sand monkey (RSM) differ significantly from those in the yellow sand monkey (YSM) and similarly how they compare to the sediments in the source bordering dune (SBD) and the contemporary creeks. From this point the relationships between the different sand body types can be examined in terms of their proposed origin, ie; are they part of one sedimentary system with various depositional loci, or, are they completely unrelated sedimentary bodies, or, do they represent points along a continuum between two endpoints.

In order to simplify the data collected from the processing of samples, the average percentage of gravel and mud (the two most variable factors) in each sand body type was calculated, see Table 5. Two population t-tests were conducted on these means (Appendix 8) to determine the statistical significance of the observed differences, the significance level was set at 5%, and a summary of the results of these t-tests is provided in Table 6.

In addition to comparison of the sand bodies, summary analysis of the sandy topsoil material of the texture contrast soil was made. This material was sampled adjacent to Dunwerian Rd. near Tinegie Creek. In keeping with the mobile topsoil theory of soil formation discussed in Chapter 2, it follows that the topographically higher sand monkeys would act as a source for this topsoil, along with material weathered from bedrock outcrop upslope. In the sampled area, the story is further complicated by the proximity of Tinegie Creek and the likelihood of the addition of material from overbank deposition.

**Table 5.** Summary of sample sites, sample numbers and preliminary results

| | RSM | YSM | SM (total) | SBD | CK. | OTHER [1] | 0.25 - 0.5m | 1.5 - 2.0m | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| No. of sites | 11 | 15 | 26 | 2 | 13 | 2 [2] | 23 | 16 | 45 |
| No. of samples | 21 | 60 | 81 | 12 | 13 | 8 | 23 | 16 | 116 |
| No. sieved samples | 10 | 44 | 54 | 12 | 12 | 8 | 11 | 11 | 86 |
| Gravel Av. (%) | 8.9 | 3.39 | 6.62 | 0.03 | 12.57 | — | 0.58 | 7.27 | — |
| Mud Av. (%) | 12.38 | 12.66 | 12.61 | 26.35 | 1.83 | — | 13.6 | 11.62 | — |
| Mean sand size | 1.03 $\phi$ | 1.17$\phi$ | 1.14$\phi$ | 1.49$\phi$ | 0.60$\phi$ | — | 1.22 | 1.09 | — |
| Mean S.D. | 0.94 | 0.89 | 0.9 | 0.8 | 0.71 | — | 0.91 | 0.93 | — |
| Gravel b.max (mm) | 60 | 30 | 60 | 3 | 150 | — | 30 | 28 | — |

(1) Not sand monkey

(2) One site adjacent to SM Dunwerian Rd., one site adjacent to Etoo Ck.

**Table 6.** Significance of differences between the sand bodies as determined by t-tests

| | RSM/ YSM | CK/ SM | CK/ YSM | CK/ RSM | CK/ SBD | SBD/ SM | SBD/ YSM | SBD/ RSM | 0.5/ 2.0 |
|---|---|---|---|---|---|---|---|---|---|
| MUD | NS | S | S | S | S | S | S | S | NS |
| GRAVEL | S* | NS | S* | NS | S | S | S | S | S |

NS Not significant at the 5% level

S Significant difference at the 5% level

S* Significant but skewed by outliers

Overall, the sandy topsoil of the texture contrast soil has higher mud content, finer mean grain size, better sorting, less gravel and a finer field texture than the sand monkey sands. However, due to the above factors, there is considerable lateral mixing of material particularly towards the edges of the sand monkeys, this causes difficulties in determining the precise lateral extent of the sand bodies.

The distinction between the RSM and YSM was made in the field on the basis of colour. The fundamental unresolved question, given their spatial relationship (RSM overlying YSM, Fig. 8) concerned whether they represent two separate depositional bodies or the two colours are a result of post depositional modification, probably due to differential drainage conditions affecting the oxidation of iron. The averages of mud content are virtually identical and a t-test show no significant difference. When the entire population of gravel percentage is included in calculating the mean, the difference between the two populations - gravel in RSM and gravel in YSM - is statistically different at the 5% significance level (but not at the 1% level). However, in the case of the RSM population, the mean is heavily skewed by three outliers, if any two of these are removed, the mean is lowered such that the difference between the two population is not significant. It should also be noted that calculation of these figures assumes a normal population distribution, a condition unlikely in natural sediments. Given these provisos, and the gradual nature of the colour change both vertically and horizontally, it would seem that the RSM and YSM do not represent different depositional bodies.

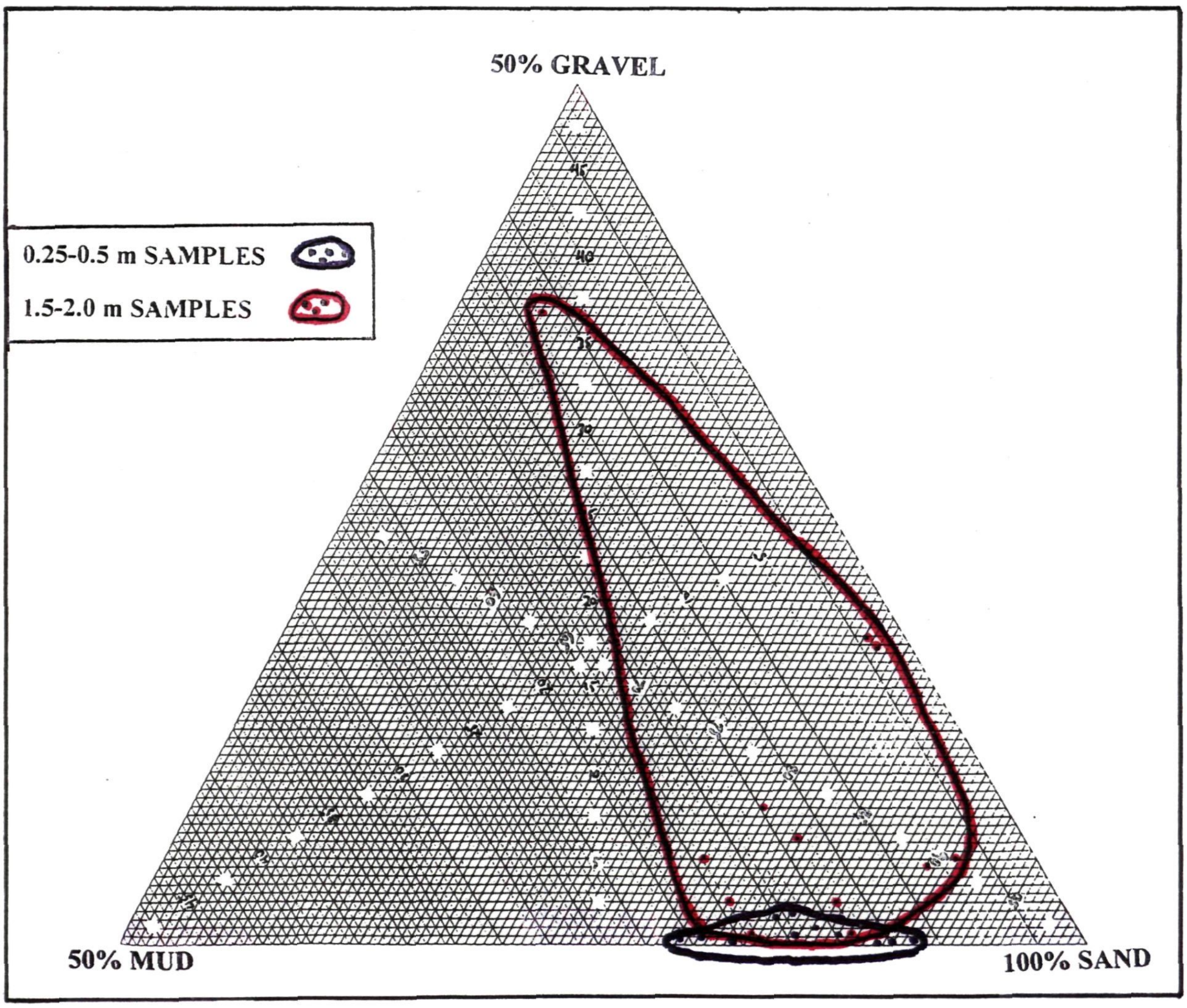
On the basis of the vivid colours of the sand bodies and in keeping with the observation of Taylor *et al.* (1983), it is proposed that the red colouration is due to the dominance of the iron mineral hematite and the yellow colour due to goethite. Both minerals are very common in Australian soils and are often found in close association. At present it is unclear as to how the YSM and RSM came to hold their current relationship but it is possibly due to different drainage conditions at the time of oxidisation since goethite is the hydrated form of hematite.

The SBD can be shown to be statistically different from all the other bodies, both in their gravel content - which is negligible - and mean mud content which is approximately twice as high as the sand monkeys and nearly 15 times the creek samples.

The creek sands exhibit a very low average mud percentage which is significantly different to both sand monkeys. The mean of the gravel population from the creeks is not significantly different to that of the combined sand monkey mean (RSM and YSM). It is statistically different to the YSM population but the creek average is heavily influenced by two outliers (as noted above) that serve to more than double the average gravel percentage. On the basis of this it is considered that the gravel content of the current creeks and the sand monkeys are not substantially different. This is an important conclusion that will be discussed further in subsequent chapters in viewing the contemporary creeks as depositional analogues to the sand monkeys.

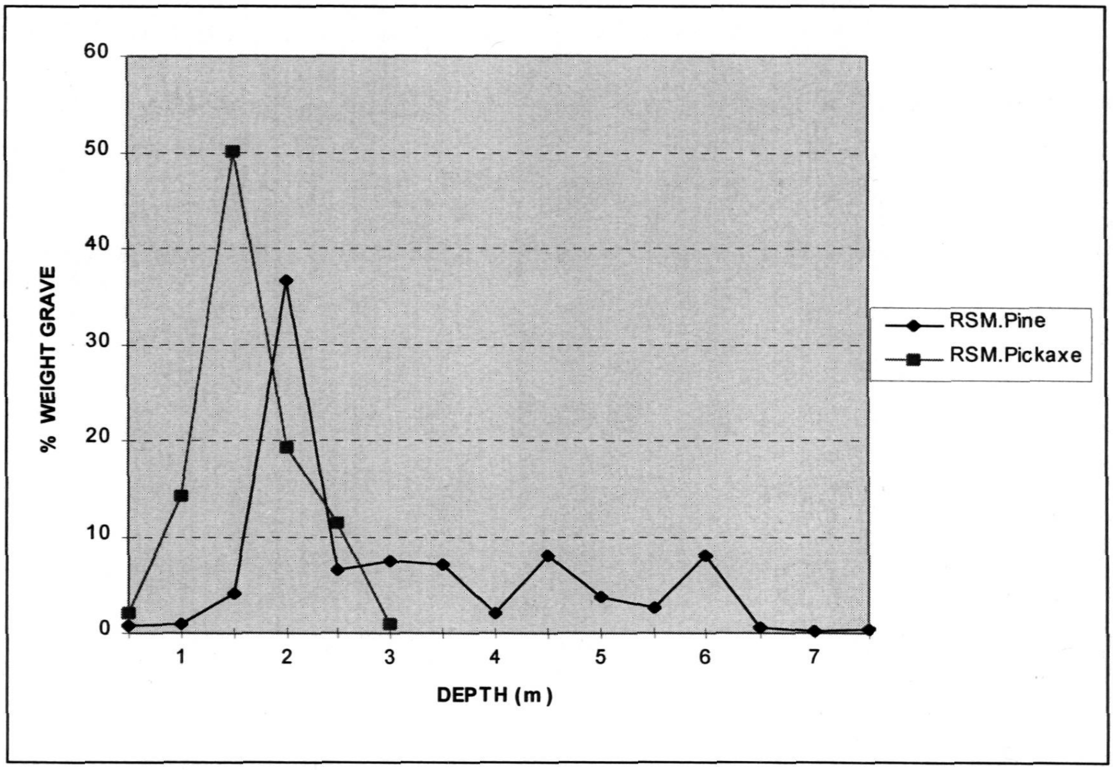
Comparison, with respect to gravel/sand/mud/ proportion was also made between all of the 0.25-0.5 m samples and all of the 1.5-2.0 m samples, (Fig 12). The groupings are quite distinct, with the upper group clustered as opposed to the more scattered arrangement of the lower group. The most variable factor is gravel content which is significantly lower in the surface material (t-test, see Table 6, last column). These samples include the RSM and YSM but not the SBD or creeks. At this stage it is sufficient to note that the materials of the near surface group are clearly more homogenous than those of the lower group. The reasons for this difference are addressed in the following chapter.

**Fig. 12.** Triangle plots for G/S/M in upper and lower samples



The vertical variability of the gravel and mud content was also investigated, see Appendix 2. It should be noted that the mud results must be treated with some caution, clayey material from the subsoil may be picked up by the auger and included in the lower samples giving an unnaturally high result. In terms of the sand monkey (SM) material - both RSM and YSM - the general trend, although variable, shows a gradual decrease in mud content with increasing depth before a sharp basal rise (as

**Fig. 13.** RSM Gravel content with depth




explained above). Gravel percentages tend to be more variable, often fluctuating with a rough peak/trough pattern possibly indicative of successive depositional episodes (Fig 13). Both RSM profiles also showed one very gravelly layer with large pebble to cobble-sized material. This vertical variability is not unexpected, and emphasises why the RSM and YSM should not be separated at this stage.

In the SBD, gravel is practically absent (and only up to 3 mm where present) but the mud fraction is very prominent, much more so than in the other sand bodies. Mud percentage showed a gradual rise with increasing depth but remained within a fairly narrow range.

Only surface samples were taken from the creek beds, so no sense of vertical variation could be gained. Baradine Creek was sampled at five sites along a considerable portion of its length ( approx. 80 km), both mud and gravel percentages were generally low (both <5% except for one site) and no consistent change downstream was observed.

### 4.3.2 Analysis of the sand fraction

Eighty-six samples were selected for further investigation through sieving of the sand fraction at 1/2 phi intervals, to obtain the standard statistical measures alluded to earlier in this chapter.

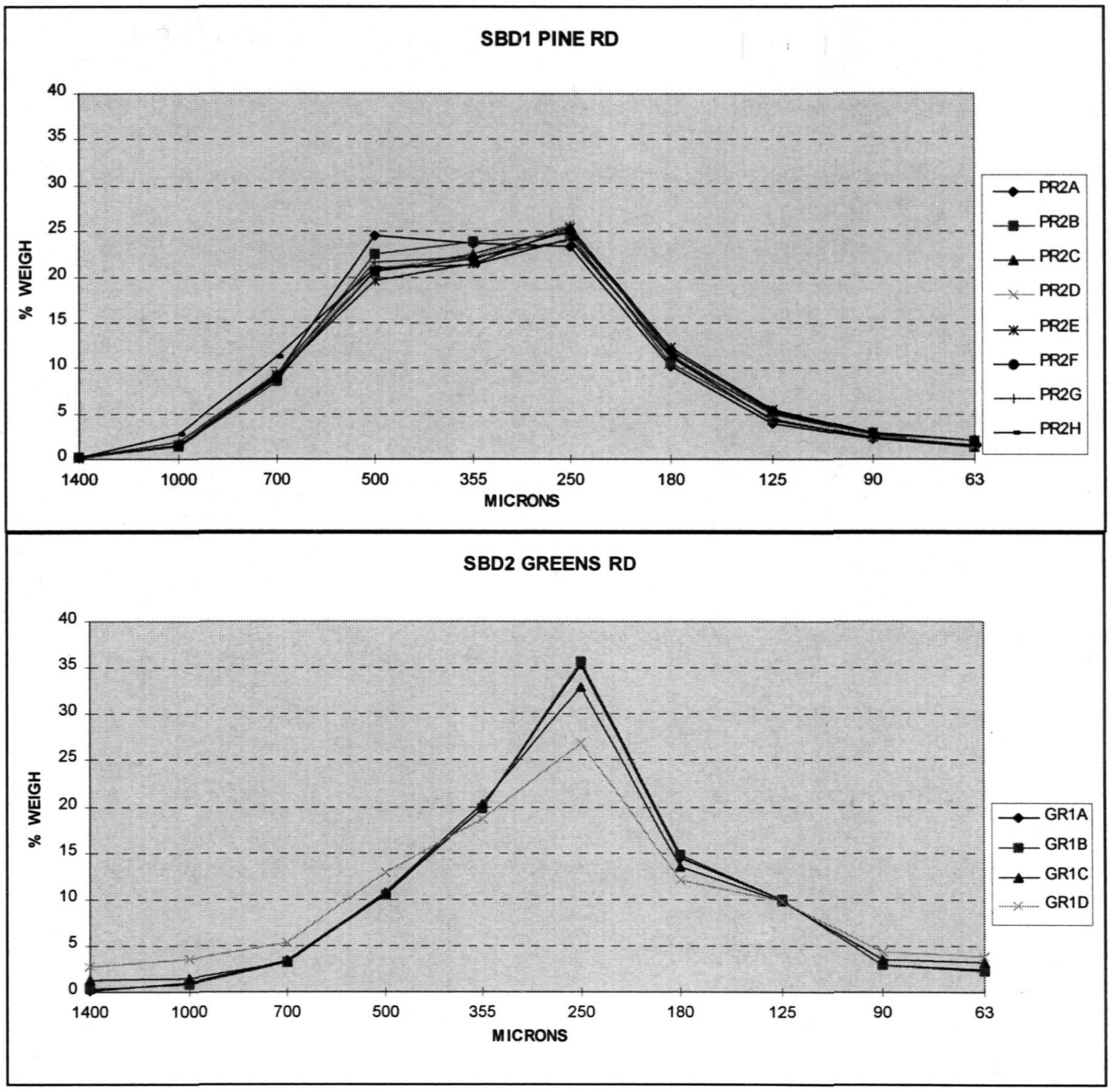
Graphs showing the distribution of the sand populations from the contemporary creek samples exhibit a pronounced peak at 500 μm (1$\phi$), aside from significant scatter among the 12 traces there does not appear to be any downstream trend in mean size or sorting over a distance of ~80 km.

Within the significant scatter evident in the distributions of the RSM and YSM (Appendix 9), two peaks, at 500 μm (1$\phi$) and 250 μm (2$\phi$) are expressed. The strength of the peaks is variable over the samples but is independent of colour. The difference in mean sand size between the YSM and RSM (1.03$\phi$ and 1.17$\phi$ respectively) is not statistically significant at the 5% level and neither is the difference in sorting (0.89 and 0.94 respectively). Using the terminology of Folk (1980), both types are generally moderately sorted with a distribution that is near symmetrical and mesokurtic.

The two SBDs overall show better sorting and generally smaller mean grain size than the other sand bodies. However, plots of the two SBD distributions are considerably different, see Fig. 14. SBD1 (Pine Rd.) exhibits a strongly bimodal distribution with clear peaks between 0.5 - 1$\phi$ and 1.5 - 2$\phi$, whereas SBD2 (Greens Rd.) has a unimodal profile with only the finer peak. A bimodal distribution suggests the action of two transporting mechanisms (Cooke and Warren 1973), a possible explanation is that SBD1, being closer to the source (Etoo Creek or the adjacent SM), received input through saltation and suspension, but SBD2 only suspended load. Another potential explanation is that the two peaks in SBD1 are parts of separate depositional episodes and SBD2 received input from only one. Noteworthy with regard to the Folk and Ward (1957) statistics, is the fact that the figures calculated show SBD1 to be better sorted than SBD2. Visual comparison of the two plots indicates that this is not the case. This is a good example of the deficiencies in simple grain size statistics. This type of problem also re-affirms the need to employ other techniques in analysing particle size data and it is unfortunate that the settling tube was unavailable.

Nevertheless, it is expected that settling tube results would reinforce the findings established thus far, in terms of distinguishing, or otherwise, between the sand bodies.

**Fig. 14.** SBD1 and SBD2 Grain size distributions




## 4.4 CONCLUSIONS

Due to inadequacies in remote sensing of the sand bodies as described in the previous chapter and the lack of depositional structures evident in the sand bodies, sedimentological analysis has taken on additional importance in achieving the aims of this project. This chapter set out to evaluate the perceived differences between the various sand bodies identified in the field and gain some understanding as to their origin.

From the sedimentological evidence, there doesn't appear to be a significant difference between the RSM and the YSM. The creek sediments are sedimentologically as well as texturally distinct from the sand monkeys and the SBD. The lack of gravel and high mud content distinguishes the SBD from the other sand bodies.

In terms of origin, the SMs contain the same 500 μm peak in their distribution as does the current creek sediment and thus there does not appear to be any reason to abandon the theory of their original fluvial deposition. Whether there has been subsequent addition of finer material, or the 250 μm peak was part of the original deposition is not clear. SBD1 contains the same two peaks of the SM, but without any gravel and with overall better sorting, This implies that its principle source is the SM between it and Etoo Creek.

In terms of the original theory of fluvial deposition, none of these findings conflict with the spatial, planform relationships outlined in chapter 3. The next chapter will further explore the relationships between the sand bodies in the light of stratigraphic and dating information derived during the course of the study.

# CHAPTER 5

# STRATIGRAPHIC AND AGE RELATIONSHIPS

## 5.1 INTRODUCTION

The two previous chapters establish that various sand bodies of the Pilliga can be distinguished sedimentologically and their planform distribution mapped. Account is given of the nature of the materials that make up the various sand bodies, their provenance and the significance of the observed differences are discussed. However, there remains a degree of equivocation regarding their association with one another in terms of:

(i) three-dimensional spatial relationships (stratigraphy) and,

(ii) temporal relationships (age).

Clarification of these connections have implications for discussion of the origin of the sand bodies. The findings of this study also build on previous work in the area, aimed at resolving the stratigraphy of all the Pilliga sediments and determining a Quaternary depositional framework.

## 5.2 METHODS

In order to examine all the sand body types in a stratigraphic context, a single transect including examples of each type was surveyed and sampled. This transect, (Figure 15a), runs from Etoo Creek at Euligal Crossing in the west, along Pine Rd. and Dunwerian Rd. to Ironbarks Crossing Rd. in the east and includes the locations of the dated samples. Adjoined is Fig. 15b which includes profile descriptions of a terrace adjacent to Etoo Creek, RSM, SBD and YSM. Sampling and sample analysis is as described in chapter 4.

The aim is to improve the understanding of the stratigraphy as described by Hart *et al.* (1996a) through more detailed sedimentary analysis, described in chapter 4, together with additional dating. Dating was carried out using the Thermoluminescence (TL) and Accelerator Mass Spectometry (AMS, Radiocarbon) methods, as per Aitken (1990).

Sites selected for dating are shown on Fig. 15a, each sand body type (except the contemporary creek) is dated using TL at a similar depth below the surface (1.5 - 1.8m) for comparison and the clay subsoil in the area was dated to determine whether it was coeval with the sandy units or an earlier deposit. Charcoal was also dated (AMS) in the upper layer of the main sand monkey and in the sandy topsoil of the texture contrast soil along Dunwerian Rd. In all, four dates were taken at different depths in the main sand monkey to gain an appreciation of its depositional history.

Clarification of the stratigraphic relationship between a contemporary creek (Tinegie) and the main sand monkey was achieved through excavation of pits and auger holes along with sedimentological analysis and confirmed that the sand monkey predates deposition by the current creek.

needs to show what dating was done at each site TL, C14 ?

Fig. 15a. Surveyed location of dated sample sites

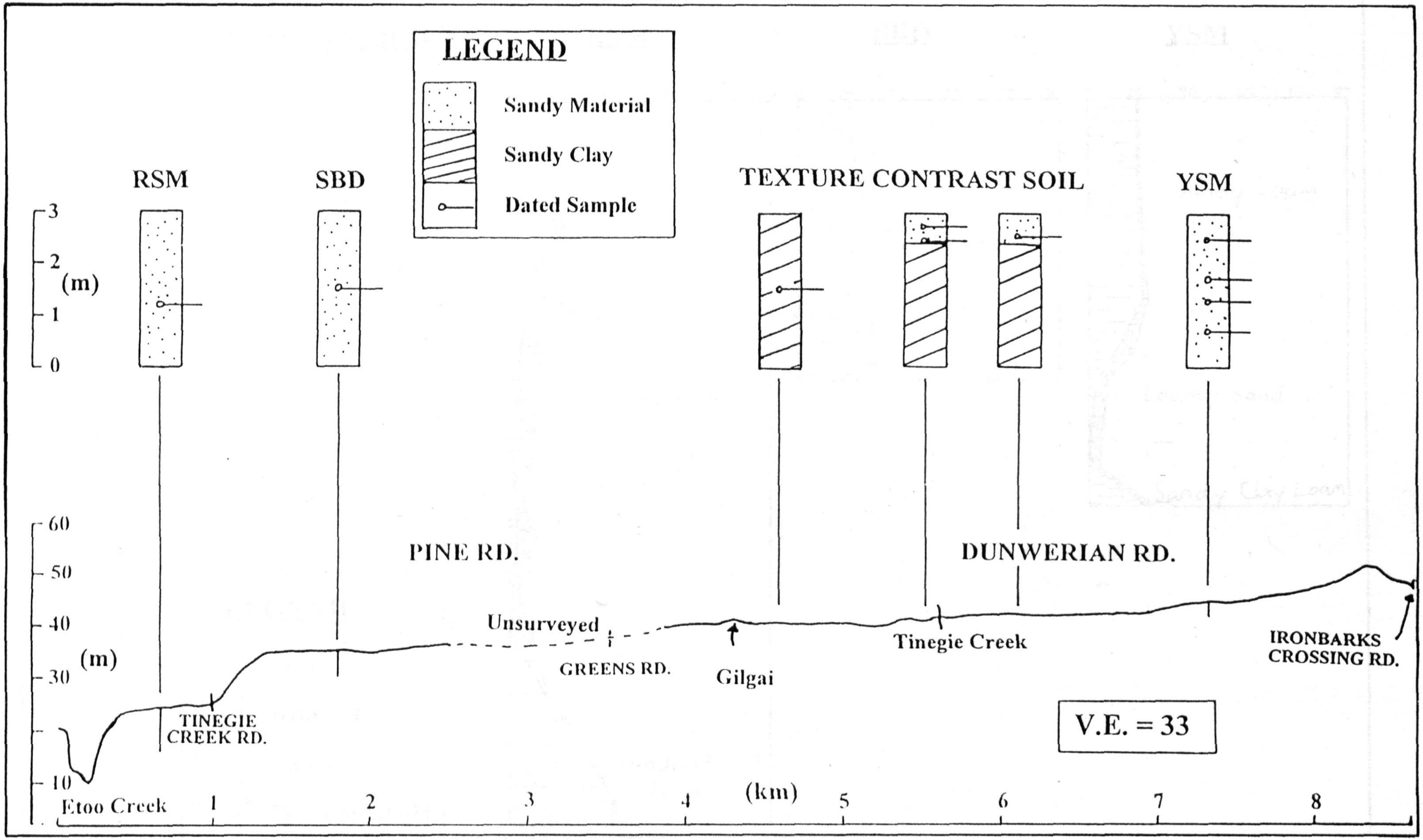
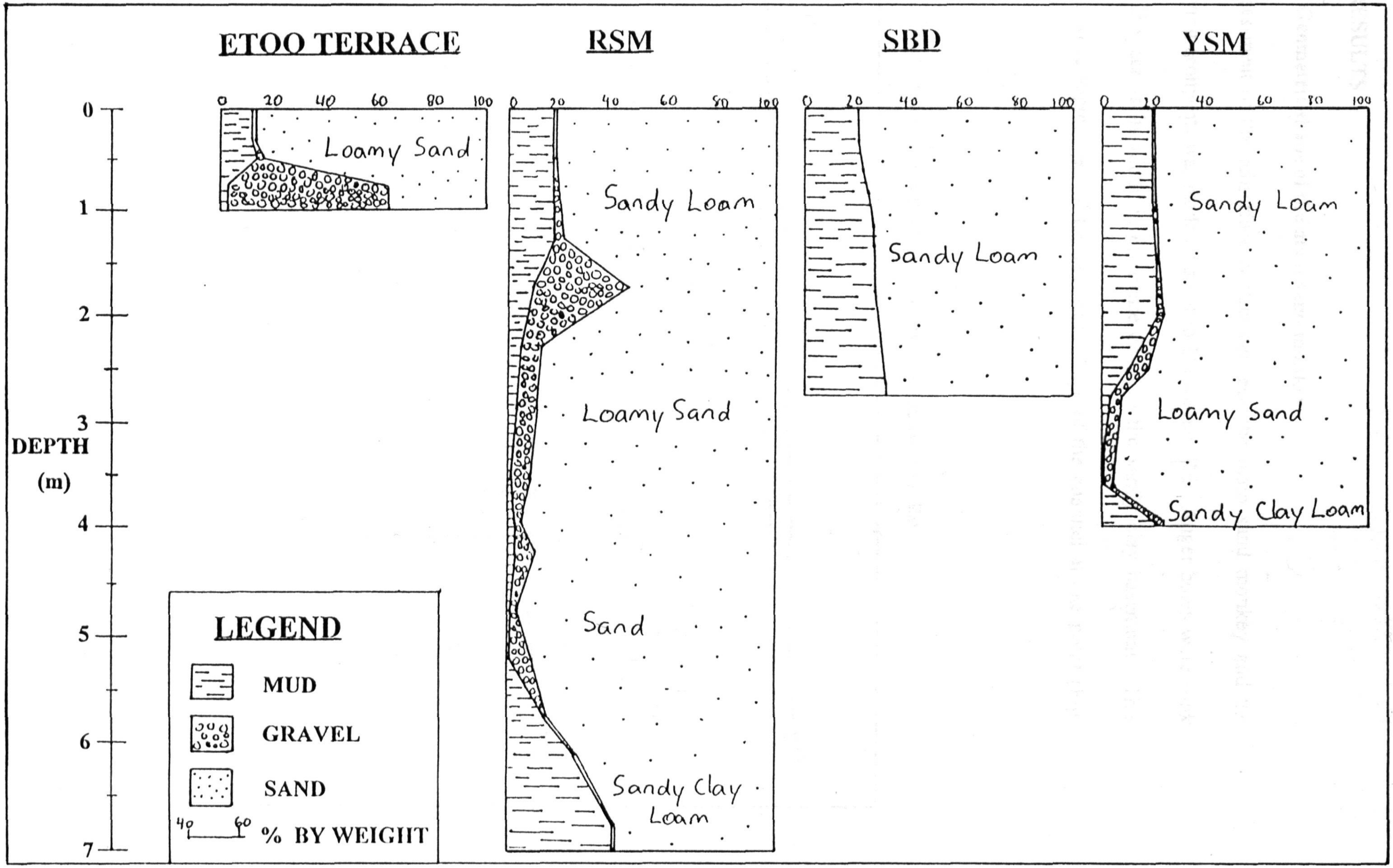


**Fig. 15b.** Profile descriptions of the sand bodies

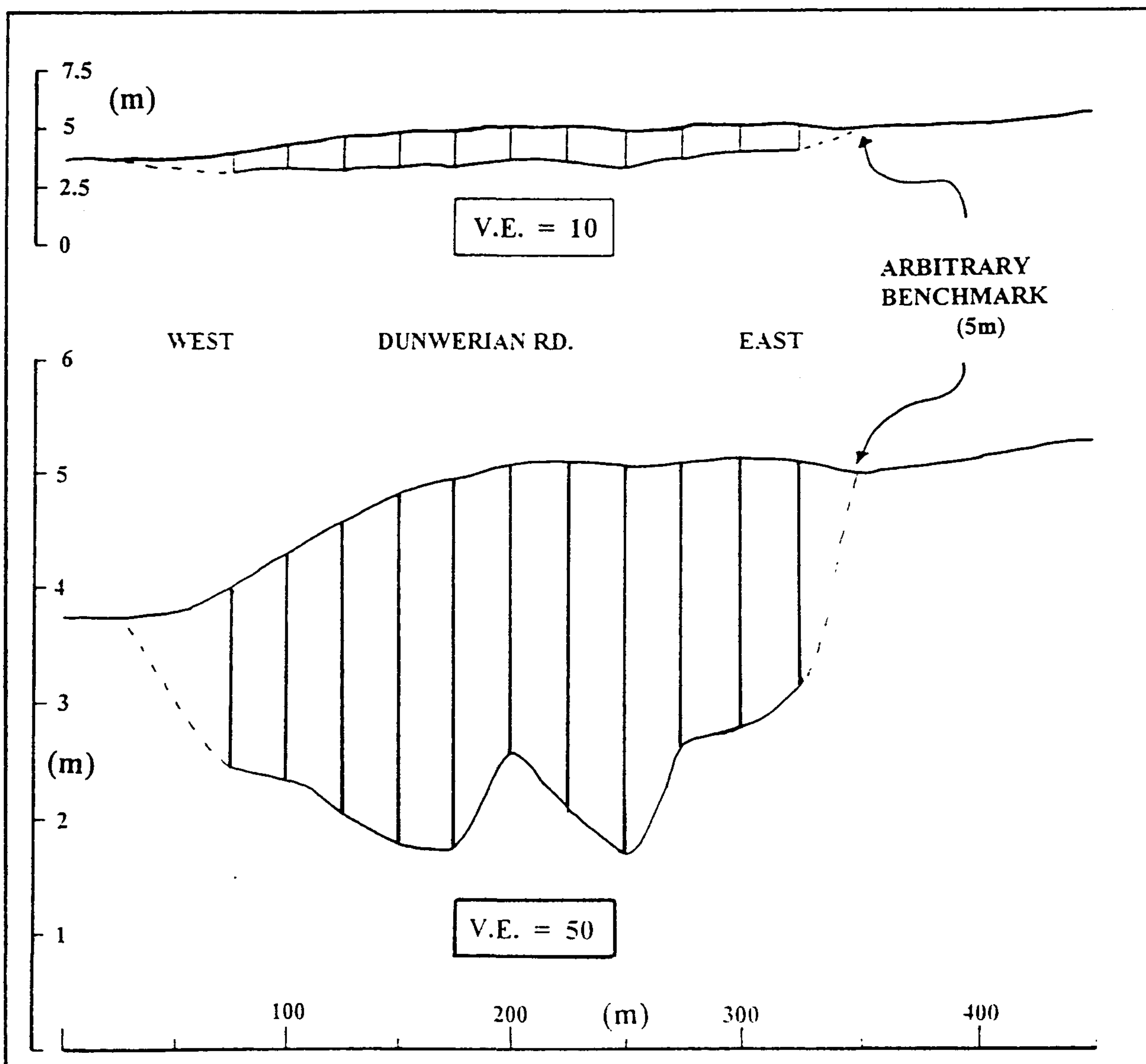


## 5.3 RESULTS

### 5.3.1 Geometric shape of the main sand monkey

An assessment of the subsurface contact between the main sand monkey and the underlying sediments was made adjacent to Dunwerian Rd. Auger holes were sunk every 25m across its width, in each case down to the sandy clay basement. This allowed some appreciation of the geometric shape of the channel at one point (Fig. 16).

**Fig. 16.** Cross-section of the main sand monkey at Dunwerian Rd.



A smooth concave up boundary is revealed between the main sand monkey and the underlying sandy clay at Dunwerian Rd., (Fig. 16). There is no evidence of a slot or gully form in the section, although it is possible that the 25m spacing between auger holes has missed such a feature. As is evident from the upper section in Fig. 16, it appears that the former channel had a high width to depth ratio possibly indicative of a relatively high energy braided system. However, due to the dearth of cross-sectional information this interpretation can only be viewed as a working hypothesis that requires further testing.

A further possibility is that the sand bodies crossing Dunwerian Rd., are the remnants of a previously, much larger entity, with erosion having removed all but the few patches currently visible. Immediately following deposition of the sand monkeys, the ground surface of the study site may have consisted of a very large sand sheet (many kilometres wide), subsequent fluvial activity having incised and eroded the poorly consolidated material, scouring most parts down to the less erodible clay. This would leave the remnant sections of the original sand sheet as elevated bodies. Wasson (1994) calculated rates of erosion in various Australian catchments, based on minimum figures and the time period available (see Table 7), approximately 44 m of ground-level lowering may have been achieved in the study area. Hence, due to the antiquity of the deposits, erosion rates present no barrier to this interpretation. As with the hypothesis described above however, more intense examination of the geomorphic character of the sand bodies needs to be made before such suppositions can be made with any confidence.

**Table 7.** Dates and sample characteristics

| SAMPLE CODE | LAB CODE | METHOD | AGE | SAMPLE | DEPTH | LOCATION |
|---|---|---|---|---|---|---|
| DRSM | W1932 | TL | 61.5 ± 6.8kaBP | Quartz | 220-240 cm | YSM, Dunwerian Rd. |
| LRSM | W1933 | TL | 45 ± 4.1kaBP | Quartz | 160-180 cm | YSM, L Rd. |
| 1024 | ANSTO | AMS | 10710 ± 150aBP | Charcoal >2.8 mm | 130 cm | YSM, Dunwerian Rd. |
| 1025 | Beta-93962 | AMS | 2140 ± 60aBP | Charcoal >2.8 mm | 50-60 cm | YSM, Dunwerian Rd. |
| 1028 | W2203 | TL | 42.9 ± 3.4kaBP | Quartz | 180 cm | RSM, Pine Rd. |
| 1034 | W2204 | TL | 38.8 ± 3.9kaBP | Quartz | 150 cm | SBD, Pine Rd. |
| 1027 | W2202 | TL | >88.6ka | Quartz | 150 cm | Clay, Pine Rd. |
| 963 | Beta-87866 | AMS | 1750 ± 50aBP | Charcoal | 33 cm | Topsoil (not SM), Dunwerian Rd. |
| 964 | Beta-87867 | AMS | 9630 ± 60aBP | Charcoal | 58 cm | Topsoil (not SM), Dunwerian Rd. |
| 969 | Beta-87868 | AMS | 3930 ± 70aBP | Charcoal | 50-60 cm | Topsoil (not SM), Dunwerian Rd. |

### 5.3.2 Dates

Analysis of the dates (Table 7), along with the three-dimensional spatial relationships shown in Fig. 15a,b. and Chapter 4 provide the basis for the stratigraphic framework presented below:

- The RSM overlies YSM, although they are probably not distinct sedimentary bodies.
- The SBD is a distinct body from the SM but formed at a similar stage.
- The sand bodies are younger than the ubiquitous clay.

- Sediment deposited by Tinegie Creek overlies and is therefore younger than the sand monkey material at L Rd. and Dunwerian Rd.
- The increasing age with depth in the sand monkey requires consideration and possibly other interpretations.

### 5.4 INTERPRETATION

As is often the case with the generation of dates encompassing different sedimentary bodies, these results do not provide absolute answers to all the stratigraphic questions within the study area, rather they supply evidence for and against different hypotheses regarding depositional history. As such interpretation of these dates is necessary in conjunction with the sedimentological and spatial results to determine the applicability of these hypotheses.

Most of the study area consists of mud deposits of varying depths which overlie the Pilliga sandstone. It is, as yet unknown whether this clay material formed through *in situ* weathering of the bedrock or represents a subsequent depositional body. This study does not include a comprehensive examination of the clay deposits and hence does not seek to make that distinction, however, dating results show that the sand bodies were not deposited at the same time as the clay. The age of clay emplacement is not definitively known, due to saturation of the TL sample (see Aitken 1990) but is significantly older than that of any of the sand bodies, despite one sand sample coming from nearly twice the depth of the clay sample. Maintaining the hypothesis that the sand monkeys are former streams, these dates suggest that the channels incised or were superimposed onto an existing clay surface and subsequently aggraded in the manner of a cut and fill sequence. These results also effectively discredit the genetic model proposed by Hallsworth and Waring (1964) for the development of the texture contrast soils.

Of particular significance to the study with regard to depositional history, is the close correlation of dates for similar depths in the main YSM on L Rd. (45 ± 4.1 ka), the RSM on Pine Rd. (42.9 ± 3.4 ka) and the SBD on Pine Rd. (38.8 ± 3.9 ka). From this relationship it is possible to propose that they represent contemporary depositional units within one active system. However, the older date gained from the Dunwerian Rd. sand monkey along with its geomorphic position (higher in the landscape and crossing the current catchment boundaries) and its pre-eminent appearance give good reason to suggest that it pre-dates the other former streams, although this does not rule out contemporaneous activity as well.

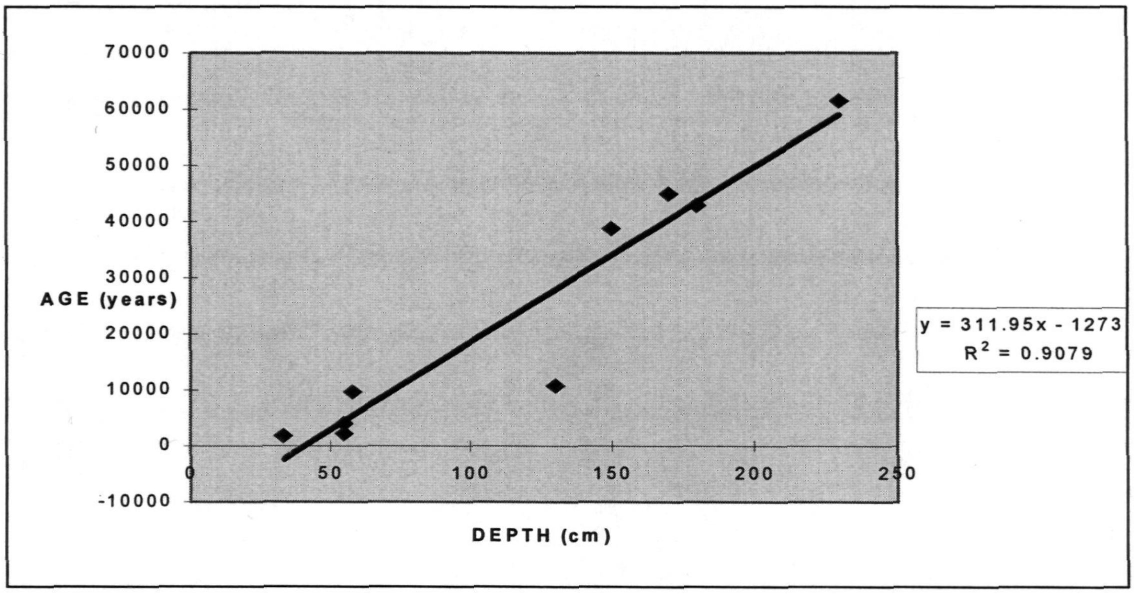
Drawing analogies with the current drainage it seems probable that the RSM is a former course of Etoo Creek, the drainage having switched to its current, lower position due to aggradation of the original bed. The base of the RSM also corresponds in height to the level of an existing inset terrace, presumably cut by Etoo Creek, suggesting that both the sand bodies lie within a channel belt where focus of incision, followed by deposition has shifted laterally (westwards in this case) over time.

Source bordering dunes have been widely documented in the Australian context, particularly related to Pleistocene and Holocene activity. Nott and Price (1991) described sand sheets a few metres deep, predominantly well sorted and medium-fine grained in the Shoalhaven area, sometimes only 200-300m from the source river and Butler (1950) identified source bordering dunes associated with prior streams on the Riverine Plain. Mabbutt (1984) described favourable conditions for source bordering dune development as follows; the middle sector of drainage with sands of moderate coarseness where channels run at right angles to the prevailing winds. These conditions closely approximate to those at Pine Rd. Furthermore several researchers (Cooke and Warren 1973; Mabbutt 1980; Pye 1987) also showed that the action of various transporting mechanisms including export suspension, local suspension, saltation and creep may result in bimodal or unimodal particle size distributions in source bordering dunes.

The SBD sampled on Pine Rd. matches many of the conditions and characteristics described by previous researchers and its age correlates strongly with that of the adjacent RSM. Coupled with the sedimentological evidence showing a broadly comparable particle size distribution this points to the RSM as its likely source.

Plotting the dates - not including the clay - against the depth from which the samples were taken shows a reasonable linear correlation (r-squared equals 0.908, see Fig. 17). The simplest explanation for this trend would be that all the sandy materials above the clay represent one depositional body that has accumulated steadily for at least 60 ka. Extending this hypothesis, the differences in the nature of the material at various points in the landscape would represent distinct sedimentary facies within the one system. However this explanation is not totally convincing as the stratigraphic relationships indicate a more complex history. The dating samples are highly sensitive to bioturbation, and given the extent of soil faunal and floral activity in the area, the dated samples from the near surface sediments may not reflect the true age of those materials ie; the length of time since deposition.

**Fig. 17.** Age versus Depth




This issue can be explored by considering the four dates from the main yellow sand monkey:

- 2140 aBP at 50-60 cm
- 10710 aBP at 130 cm
- 45000 aBP at 160-180 cm
- 615000 aBP at 220-240 cm

At least three alternative hypotheses can be considered to account for this set of dates.

1. Continuous fluvial deposition as described above, beginning at least 61.5 kaBP and persisting up to the near present. To sustain this hypothesis, a large increase in the rate of sedimentation is required from around 10 kaBP and an even larger increase from approximately 2 kaBP (Table 8). Thus rapid deposition in the recent past is needed but this is not supported by sedimentological evidence. For example the upper layer does not show larger mean grain size or increased gravel content, as might be expected during a phase of rapid deposition. Similarly there is no evidence of sedimentary structures which are more likely to survive during such recent periods of rapid sediment accumulation.

**Table 8.** Required rates of sedimentation *

| DEPTH DEPOSITED | TIME PERIOD | LENGTH OF TIME (ka) | APPROX. REQUIRED RATE (cm/ka) |
|---|---|---|---|
| 50 cm | ~ 2 - present | ~ 2 | 25 |
| 80 cm | ~ 10 - 2 kaBP | ~ 8 | 10 |
| 50 cm | ~ 45 - 10 kaBP | ~ 35 | 1.5 |
| 60 cm | ~ 60 - 45 kaBP | ~ 15 | 4 |

* These data have not been corrected for minor differences in bulk density (Appendix 4)

2. Sediment accumulation in two stages, with a depositional hiatus or 'switching-off' of the system sometime after 45 kaBP and re-activation at or before 10 kaBP. This scenario also requires rapid Holocene deposition and may be expected to show some sedimentological distinction between the two phases as noted above. Like the previous hypothesis, it is also necessary to account for the increase in sedimentation rate within the last 2 ka in a landscape position of a localised topographic high.

3. A third hypothesis involves active stream deposition until no later than 45 kaBP, which brought the surface of the sand monkey up to its current level. Approximately coeval or just after this fluvial activity switched to other areas leading to the formation of the RSM and SBD. However, for this to occur it is necessary to explain the upper two dates (2 and 10 ka) which must be regarded as anomalous. Thus a mechanism is required that will lead to younging of the near-surface sediment (at least down to 130 cm). Such an effect may be achieved through bioturbation, the upper 1.3-1.5m has since been constantly reworked and bioturbated through the action of termites, ants, other invertebrates, burrowing animals and trees uprooting, leading to a type of biomantle described previously by Humphreys and Mitchell (1983;1988), Humphreys (1985) and Johnson (1990) among others.

The extent of this reworking is considerable and evidence presented in Chapter 6 suggests that the two lower dates may also be affected. This has obvious direct implications for post depositional modification of the sand bodies and as such will be addressed further in the next chapter. Of relevance to stratigraphic interpretation is the effect of bioturbation on the validity of the dates calculated for the near surface sediments. Briefly, the displacement of subsurface material (particularly of sand size) and its subsequent redeposition on the surface will facilitate the burial of charcoal, used in each case to date the near surface material. Aside from becoming deeper in the sand body due to the above mechanism, large pieces of material have also been found to sink through sedentary sand deposits (e.g. Moeyersons, 1978; Johnson 1990). Hence the age calculated for a piece of charcoal within the zone of bioturbation is likely to be much younger than the actual depositional age of the sediment in which it lies.

In the case of the TL dates taken from quartz grains at 150-160 cm and 220-240 cm, evidence suggests that these dates may also be affected by bioturbation. Exposure to sunlight 'resets' the TL clock, thus the date gained will represent the last time that the material was brought to the surface, and so can only be treated as a minimum age, even if only partial resetting occurs. Similar qualifications apply to the interpretation of the dates taken from the sandy topsoil of the texture contrast soil (Table 7, sample codes 963, 964, 969). The proposed model for genesis of this material, as outlined in Chapter 2, favours its description as a layer, genetically separate to the heavier textured subsoil, that is continually undergoing overturn through bioturbation and exposure to surface processes. Due to its shallow depth (< 0.5m), evidence suggests that its entire volume is subject to the effects of bioturbation. Hence, any dates taken from this material can only be assumed to represent a minimum age of the sediment.

Given the opportunity for further research, more detailed investigation into the nature of the sand bodies associated with Talluba Creek and comparison with those near Etoo Creek, especially in terms of dating has the potential to confirm the observations of this study or conversely highlight the need for more thorough investigation. A further avenue is into the spatial distribution of the main sand monkey to the south where, logging activity, current sedimentation and bedrock outcrop make mapping through API difficult. The channel geometry, stratigraphic relationships with current drainage and age of the sediments would all prove instructive in assessing local palaeohydrological conditions.

## 5.5 CONCLUSIONS

In summarising the basic features of the stratigraphic sequence in the study area, it is necessary to take into account the planform and cross-sectional spatial relationships and the provisos concerning the dating results. With respect to these factors a likely depositional history for the Pilliga is as follows:

1. Deposition/Weathering in situ of the sandy clay facies overlying the Pilliga Sandstone, at some time >100 kaBP.
2. At the very latest by 60 kaBP, incision of the clay surface by sand/gravel load streams.
3. Net aggradation of these streams up until no later than 40 kaBP, along with formation of SBDs.
4. Abandonment of former streams and switch to current drainage tracts (or other, more recent former channels).
5. Bioturbation overturns the upper layer of sediments in all places, affecting the age relationships as represented by the dates attained.

# CHAPTER 6

# POST DEPOSITIONAL MODIFICATION

## 6.1 INTRODUCTION

The age results presented in the previous chapter show that the sand bodies have persisted in the landscape for at least 40 ka and probably longer than 60 ka in some cases. This latter date extends back into Oxygen Isotope Stage 4 (Nanson *et al.* 1992) and given the fluctuation in climate and vegetation (Dodson and Wright 1989) that has occurred in the ensuing period along with the magnitude of time involved, it is reasonable to expect that some alteration of the sand bodies would take place. The work presented in this chapter aims to assess the result of pedogenetic processes and the effect of post depositional addition or removal of material on the character of the sand bodies.

In order to assess the extent of post depositional modification (PDM) successfully it is necessary to have some understanding of the original condition of the bodies at the time of deposition. In the absence of a clear understanding of the geomorphic character of the former streams, it was decided that it would be appropriate to use the contemporary creeks as a depositional analogue or a starting point from which to measure PDM. This assumption involved here is based on several factors:

- the creek sand and the sand monkey sand contain substantially the same material.
- both have the same exclusive source - the Pilliga Sandstone.
- drainage is in virtually the same direction.
- a similar calibre of gravel is observed in both deposits

- there is no evidence for widespread geomorphic alteration of the catchment over the time period being considered, such as faulting, uplift, intrusion or subsidence, other than the erosion and deposition under evaluation.

Particle size analysis, the results of which are presented in Chapter 4, identified four issues to be addressed within the context of PDM. Comparison between the sand monkeys and the current creeks showed up two principle differences that required explanation and two more were identified through independent analysis of various sand body profiles.

1. The sand monkeys have a mean mud (<63 micron fraction) content ~6 times that of the contemporary creeks.
2. The sand monkeys display an earthy fabric, as opposed to the single grain sand fabric of the current creeks.
3. The samples taken from the upper layer of the sand monkeys (nearer the surface) show significantly higher mean gravel percentage than those from lower down.
4. The sand bodies show a complete lack of sedimentary structures.

## 6.2 METHODS

The methods used to characterise the materials for assessment of PDM were essentially the same as those outlined in chapter 4. In addition further techniques were employed.

Bulk density data collected during the course of an undergraduate project are used (Appendix 4). It was obtained by weighing an oven-dried (at 105° for 24 hours) 100

$cm^3$ volume of material, at various depths down the main yellow sand monkey profile. Particle size data and volume measurements of ant mound material conducted for the above project are also used here (Appendix 5).

Fourteen Kubiena-tins (9 cm x 9 cm x 5 cm) were used to obtain undisturbed material at different depths in the main sand monkey. These were analysed under a binocular microscope in the laboratory, using a suction tube to carefully remove material. This allowed broad description of the fabric of the samples and assessment of the amount of material affected by recent bioturbation, by identifying active channels and pedotubules following the techniques in Humphreys (1985, 1994).

Thin sections were cut from impregnated blocks of material with intact fabric, and observed under a polarising petrological microscope and photomicrographs were taken (Fig. 19). Using this technique, the fine microstructure and grain to grain relationships in the sand monkey materials were analysed.

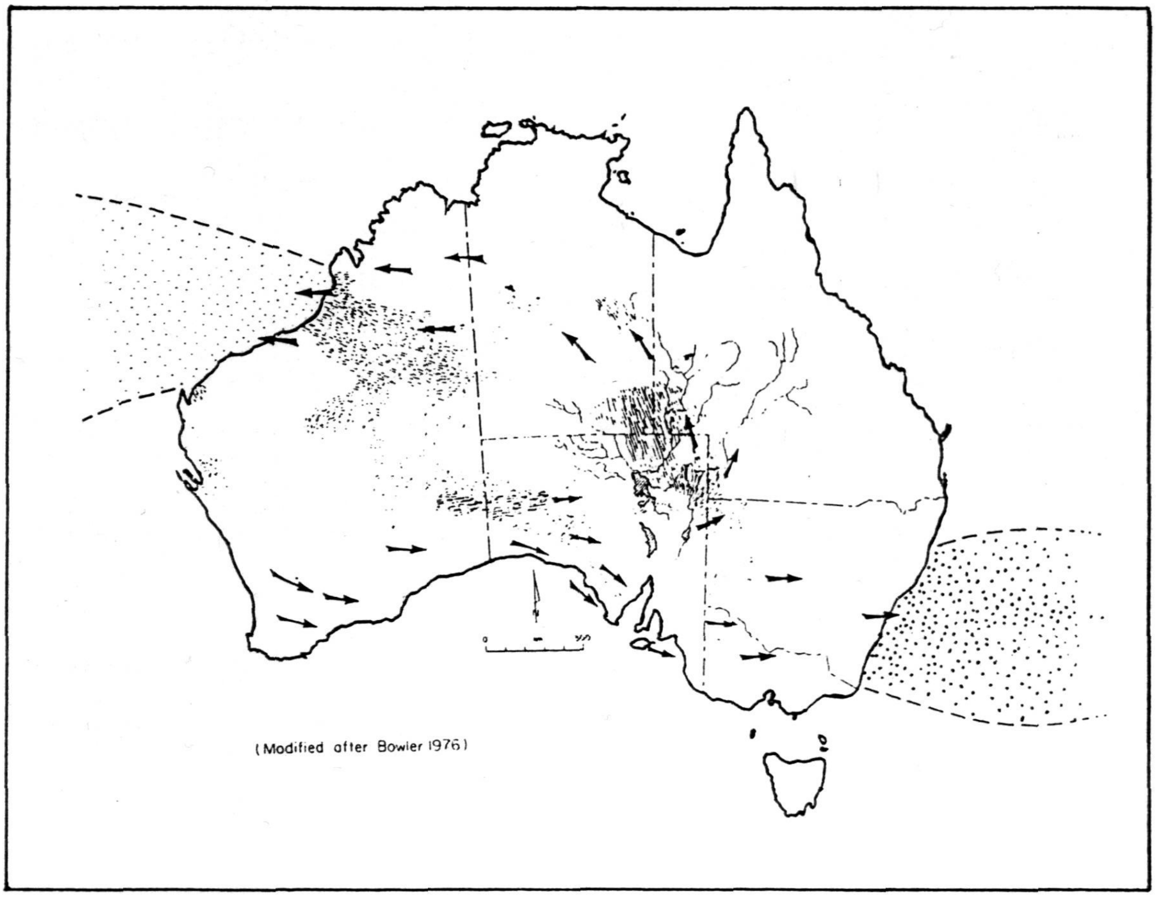
A final method employed in an effort to resolve the provenance of the mud fraction was X-ray Diffraction (XRD) analysis. The <63μm fraction was isolated and analysed through this technique which provides bulk mineralogy of the sample, as per Dunitz (1995). Samples were taken from the RSM on Pine Rd., the YSM at Dunwerian Rd., the SBD on Pine Rd., the sandy clay subsoil adjacent to the gilgai on Pine Rd. and the columnar clay subsoil underneath the mallee vegetation on Dunwerian Rd.

## 6.3 MUD PERCENTAGE

As identified earlier, the sand monkeys contain considerably higher mean mud percentages than do the creek sands. There are two feasible explanations for this result. One is that the former streams (sand monkeys) carried a mixed sediment load including a gravel/sand component and a mud fraction as opposed to the almost exclusive gravel/sand load in the present-day creeks. This explanation requires a considerable change in river style from lower to higher energy. Such a change is not supported by sedimentological or planform evidence (Fig. 16). The second possibility is that the sand bodies have received a secondary input of mud-sized material subsequent to original fluvial deposition.

Assuming that the two streams systems are not of a fundamentally different character, then a source of the secondary mud must be found. Given the particle size of the material in question and the geomorphic situation of the study site, the most likely source is aeolian. A possible source for this material is the Lake Eyre Basin. McTainsh (1985) argues that soils over large areas of NSW, Victoria and Queensland received significant aeolian input from this area during arid phases of the Quaternary, an idea supported by Bowler (1976) and Sprigg (1982), see Fig. 18. The Pilliga lies within the proposed area of reception of this material and the fact that the sand monkeys show an age of at least 40 ka, which spans the arid phase of Oxygen Isotope Stage 2, suggests that they would have been influenced by such large-scale aeolian deposition.

**Fig. 18.** Quaternary dust systems (from McTainsh 1985)




Examination of the particle size distribution of the SBDs, Fig. 14 shows a strong peak at 250μm, and very little fine sandy material. The fact that these bodies also contain a significant separate (in terms of particle size distribution) mud proportion suggests that formation took place as a result of two depositional episodes. The primary development of the sandy SBD followed by subsequent aeolian accession of fine (<63μm) material. This interpretation conforms with the observations of Butler and Churchward (1983) who state that source bordering dunes generally do not contain a primary dust component. It is sometimes possible to positively identify aeolian input when the mineralogies of the dust and the underlying lithology are very different (Chartres 1982). Arditto (1983) found that the clay fraction of the Pilliga Sandstone contains mostly authigenic kaolinite formed through the interaction of ground water and small detrital grains within the sandstone and Hallsworth and Waring (1964) also found kaolinite to be the dominant clay mineral in the Pilliga soils. Chapter 4 established that the sand monkeys are sourced solely from the Pilliga Sandstone, hence if the mud fraction could be shown to contain a significant proportion of clay minerals other than kaolinite, then it would be reasonable to assume that it has come from an outside source.

In order to trace the source of the mud fraction within the sand bodies, XRD analysis was conducted on the $<63\mu m$ fraction since only bulk mineral composition was required. This showed that in all the materials tested, including sand monkeys and SBD, the mineralogy was dominated by poorly crystallised clay and an overwhelming abundance of quartz. These factors were responsible for the generally inconclusive results. Kaolinite was the only clay mineral positively identified suggesting that any other minerals occurred only in trace amounts. Overall, the information gathered through this technique has proved of little value to the study.

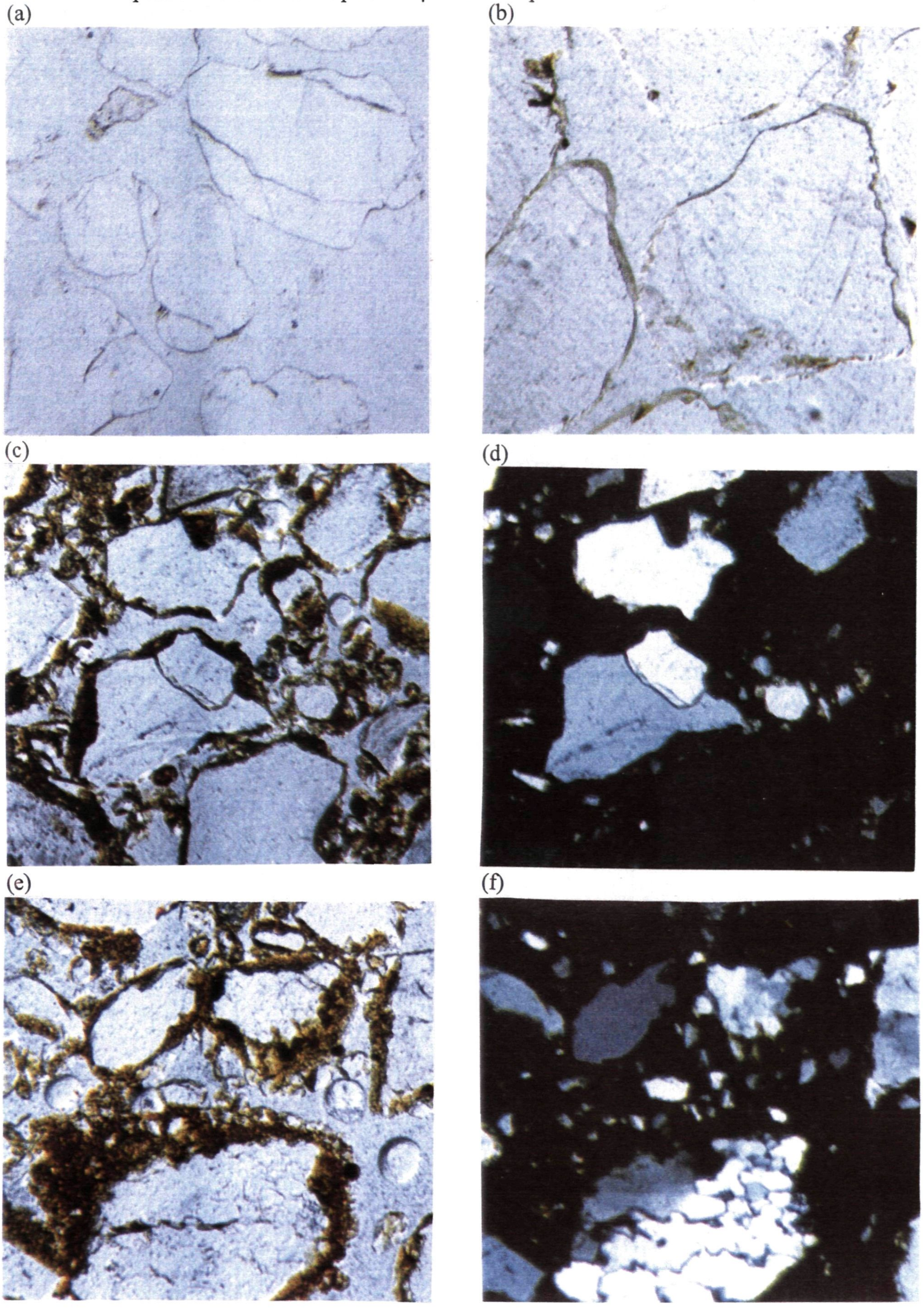
## 6.4 EARTHY FABRIC

Related to the high mud percentage detected in the sand monkeys and the SBD is the presence of an earthy fabric. Stace *et al.* (1968) recognised this fabric as typical of the Great Soil Group of Earthy Sands, but made little attempt to explain its genesis. Their description shows that an earthy fabric has fine clay and oxide particles coating and forming bridges between quartz grains.

In thin section the fabric of the YSM shows fine particles form coatings and braces of variable thickness around and between most, but not all quartz grains, (Fig. 19). In the terminology of Bullock *et al.* (1985), the related distribution pattern is intermediate between gefuric and chitonic. These means the larger particles retain a skeletal function but that it is supported in patches or domains of finer material. This type of arrangement retains a porous nature.

Accounting for the genesis of the gefuric/chitonic microstructure is somewhat conjectural. However, it is difficult to explain how this type of fabric could form through fluvial or aeolian deposition. The question that is relevant to this study is whether an earthy fabric, such as is observed, will form from the simple mechanical inwashing and pervection of clay or whether some further mixing process is required. When viewed in thin section, it was noted that the thickness of the coatings around the quartz grains is variable as is that of the bridges, to the point of being absent in some places. If the clay were simply washed through the profile vertically from the surface, one may expect the coatings on the upper surfaces of the grains to be generally thicker. This theory can be tested, as the orientation of the slides is known. No such preference was observed.

**Fig. 19.** Photomicrographs of in tact fabric. (a), (b) Etoo Creek, showing single grain fabric with large pore spaces, plane polarised light, (c) main sand monkey, Dunwerian Rd., 15 cm depth, plane polarised light, (d) same photo, under crossed polars, (e) main sand monkey, Dunwerian Rd., 85 cm depth, plane polarised light, (f) same photo, under crossed polars. Field of view equals 650μm in each photo.



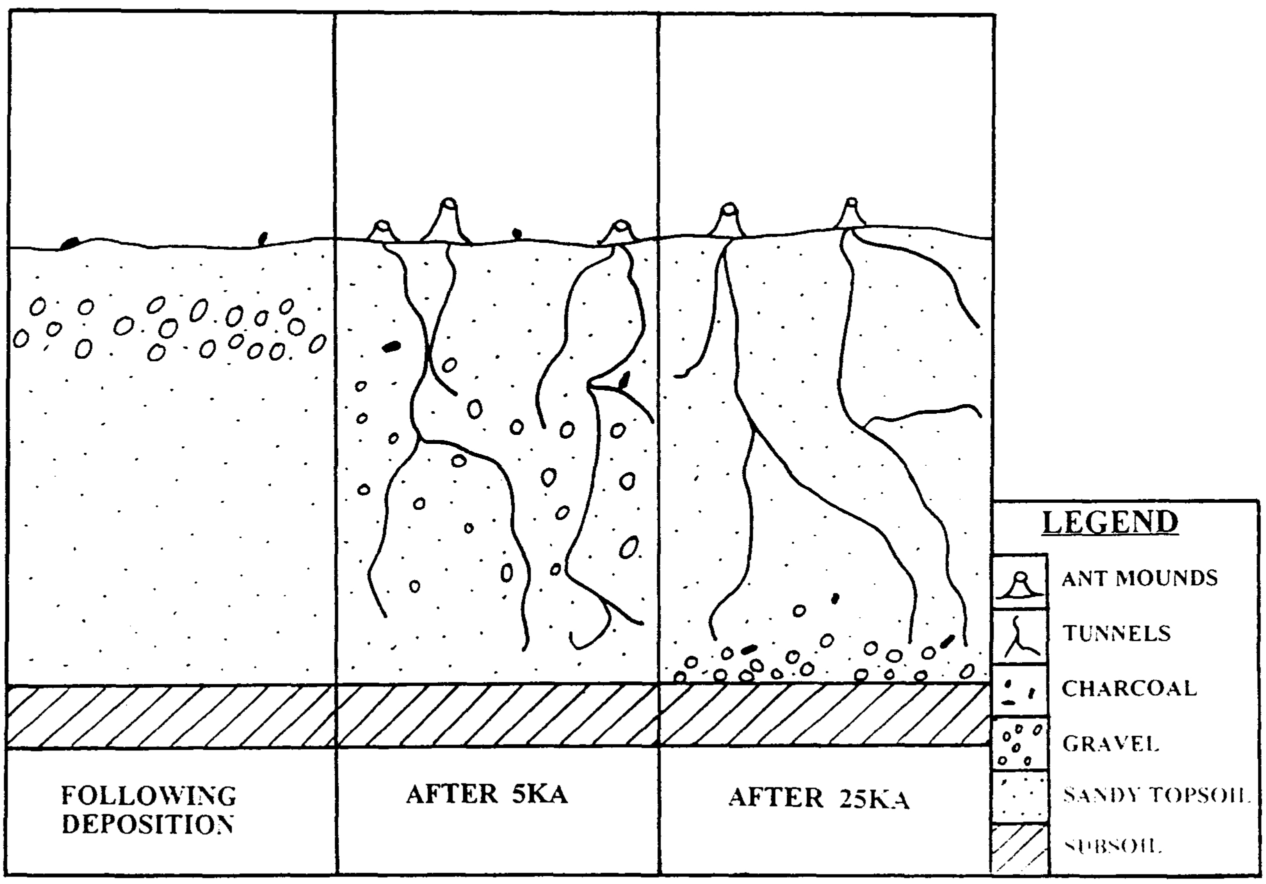
This led to the proposition that some form of overturn or mixing of the material has occurred. Mechanical turnover as might be expected in shrink-swell clay material is not likely given the sandy nature of the sand monkeys and low proportion of reactive clays. However, an equivalent effect may be produced by bioturbation which is known to occur at the study site. The action of ants and termites in particular, digging tunnels and nests and transporting material to the surface constantly realigns the particles in relation to the surface and any finer material washed in will end up randomly distributed about the quartz grains.

## 6.5 PARTICLE SIZE TRENDS WITH DEPTH

Samples taken from greater depth below the surface of the sand monkeys (1.5-2 m) showed significantly higher mean gravel content than those from near the surface (0.25-0.5 m), see Table 6, Fig. 12. This trend was evident across all sand monkeys sampled, regardless of colour, size or relative topographic position.

These results indicate an homogenisation of the upper layer, as compared to the lower samples. Humphreys and Mitchell (1983) identified bioturbation as having this effect due to the finite size range of the material that can be moved by soil fauna. At the study site analysis of the mound material of the most active species was found to be smaller than about 2 mm, ie; the ants only transport sand-sized material to the ground surface. As this material is being mined from the subsurface and transported to the top, anything larger is left to sink down through the profile (fig. 20). This process could be responsible for the gravel distribution in the sand bodies. A further result of this homogenisation is the destruction of residual sedimentary structures, as the material forming these structures is overturned and redistributed.

**Fig. 20.** Schematic, showing the effect of bioturbation on gravel and charcoal in a sandy substrate




A further trend apparently related to depth, is the tendency for mud content to fall towards the base of the sand monkeys, see Fig. 15b. The sharp rise near the subsoil contact is anomalous, due to clayey subsoil material being picked up by the auger and included in the basal samples. This reduced mud content may be caused by ground water flow through the sand monkeys following periods of heavy rain which presumably removes fine material laterally. It was noted in the field that sands just above the subsoil in the sand monkeys are often cleaner and whiter with a coarser field texture, as well as being less muddy than sands above.

This theory is supported by Waring's (1950) study that found ground water at the base of three sand monkey deposits following rain and cites anecdotal evidence of farmers sinking wells on sand monkeys. Very wet sediment was also found at the base of one sand monkey during the course of this study confirming Waring's observation that they still form drainage lines after rainy periods.

Alternatively, the trend may be explained in terms of the mud not having reached these depths due to insufficient time. However, this is difficult to reconcile with the fact that a mud depleted zone, commonly about 50 cm, thick is found above the basal contact regardless of the depth of the sand monkey.

The same trend is not observed in the SBD profile, which shows a slight but consistent increase in mud content from the surface to the base of the deposit. Such a trend provides evidence in favour of the genetic model proposed for the SBD, in that this deposit is formed on the side of a slope and does not appear to be a former drainage tract and presumably, does not experience the lateral removal of fines through ground water action. This may also account for the higher overall mud content within the SBD as compared with the sand monkeys, despite their similar age and hence time of exposure to outside aeolian input.

## 6.6 BIOTURBATION

The effect of bioturbation on soil formation and development can involve the action of many processes, several of which are directly relevant to the situation in the study area, these include; the action of ants, termites and other invertebrates in depositing subsurface material above ground in the form of mounds, nests, sheeting and spoil from excavation, trees uprooting during windy periods overturning localised sections of sediment and the activity of mammals, birds and reptiles in burrowing, excavating and nesting in the near surface soil.

Of these, the first is considered to be the most important in terms of its effect on the sand monkey sediments. Ants of the genus *Aphaenogaster* (probably *A. barbigula*), are abundant on the sand monkeys, to the extent that their distinctive conical mounds are an important marker signifying the presence of sand monkeys, (see chapter 3, Road Traverses). At the time of the study, the mean volume of material in *Aphaenogaster* mounds on one sand monkey was 121.5 $cm^3/m^2$. This total was calculated by finding the mean volume of material in one ant mound and multiplying this by the average number of mounds per square metre, recorded in a 20m x 20m quadrat. Rates of mounding by *Aphaenogaster* on the sand body have not been measured, However, in western NSW, Eldridge and Pickard (1994) recorded mounding of $336 g/m^2/y$ on sandy aeolian soils where the rainfall averages about 350 mm per year. This is about 40% of the rate of mounding by A. *longiceps* recorded on sandy soils at Cordeaux, where the average annual rainfall is approximately 950 mm (Humphreys 1985). On this basis, a mounding rate of about $450\text{-}500 g/m^2/y$ might be expected in the Pilliga (average annual rainfall 600 mm). Mounding only represents an unknown proportion of total soil bioturbation since it does not include subsurface mixing.

Hart (1992) made a more extensive examination of the rate of termite overturn on different sites in the forest. Her study found that the top 10 cm of soil would be overturned in 261-1014 years (depending on vegetation type), this is noted to be a greatly overstated time period as only termite sheeting was measured. Although this study was not conducted on a sand monkey it does highlight the enormous potential for faunal overturn of sediments in the Pilliga.

Aside from the pedogenetic effects of bioturbation, overturn of the sediment has serious implications for the interpretation of dates obtained from within the zone affected by bioturbation. As mentioned in the previous chapter, both AMS and TL techniques are very sensitive to overturn of sediments that are being dated and have the potential to show dates that are significantly younger than the actual depositional age.

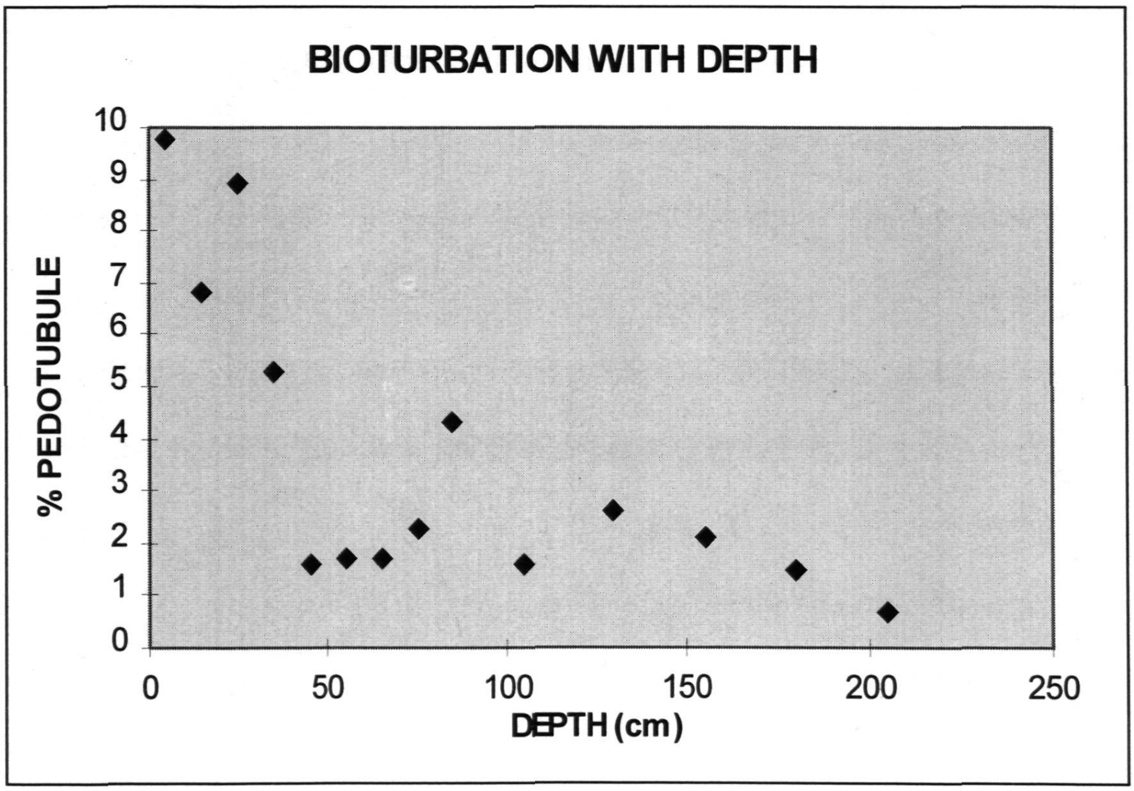
The dates gained for the upper two samples in the main sand monkey (50-60 cm and 130 cm) were taken from AMS dating of pieces of charcoal (b-axis >2.8 mm), the age thus gained corresponds to the date the charcoal was burnt and deposited on the ground surface. In order that the charcoal represents the age of the sediment in which it lies, it must be covered by newly deposited sediment soon after burning and remain within this strata until excavated for dating. Where there is significant bioturbation of the type observed in the Pilliga, the charcoal is quickly buried, but by sediment removed from beneath it by soil fauna and transported to the surface. The effect is that the charcoal will sink through the profile and the age it shows will bear little resemblance to the age of the sediments from which it has been taken, see Fig. 20. Taking into account this process, the only interpretation that can be made of the dates is that the sediment from which they have come is certainly not younger than the ages calculated.

The depth of soil affected by bioturbation is dependant mainly on the species responsible, but also the depth at which any depositional or authigenic barriers may occur, such as large gravel lenses or indurated zones. Kubiena tins were obtained at close intervals from the surface to a depth of 2.09 m. The percentage area of active faunal channels and pedotubules was determined for each tin by analysing the micromorphology of the fabric at low magnification. This size of this area is assumed to be representative of bioturbation rate (Humphreys 1994). Evidence of bioturbation was observed to at least 2 m, but the rate of overturn appears to decrease with depth (Fig. 21). A similar result was reported by Humphreys (1994) in a 40 cm thick, fine sandy loam topsoil in a texture contrast soil.

Bulk density data shows an increase of ~0.1 g $cm^{-3}$ at approximately 0.5-0.6m depth, suggesting that this level may define a limit for a particular species or type of excavation. Several factors also point towards the fact that there is a significant fall in the rate of overturn at a depth of 1.3-1.5m.

- The dates for the main sand monkey display a large difference (~35 Ka) between the 130 cm sample and the 150-160 cm sample.
- The wide variation of gravel content comes from depths of 1.5-2m. As ants do not move coarser, gravel-sized material, an accumulation can be expected below the zone of active bioturbation.
- The existence, at 1.85-2.10m of fine (1-2 mm x 4-5 mm) iron oxide bands. These are probably formed by secondary mobilisation and oxidation of iron minerals through the action of sub-terranean water flow. The presence of such delicate features suggests relative stability of the sediments and hence a much reduced rate of bioturbation at this depth.

**Fig. 21.** Rate of Bioturbation with depth



## 6.7 CONCLUSIONS

Up until this study, work on the sand bodies in the Pilliga had involved little more than speculation of their fluvial origin. This chapter has shown that a strong case can be made for substantive modifications of the original sand bodies during all or part of the last 40 - 60 ka.

Accepting that the current creeks can be used as depositional analogues for the sand monkeys - but giving due regard to the assumptions that this entails - it is obvious that a significant input of fine (<63μm) material has occurred. The most likely source is aeolian dust from the Lake Eyre Basin, probably entrained during the most recent Pleistocene arid period, Oxygen Isotope Stage 2.

Bioturbation, reworking the near-surface sediment, probably to a depth of at least 2m, began soon after channel abandonment. Mostly through the work of invertebrates, material has been constantly removed from the subsurface and re-deposited on the surface. Through this mixing action, aeolian clay that is being washed through the profile is re-organised into an earthy fabric. Also as a consequence of this reworking, gravel, that cannot be moved by the soil fauna has moved down to below the zone of bioturbation.

A zone of variable depth, immediately above the sandy clay basement of the sand monkeys still acts as a conduit for ground water. This zone is depleted of mud-sized particles by lateral transport, leaving generally cleaner sand than that which is above.

It is significant that this does not occur in the SBD, providing further evidence for a different mode of deposition.

In isolation these fragments of evidence suggest of the possibility of bioturbation causing alteration of the sand bodies of the Pilliga. Considered together they are confirmation of the enormous impact of biological activity and its potential for PDM. The creation of a kind of biomantle (Johnson 1990) in the sand bodies along with considerable aeolian dust accession has greatly altered the nature of the sand monkeys, as is evidenced by their differences to the current creek sediment.