CRCLEME
Cooperative Research Centre for Landscape Evolution & Mineral Exploration

AEOLIAN DUST: IMPLICATIONS FOR AUSTRALIAN MINERAL EXPLORATION AND ENVIRONMENTAL MANAGEMENT

Australian National University Symposium

FIELD GUIDE

Aeolian Material in the Yass River Valley

Compiled by
K.M. Scott, X.Y. Chen and R. Gatehouse

CRC LEME REPORT 101

25 & 26 November 1998

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CRC LEME is an unincorporated joint venture between The Australian National University,
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INTRODUCTION

This field trip to four sites in the Canberra-Yass area (Figure 1, see also Figure 17 for geology) aims to demonstrate profiles where the aeolian component is significant. It shows that in many cases the aeolian component is not immediately obvious and requires detailed study to prove its presence, especially where it is admixed with residual soil.

The field trip demonstrates that no one technique/discipline provides all the information necessary to develop an understanding of the aeolian deposition processes. Only by the integration of geomorphology, soil science, geochemistry and mineralogy will the regolith geologist be able to elucidate some understanding of the regolith processes and landscape evolution.

This field guide provides information on the four sites from various disciplines. We ask you to investigate how information outside your discipline can help you in your studies.

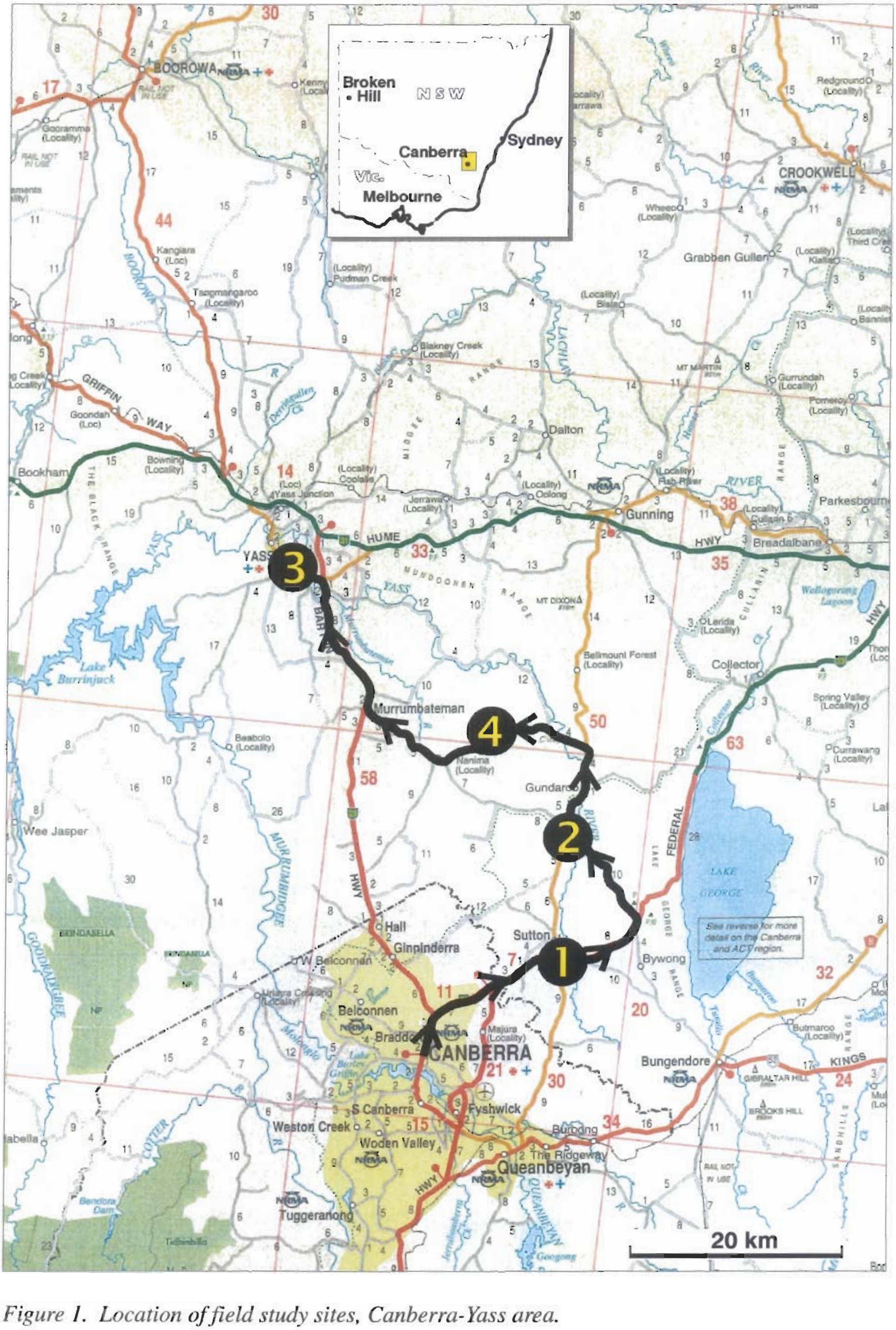

Figure 1. Location of field study sites, Canberra-Yass area.

1. SUTTON FIELD SITE: X.Y. CHEN, K.M. SCOTT

Location: 35° 10' 41" S 149° 17' 20" E
Elevation: 640m a.s.l.
Bedrock: Adamellite
Aeolian component: Small amount of aeolian material in top 1 metre

At this road cutting 2km south east of Sutton and adjacent to Canberra-Goulburn freeway, shallow soils and underlying adamellite saprolite are exposed (Figures 2 and 3). Several quartz veins extend through the saprolite into soils and stone lines in the soils indicate downslope movement (colluvial processes). The soils here include lithosols (Rudosols and red podzolic soils (red Chromosols), very commonly seen on such rolling low hills and rises of granite in this region. The morphology and occurrence of the soils do not give any evidence of aeolian dust additions.

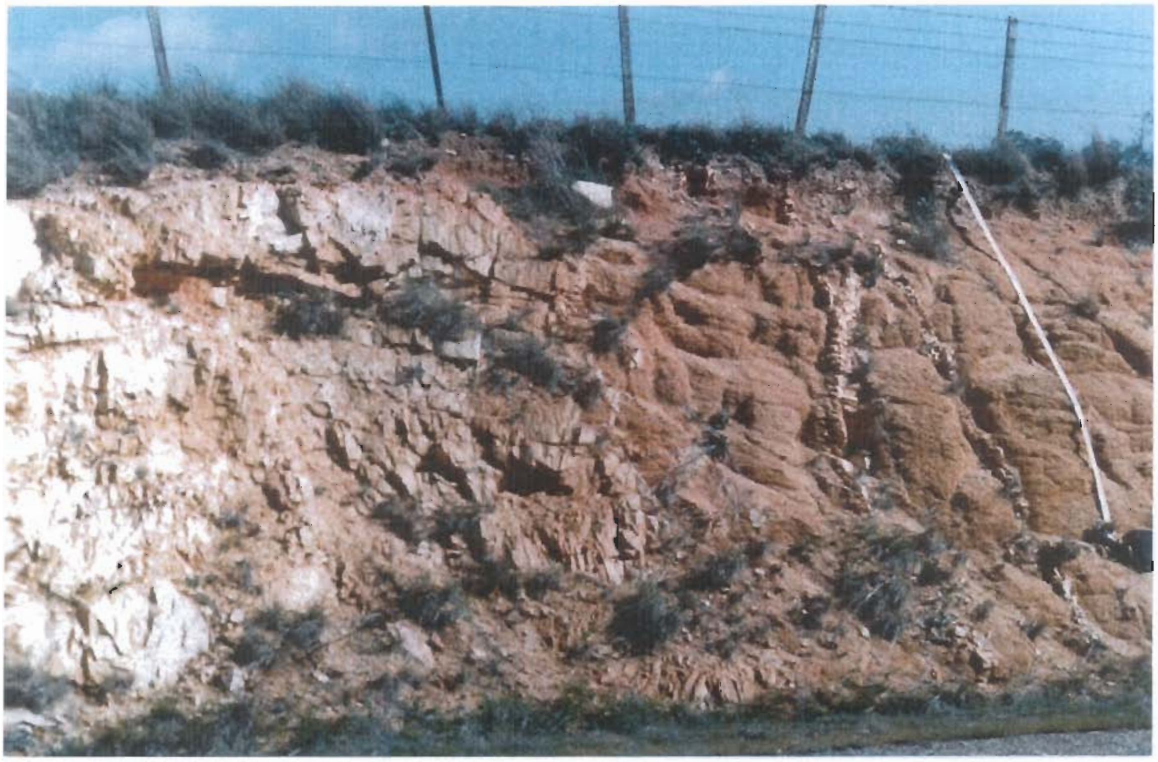

Figure 2. Sutton road cutting, showing veins through saprolite.

However, a soil profile about 150m northeast of this road cutting has been studied in great detail and the researchers (Walker *et al.,* 1988; Chartres *et al.*, 1988) concluded that substantial aeolian dusts are present in the soil. Unfortunately, the profile was studied from hand auger hole and no exposure available.

Some descriptions and data of the studied profile are extracted from Walker *et al.*, (1988), Chartres *et al.*, (1988) and Chartres and Walker (1988) as follows:

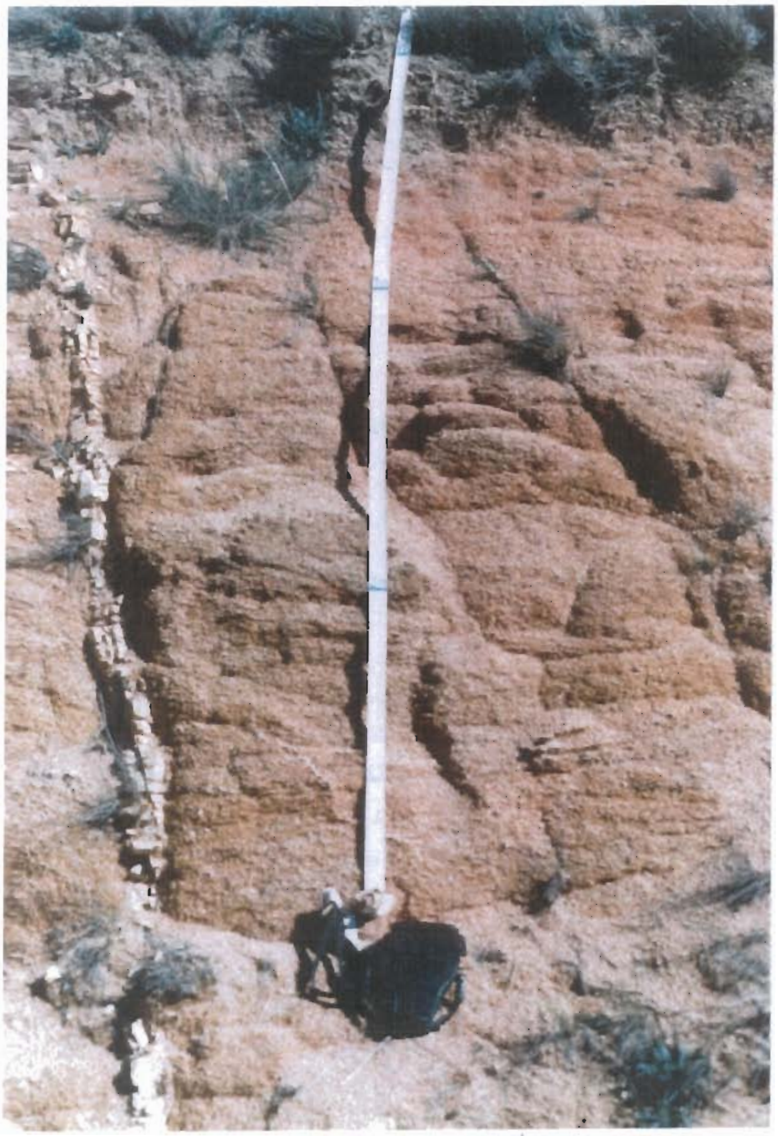

Figure 3. Detail of vein and soil, Sutton.

Profile Characteristics

The site sampled at Sutton was located on a hillcrest developed within a small (10 km^2) outcrop of adamellite containing some aplite dykes and quartz veins, particularly near the summit of the hill. The soil profile in the auger hole shows an abrupt change from sandy loam to clay at 31cm (Table 1).

Table 1. Soil profile at crest of hill, Sutton (after Walker *et al.*, 1988).

Depth (cm)	Horizon	Description
0-5	A_{11}	10 YRS3/3; coarse sandy loam; moderately firm in the dry state;
5-10	A_{12}	as above
10-17	A_{13}	10YR4/3; as above; clear change to
17-25	A_2	5YR5/6; coarse sandy loam; apedal; moderately firm in dry state; gradual change to
25-31	A_3	5YR5/6; coarse sandy loam; apedal; very firm in dry state; abrupt change to
31-37	B_{21}	2.5YR4/4; medium clay; moderate grade of coarse angular blocky structure; very firm in moist state;
37-47	B_{22}	2.5YR4/6; with 2.5YR4/4 on ped surfaces; as above; gradual change to
47-60	B_{31}	2.5YR4/6 with 5YR3/3 ped surface mottle; gritty light clay; moderate grade coarse angular blocky structure; cutan on ped surfaces; very firm; soft weathered feldspars in mica evident; gradual change to moderately firm to very firm weathered granite (clayey gravel) with occasional slightly clayey zones; grains covered with 2.5YR4/6 clay coatings but less so with depth
60-65	B_{32}	as above; gradual change to
65-150	C	2/5YR4/6 with 7.5YR3/3 ped surface mottle; clayey coarse sand and gravel; apedal massive structure; cutans on ped faces; becomes firmer with depth; occasional clay seams.

Chemical and Mineralogical Features of the Profile

Analysis of material from the profile shows that the A horizon is enriched in Si, Ti and Zr but depleted in Al, Fe, Mg, Ca, K, Ba, Co, Ga, Pb and V relative to deeper parts of the profile (Table 2). These features could be the result of weathering of the adamellite but the Ti/Zr ratios suggest that a major break occurs at 31cm.

B horizon material has high Al, Fe, Co, Cr, Ga, Ni and V but lower Si and Na than the other material in the profile. Such material also has higher Ti/Zr ratios than either the A or C horizons.

Table 2. Chemical composition of material from Sutton Profile (majors, wt%. minors, ppm)

Sample No.	109131	109133	109135	109136	109138	109140	109142
Horizon		A		B		C	
Depth (cm)	0-5	10-17	25-30	31-37	48-60	75-103	116-135
SiO_2	77.8	81.8	80.0	60.3	66.3	74.2	66.3
Al_2O_2	9.08	9.35	10.6	19.2	16.8	13.5	15.9
Fe_2O_3	1.10	1.05	1.58	5.53	3.97	2.40	3.96
MgO	0.15	0.11	0.15	0.52	0.54	0.51	0.92
CaO	0.52	0.47	0.48	0.57	0.75	1.29	1.13
Na_2O	2.81	2.96	2.81	1.54	1.61	2.39	2.19
K_2O	1.16	1.21	1.36	1.23	2.39	2.69	2.68
TiO_2	0.40	0.43	0.48	0.56	0.34	0.23	0.38
MnO	0.04	0.04	0.01	0.01	0.01	0.02	0.02
P_2O_5	0.06	0.03	0.02	0.03	0.02	0.02	0.03
SO_3	0.04	<0.01	<0.01	0.01	<0.01	<0.01	<0.01
Ba	180	200	230	280	430	480	670
Ce	47	40	32	30	30	78	110
Cl	30	30	20	<20	<20	30	20
Co	2	5	4	10	6	5	7
Cr	11	14	15	30	21	11	17
Cu	1	10	7	3	5	4	1
Ga	9	8	12	25	20	15	20
La	18	16	17	25	21	53	100
Nb	18	17	20	19	17	13	16
Ni	<5	<5	6	10	9	<5	7
Pb	21	17	17	25	20	25	22
Rb	40	42	48	58	85	95	99
Sr	100	97	100	95	96	130	160
Th	9	9	11	23	16	19	25
U	2	2	2	4	3	2	3
V	26	26	33	88	59	33	54
Y	20	22	22	24	25	36	81
Zn	15	11	11	29	33	19	32
Zr	260	270	270	150	99	99	150
Ti/Zr	9.2	9.4	10.6	22.0	20.6	13.9	15.2

Inspection of the mineralogical profile reflects this concentration of clays in the B horizon and lower abundance of plagioclase there (Figure 4).

Particle Size Distribution and the Nature of Quartz

A and C horizon material displays an unimodal particle size distribution with a mean in the medium-coarse sand range (Figure 5). However the B horizon material show a bimodal distribution with the greatest wt% values occurring in the clay range.

Close inspection of Figure 5 shows that there is a pronounced weight percent peak in the 62-31μm size class, which gradually decreases from A to B horizons and disappears in C horizons. These coarse silt particles are regarded as reflecting aeolian dust accession

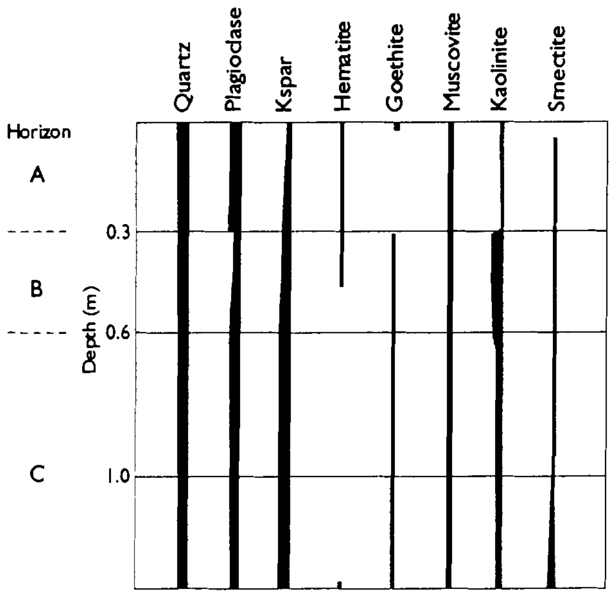

Figure 4. Mineralogical variations, Sutton Profile (after Dickson and Scott, 1990)

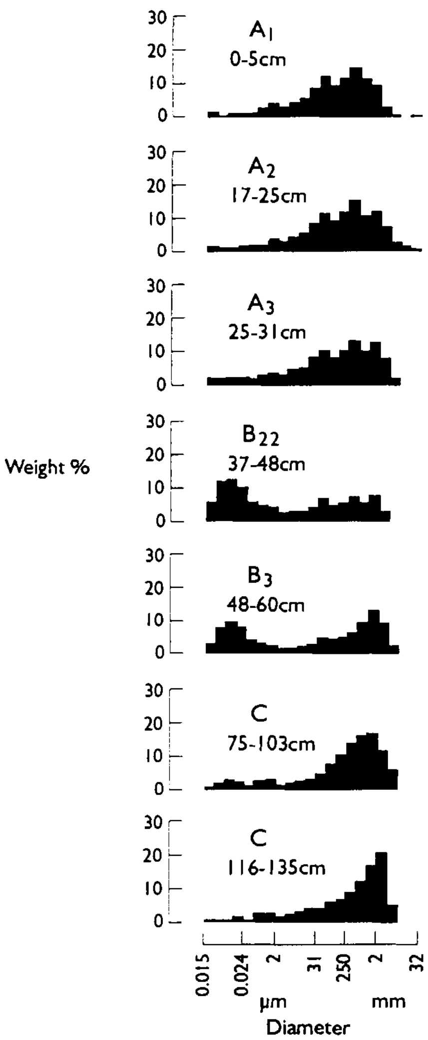

Figure 5. Particle-size histograms, Sutton Profile (after Walker et al., 1988)

Quartz grains in the profile behave differently, with those in the C horizon breaking easier than those in the A or B horizons (Walker *et al.*, 1988)

Oxygen-isotope Analysis

The oxygen isotopic composition of different sized quartz grains in soil and bedrock was analysed (table 3). The proportions of aeolian-deposited quartz in selected horizons are estimated, based on assumption that the aeolian-deposited quartz has a mean $\partial^{18}O$ value of 13.8 and the granite a mean value of 9.6

Table 3. Oxygen isotope analyses of soils and rocks, Sutton (after Chartres *et al.*, 1988)

Horizon	Depth (cm)	Size Fraction (μm)	$\partial^{18}O$ (%o)	Quartz Content (%)	Aeol-dep Quartz (%)	50-31μm fr.in hori. (%)	Aeol.-dep. (50-31μm) quartz as % of horizon
A_2	17-25	50-31	11.7	56	50	8.0	2.2
A_2	17-25	2000-250	8.7	69			
C	75-103	50-31	11.6	19	48	5.0	0.5
C	75-103	2000-250	8.9	36			
Adamellite	500	Crushed rock	10.1	26			
Aplite	200	Crushed rock	7.2	36			

Conclusion

Particle size analysis and oxygen isotopes indicate that there is a small component of aeolian material present in the soil developed above weathered adamellite at Sutton. Chemical and mineralogical study of the profile suggests that clay illuviation is important in the B horizon but chemical changes can still be seen in the profile. Such changes should alert the regolith geologist to the possibility of significant changes occurring with the profile.

2. SOUTH GUNDAROO SITE: X.Y. CHEN, K.M. SCOTT, R. GATEHOUSE

Location:	35° 4' 46" S 149° 15' 49" E
Elevation:	610m a.s.l.
Bedrock:	Sandstone/siltstone
Aeolian component:	At least 1.15m of aeolian material, deposited in at least two episodes

The South Gundaroo profile is an exposure in a road cutting across a low east-west ridge (elevation 610m), 5km south of Gundaroo. The exposure consists of a 2.5m thick sequence of sediment and soil on bedrock (Figures 6, 7 and 8).

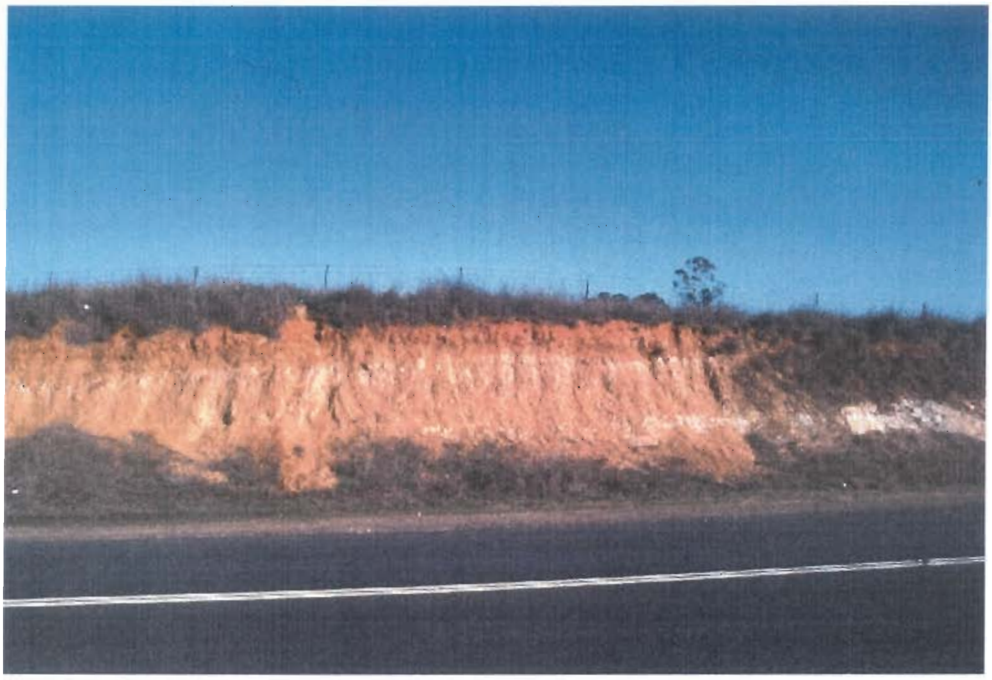

Figure 6. South Gundaroo road cutting.

Figure 7. Soil profile, South Gundaroo.

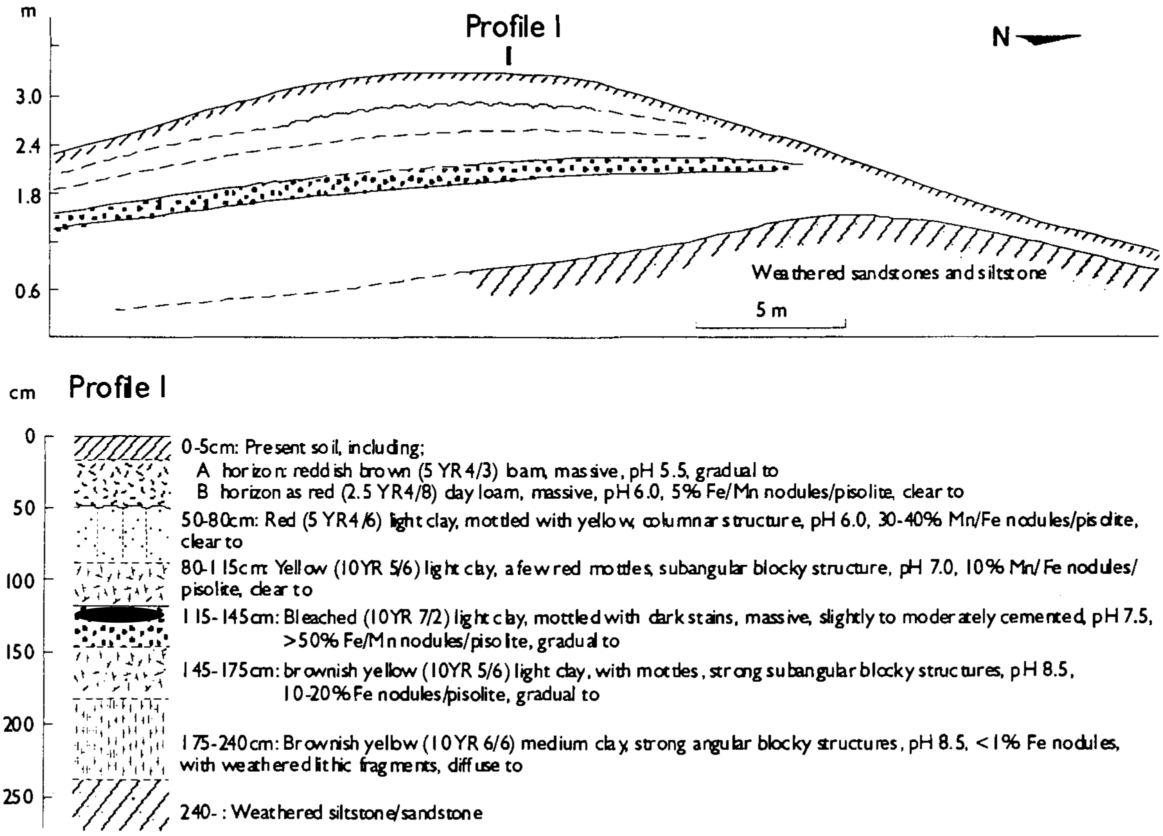

Figure 8. South Gundaroo road cutting and profile details.

Profile Characteristics

The bedrock consists of interbedded and dipping sandstone and siltstone. The upper surface of the weathered bedrock is highest at the northern slope of the ridge where the soil is thinnest (20-30cm). The bedrock slopes slightly downward from the crest to the southern slope. The soil and sediment are thickest at the crest of the ridge (Figure 8).

The lowest layer (175-240cm) contains fragments of bedrock and is interpreted as *in situ* weathering material. The particle size data (Figure 9) shows that the fine sand and coarse silt mode, that is evident in the upper profile, is absent from this layer. The overlying clay (145-175cm) retains the structure of the underlying material although no bedrock fragments are recognised. It tends to be mottled and pisoliths are present.

The bleached layer (115-145cm) contains abundant pisoliths and is interpreted as the A_2 horizon of the palaeosol. The original A_1 horizon was probably eroded before the overlying red and yellow clays were deposited. This A_2 horizon represents a major disconformity in the sequence. Soil morphological properties suggest that there is another major disconformity underlying the present soil at about 50cm below the surface.

The origin of the red and yellow clays overlying the bleached A_2 are interpreted as mainly from aeolian dust because:

1. The major unconformity indicated that the layers above the buried A_2 cannot be *in situ* weathered products;
2. Profile occupies a crest position, thus the soil and sediment are not likely to be derived from colluvial processes; and
3. The crest is located far from any major streams, thus the soil and sediment are not likely to be derived from alluvial sources.

The above interpretation does not exclude the possibility that some aeolian dust may also present in the sequence below 115cm.

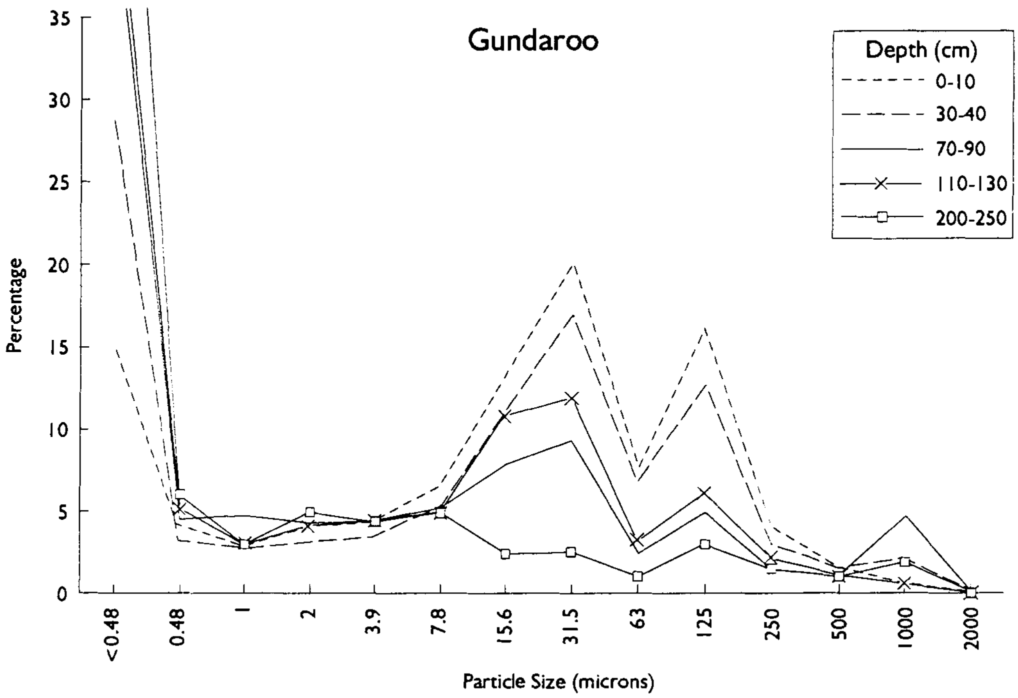

Figure 9. Particle-size distribution in soils at South Gundaroo

The particle size data (Figure 9) show a significant weight percent peak in the 63-16μm size class in the red clay, yellow clay and bleached A_2 horizon (115-145cm), but is totally absent in the basal layer (175-240cm). This is interpreted as evidence of aeolian dust accession. There is another weight percent peak in the 250-63μm size class (medium-fine sand) which is in the range of the particle size of dune sand. These concentrated medium-fine sands may be derived from local materials transported by wind as a saltation load.

Chemical and mineralogical features of the profile.

Analysis of the material from the profile reveals a significant geochemical break between the two basal samples and the overlying material (Table 4). The major differences are higher Al, Fe, Mg, Na, Ga, Sr (and V) but lower Si, Ti, Mn, P, Ce, La and Zr in the basal samples.

The material above 145cm is relatively similar despite some enrichment in Si and depletion in Al and Fe in the uppermost material relative to other samples. This similarity is reflected by Ti/Zr values varying between 12 and 15 relative to the values >20 for the basal samples (Table 4). The elevated K and Na in the upper two samples is however not consistent with normal weathering processes operating on *in situ* material.

Mineralogically the most obvious changes occur at 2.4m when the amount of feldspar, chlorite and mica decreases and goethite and kaolinite are formed as the rocks break down (Figure 10). There is no obvious change at 145cm. The presence of Kfeldspar in the profile above 0.7m is inconsistent with simple weathering processes.

Table 4. Chemical composition of material from South Gundaroo profile (majors, wt%; minors, ppm)

saprolite

Sample No.	138287 *	138288 *	138289 *	138290	138291	138292	138293
Depth (cm)	1	30	70	100	125	170	200
SiO_2	78.0	69.1	67.2	67.6	74.9	54.9	57.8
Al_2O_2	8.29	14.8	16.0	13.9	10.0	17.1	18.2
Fe_2O_3	2.73	5.03	4.44	6.29	5.73	9.54	6.22
MgO	0.32	0.49	0.52	0.48	0.43	0.77	0.94
CaO	0.18	0.21	0.19	0.13	0.13	0.20	0.23
Na_2O	0.30	0.25	0.17	0.17	0.21	0.31	0.67
K_2O	1.21	1.62	1.11	0.98	1.02	1.35	1.48
TiO_2	0.95	1.11	0.96	0.90	0.95	0.73	0.63
MnO	0.12	0.06	0.08	0.07	0.12	0.05	0.02
P_2O_5	0.08	0.06	0.04	0.04	0.04	0.04	0.02
SO_3	0.04	0.02	0.02	0.01	<0.01	<0.01	<0.01
As				12	12	19	8
Au (ppb)				<5	5.8	<5	<5
Ba	270	320	200	190	270	260	270
Br				2	<1	2	0
Ce	61	91	69	76	110	50	28
Cl	70	90	150	60	<20	110	340
Co	11	11	20	25	28	36	7
Cr	46	62	42	82	79	78	61
Cs				4	4	7	4
Cu	34	62	55	27	24	23	16
Ga	9	16	20	17	13	21	22
Hf				13	14	7	5
La	31	42	34	20	30	21	22
Nb	26	25	23	20	23	19	20
Ni	15	26	37	24	19	30	30
Pb	30	31	30	30	35	34	17
Rb	78	120	100	77	64	97	97
Sb				0.8	0.8	1.0	0.5
Sr	39	51	46	42	42	53	65
Th				16	14	16	16
W				<2	5	3	6
U				3	2	3	3
V	57	99	76	100	98	130	100
Y	29	33	20	28	32	31	21
Zn	40	51	57	38	31	41	36
Zr	470	320	430	400	440	220	150
Ti/Zr	12.1	15.6	13.5	13.6	13.0	20.1	24.5

* -63μm fraction of soil

Table 5. Comparison of fine and coarse fractions in soils, South Gundaroo (majors, wt%; minors, ppm)

Sample No.	138287		138288		128289	
Fraction	+2mm	-63µm	+2mm	-63µm	+2mm	-63µm
SiO_2	71.5	78.0	63.5	69.1	58.7	67.2
Al_2O_3	6.80	8.29	9.00	14.8	9.81	16.0
Fe_2O_3	10.8	2.73	17.7	5.03	20.8	4.44
MgO	0.24	0.32	0.27	0.49	0.30	0.52
CaO	0.09	0.18	0.09	0.21	0.09	0.19
Na_2O	0.19	0.30	0.10	0.25	0.08	0.17
K_2O	0.83	1.21	0.86	1.62	0.81	1.11
TiO_2	0.71	0.95	0.78	1.11	0.83	0.96
MnO	0.15	0.12	0.59	0.06	0.95	0.08
P_2O_5	0.13	0.08	0.10	0.06	0.14	0.04
SO_3	0.02	0.04	0.01	0.01	<0.01	0.02
Ba	130	270	380	320	570	200
Ce	66	61	140	91	150	69
Cl	<20	70	75	90	<20	150
Co	10	11	45	11	48	20
Cr	160	46	220	62	210	42
Cu	30	34	39	61	41	55
Ga	8	9	13	16	13	20
La	19	31	33	42	32	34
Nb	23	26	23	25	24	23
Ni	14	15	21	16	19	23
Pb	43	30	120	31	120	30
Rb	48	78	56	120	53	100
Sr	26	39	31	51	36	46
V	190	57	280	99	330	76
Y	22	29	27	33	31	20
Zn	29	40	32	51	32	57
Zr	460	470	410	320	400	430
Ti/Zr	9.3	12.1	11.5	15.6	12.4	13.5

Pisolith development and exploration

Visual and physical examination of the sieved coarser material from the upper 70cm of the profile reveals that the material coarser than 250µm is generally magnetic and consists of pisoliths and some angular to sub-rounded quartz. The coarse material is richer in Fe, Mn, P, Cr, Pb and V but depleted in Si, Mg, Ca, Na, K, Ti, Cu, La, Rb, Sr and Zn relative to the –63µm fraction (Table 5). This concentration of Fe into the coarse fraction and the retention of elements like Cu and Zn in the fine fraction needs to be considered when an exploration programme uses soil as the sample medium.

Interpretation of the profile

From the soil scientist's perspective, the profile consists of material derived from the weathering of sandstone and siltstone forming a soil profile which has been partially stripped (A_1 removed, A_2 retained). Subsequently 115cm of aeolian material has been deposited probably in two distinct episodes.

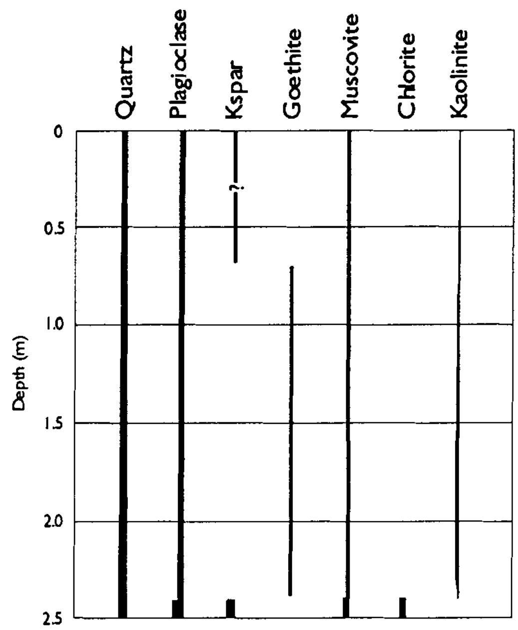

Figure 10. Mineralogical variations, South Gundaroo (determined by X-ray diffraction)

Chemistry suggests that the aeolian material at South Gundaroo is 145cm thick but it cannot by itself define separate episodes within that sequence.

Integrating the soil science, geomorphology and regolith chemistry could imply 3 episodes of aeolian deposition with breaks at 115cm and 50cm. Three episodes of aeolian deposition are recognised in the Wagga Wagga area, 150km to the west (e.g. Beattie, 1972)

3. YASS RIVER SITE: **R. GATEHOUSE**

Location: 34° 52' 06" S 148° 57' 22" E
Elevation: 520m
Bedrock: Dacite
Aeolian component: At least 1.4m of aeolian material

The Yass River profile is a 3-5m thick sequence of layered soils on bedrock in a road cutting on a hill crest (elevation 520m) near Villa Nuova homestead on the Yass Valley road 5km south east of Yass (Figures 11 and 12).

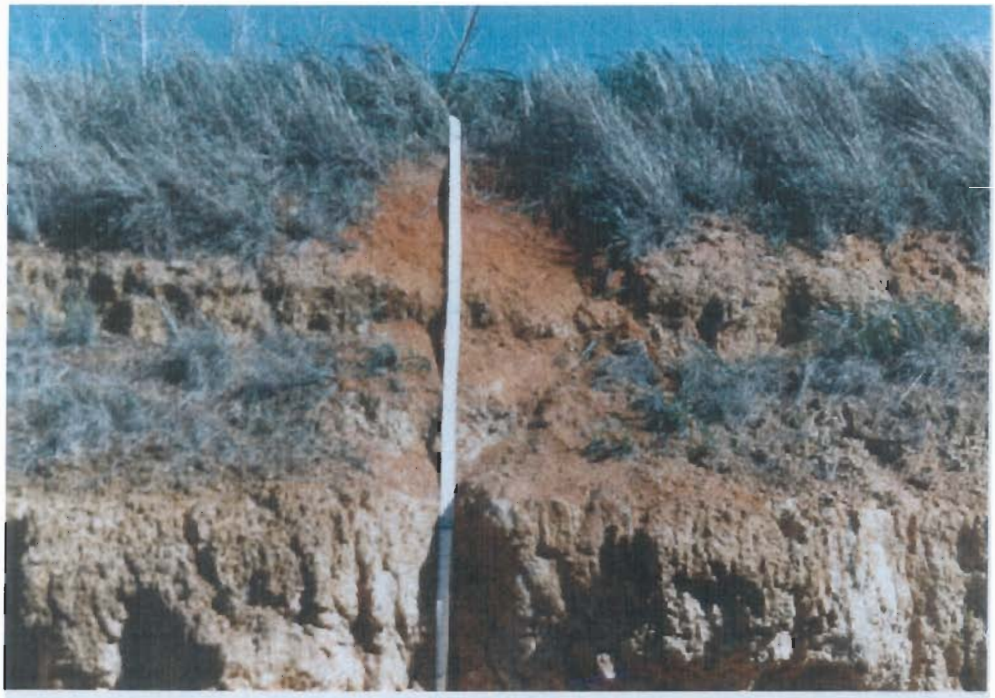

Figure 11. Soil profile, P1, Yass River.

Profile Characteristics

The sequence consists of superimposed soil profiles, which include a modern soil and one or more palaeosols. The modern soil disconformably overlies a hardpan layer which forms the upper surface of the palaeosol at 140cm depth (Figures 11 and 12). The hardpan parallels the surface topography, but the thickness and lateral continuity of the hardpan is obscured in places along the exposure because of collapse. The upper hardpan overlies a yellow clay layer of varying thickness, and this clay layer in turn overlies a second hardpan that sits directly on dacitic saprolite.

The modern soil has formed in transported material. It is hypothesised that the material contains a significant aeolian component that includes both far travelled and locally derived dust, indicated by a bimodal distribution of particle sizes in the soils (Figure 13). There is a major disconformity between the modern soil and the underlying palaeosol. At the eastern end of the exposure, the disconformity is a sharp contact between a 10cm thick mottled gray and red clay layer and the hardpan. Further along the section a bleached horizon becomes evident above the hardpan (this is more noticeable where the hardpan has collapsed). At the western end of the section, a stoneline of river gravel occurs between the saprolite and the palaeosol.

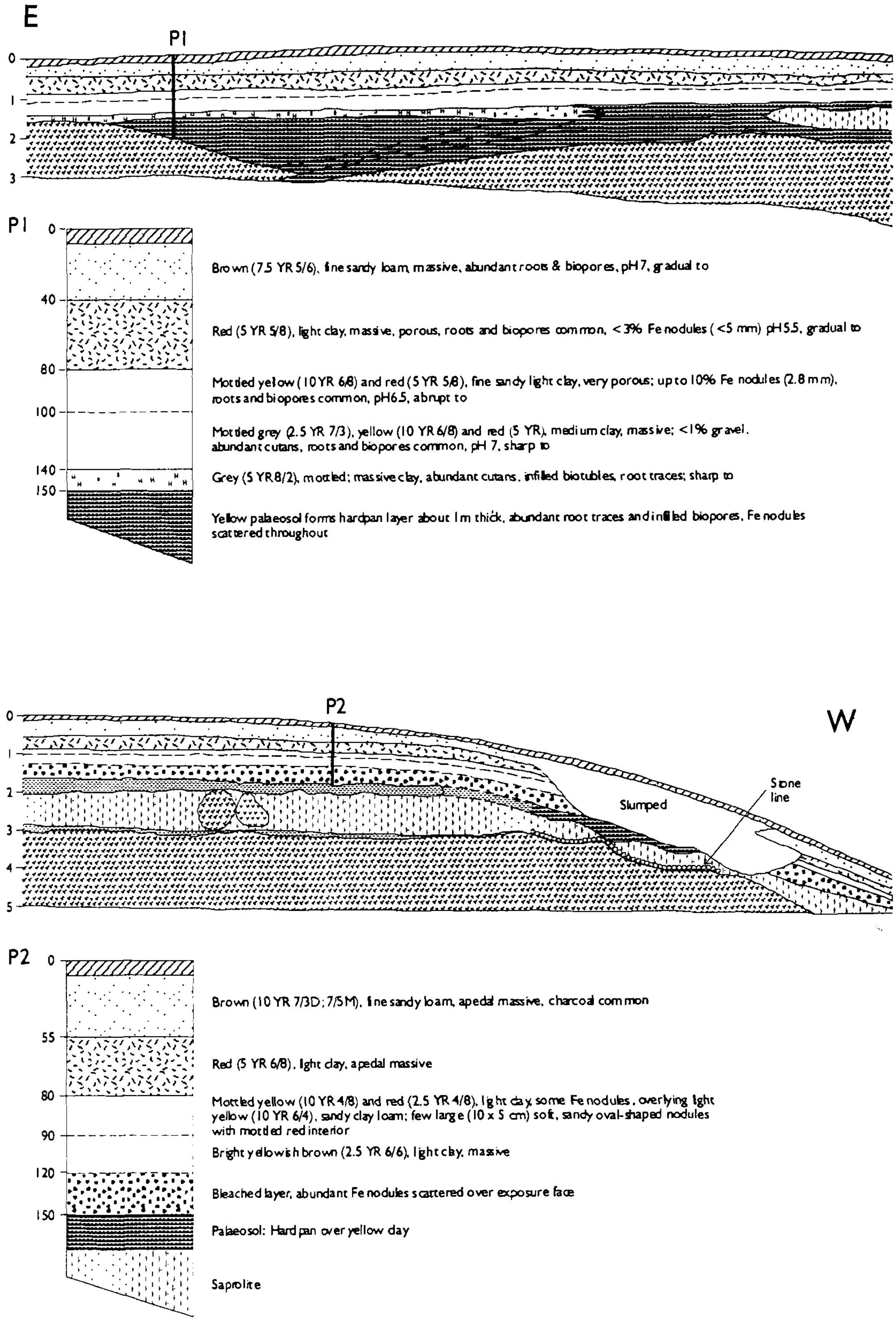

Figure 12. Yass River Site and profile details.