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THE GENERAL DISTRIBUTION AND CHARACTER OF SOILS IN THE MURRAY-DARLING RIVER SYSTEM

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GENERAL CHARACTER OF THE REGION

A brief general appraisal of the soils occurring over such a large area as the Murray-Darling River System demands stringent condensation of the actual soil variations. The area for consideration is approximately 800 by 1,250 km (see Fig.1) and, within a few metres in many instances, the soil varies markedly. Condensation would be effected by classification to the higher categories of any one of the several classification systems which are available, if the differentiae of the taxonomic classes bracketed the local variation in actual areas. But this cannot be counted on, and the best condensations are made on the criteria of their juxtaposition in the landscapes in which the soils are found.

Fig. 1 shows some of the main landscapes of the Murray-Darling System, in particular the depositional riverine plains and the areas characterised by sand dunes. The system is peculiar in having two separate riverine plains across which tributary streams flow, gathering into trunk streams which then traverse plains of a non-riverine character, dominated by sand dunes. The tributaries rise in high rainfall, mountainous country on the south and east of the system, and the trunk rivers flow into land of diminishing rainfall, from which there is little or no contribution to flow, but rather a loss. Some of the northern tributaries rise in less mountainous, lower rainfall country than the eastern and southern tributaries.

The southern riverine plain has been previously named the 'Riverine Plain of South Eastern Australia' (Butler 1950), and this name will be used here. The northern riverine plain will be called the Darling Riverine Plain. It will be noted in Fig. 1 that the Riverine Plain of South Eastern Australia is abutted immediately on the west by the dune lands (here inscribed Murravian Gulf from the marine incursion in this area in Tertiary time). In contrast the Darling Riverine Plain has a fringe some 300 km wide of undulating country separating it from dune lands to its west and southwest. This fringe will be referred to as the Bourke Tableland; it contains a number of ranges of low hills only a few of which are named. The Grey Range and the Main Barrier Range form the western boundary.

Knowledge of the soils throughout the Murray-Darling System is very uneven: the best known parts are generally to the south and on the riverine plains. The soils will be discussed collectively for each of the provinces in turn, the provinces being the subdivisions mentioned above and indicated in Fig. 1.

THE SOILS OF THE RIVERINE PLAINS

Extensive studies of soils and landscape in the Riverine Plain of South Eastern Australia (Butler 1950, Butler *et al.* 1973) have led to the condensation of soil and landscape variation into the characteristic sequence shown in Fig. 2. This represents a transect of soils, adjacent pairs of which are found to occur in nature adjacently, and in the shown topographic relationship. This characteristic sequence of soils is associated with 'prior streams', deserted sedimentary structures issuing in radial pattern from the debouchment of each tributary stream onto the riverine plain.

(a) *The Soils of the Riverine Plain of South Eastern Australia* are depicted in the characteristic soil sequence in Fig. 2. There is an overall grading from sand to heavy clay in the span of the sequence, an overall increase in soluble salts and base saturation, and a span in colour from red-brown to grey. The soils show well-contrasted profile differentiation, with eluviation/illuviation of clay and lime indicated. The full span of soils is earthy red sands, to sandy red-brown earths (Stace *et al.* 1968)

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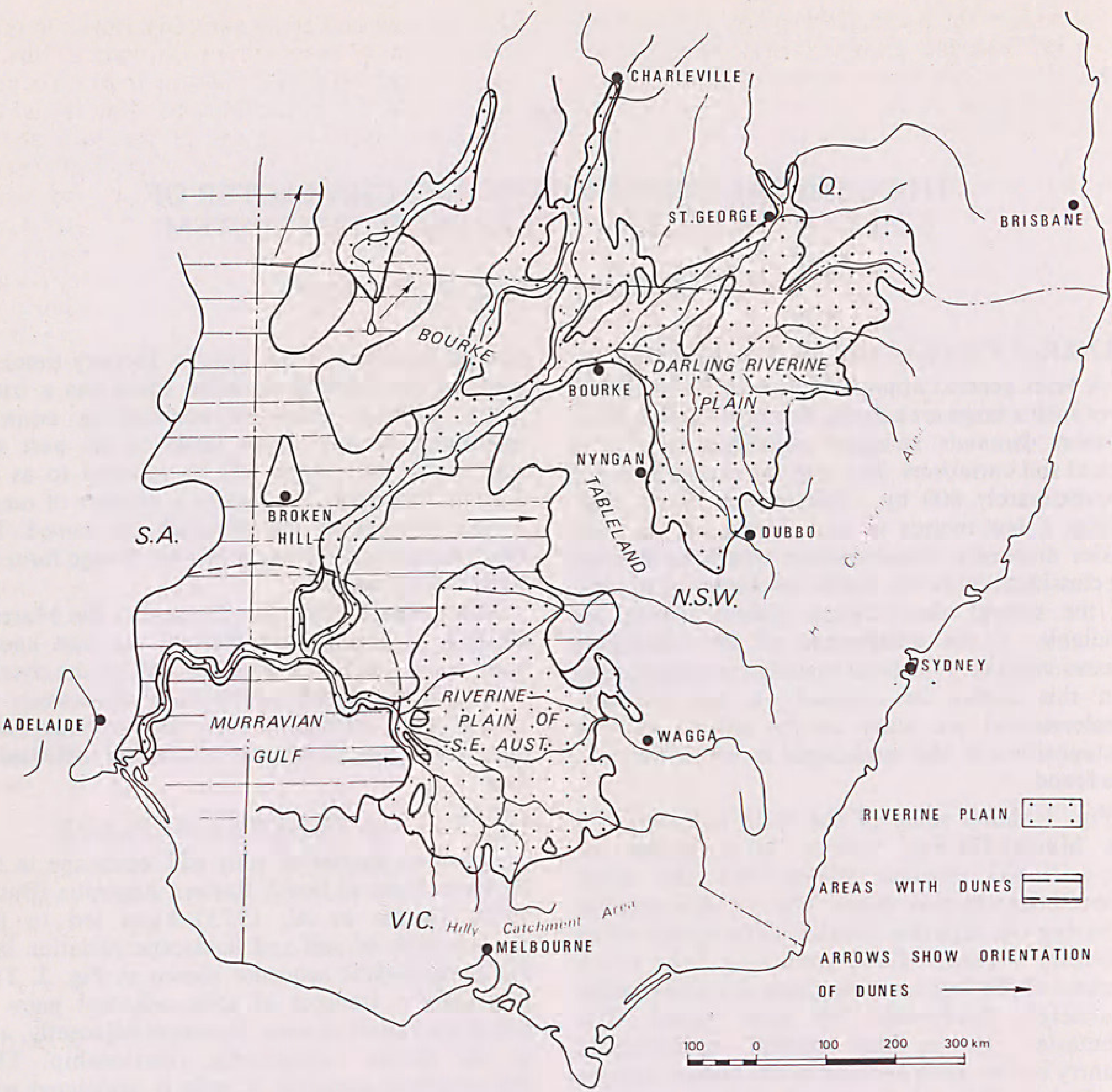

FIG. 1 — Murray-Darling River System showing landscape features. Compiled from data from Northcote *et al.* (1975) and Löffler and Ruxton (1969).

to red-brown earths to brown and grey clay soils of significant salinity.

This characteristic sequence of soils is applicable to all of the alluvial fans of the tributary streams of the Murray system: Murrumbidgee, Murray, Ovens, Goulburn, Campaspe and Loddon Rivers. Though the lithology of the catchments shows some variation, chiefly in the basalt present in the Loddon catchment, there is no significant soil variation on the plain associated with it.

(b) *The Soils of the Darling Riverine Plain:* Soil studies have been made of the Macquarie alluvial fan (Downes & Sleeman 1955), of the Namoi (Stannard & Kelly 1977), the Gwydir (Stannard & Kelly 1968), the MacIntyre River, Moonie River (Isbell 1957), and the Balonne and the Maranoa Rivers (Gunn 1974). Though there are numerous grounds supporting a prior stream proposition for this riverine plain, the component soils show a different proportion and character from their counterpart in the Riverine Plain of South Eastern Australia. Not only are the soils different from those down south but each alluvial fan of each tributary may differ in its own way.

The soils of the Namoi alluvial fan (Stannard & Kelly 1977) have a prior stream pattern, but the proportion of red-brown earths in the section is small, and most of the transect is taken up with grey self-mulching soils. Stannard & Kelly (op. cit. p. 87) state that the salt content of the soils is lower than for equivalent soils in the Riverine Plain of South Eastern Australia, and the salt does not increase with distance down the prior stream as it does in the south. These clays of the Namoi system compare with those of the Barwon further west, which are illite-kaolinite but less self-mulching. The Namoi clays have a high proportion of montmorillonite, and their particular characteristics are associated with the significant proportion of basalt in the catchment. The Barwon clays are associated with the more northern tributaries, the MacIntyre, Moonie, Balonne etc, and with their catchment areas and their mantle of Tertiary weathering.

The Gwydir alluvial fan and catchment have similar characteristics to those of the Namoi (Stannard & Kelly 1968) but the Macquarie is different in having a high proportion of red-brown earths in its alluvial fan (Downes & Sleeman 1955). In this it is like the alluvial fan of the Murrumbidgee River, and unlike those of the Namoi and Gwydir Rivers. There is very little basalt in the catchment of the Macquarie River.

Information on the south-flowing tributaries of the Darling Riverine Plain is less complete than for the west-flowing tributaries. Main sources are Isbell's (1975) study of the MacIntyre and Moonie section, and Gunn's (1974) for the Balonne and Maranoa. There are differences in overall pattern in that the riverine deposits are valley plains, and coalescing valley plains, rather than the coalescing alluvial fans of the west-flowing tributaries. There are other differences including the occurrence of some terraces and some variation from the prior stream form. However there are deserted stream structures with sandy soils merging to plains of grey cracking clays. A conspicuous feature is the solodized-solonetz character of the soils at the sandy and mid-textured section of the sedimentary spectrum. These are soils with abrupt and highly contrasting A horizon — B horizon contrast and interfaces, a marked dominance of Mg on the exchange complex, and a variable tendency toward exchangeable Na and salinity in the lower horizons. The solodized-solonetz soils form a significant proportion of the characteristic soil sequence and take the place of red-brown earths in Fig. 2. The salt and sodium characteristics of this spectrum of soils are apparent to only a moderate degree in the eastern tributaries but increase in the more western, low rainfall section.

The source areas of these streams and their sediments are the deeply weathered Tertiary landscapes of southern Queensland where typical soils are residual red earths, often lateritic, loamy solodized-solonetz soils, and brown and grey undulating clay plains on bleached weathering zones. Kaolinite is the dominating clay mineral.

In summarising the soil array of the two Riverine Plains, it may be noted that whereas there is a marked degree of uniformity among the alluvial fans of the Southern Riverine Plain, the Darling Riverine Plain varies in a number of ways, with differences there between one alluvial fan and another. The south-flowing tributaries are marked by the occurrence of solodized-solonetz soils, whilst the west-flowing tributaries are marked by the character and dominance of their grey self-mulching clays. Both peculiarities seem to be associated with the character of their respective catchments.

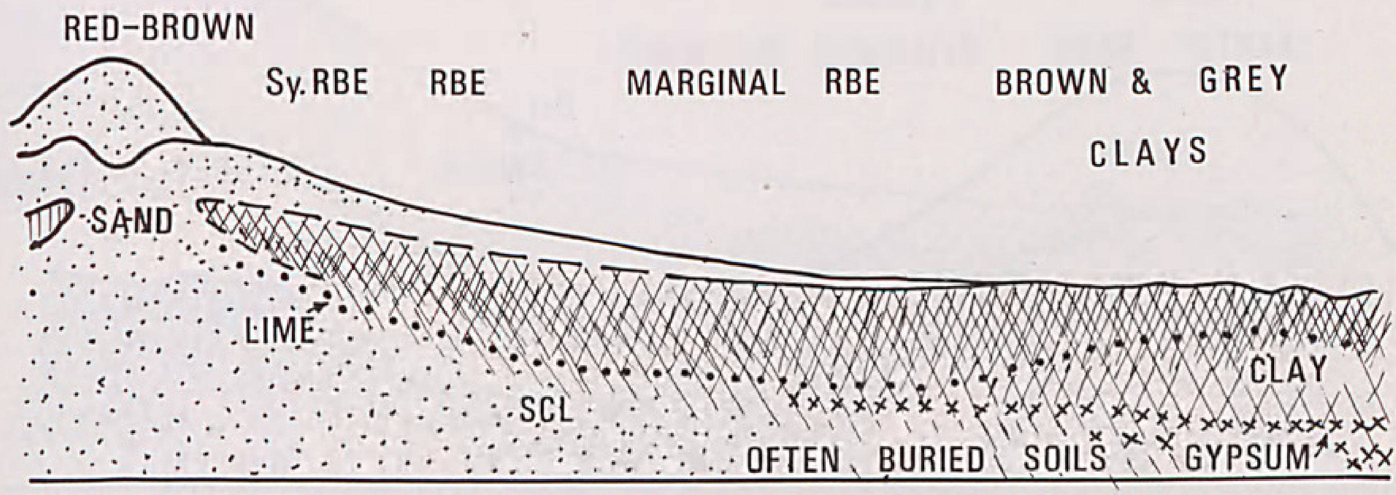

FIG. 2 — Characteristic soil sequence: Riverine.

SOILS OF THE DUNE LANDSCAPE

The dune landscape in the region is most frequently characterized by parallel, linear dunes. These have consistent orientations in each locality. Each reflects the direction of the dominant local aeolian movement, as shown by the arrows in Fig. 1. There is variation from locality to locality in the amount of sand, its colour, and the proportion of sand to associated clay and lime. Where there is most sand the dunes are close together and irregular, and where it is least and verging on absence sparse coppice dunes take the place of linear dunes. Though the proportion of clay and lime in the dunes may vary without affecting their shapes, the specific clay dunes adjacent to dry lakes are exclusively of crescentic shape.

Fig. 3 is the characteristic soil sequence for the dune transect. It is largely based on experience in the Murravian Gulf section of the dune field areas. The areas of dune field further north in the region are not so well known. Fig. 3 is a section transverse to the length of the dune, and extends half way across the adjacent flat or swale. There is a marked sorting of material, with maximum of sand at the crest of the dune, and maximum of clay, lime and salt in the central swale position. Soil profiles generally show a marked eluvial-illuvial segregation of clay, lime and salts, usually with gradational changes (Gc of Northcote 1971), though further out on the swale Drl and Ug (grey cracking clays) may be present. Where these well-differentiated profiles are found the dunes have obviously been stable for a pedologically significant period. However since the dune zone extends into very low rainfall area, some dune areas would have a shorter or nil record of stability, and then soil profiles would be less differentiated.

Mention must be made of the dunes which are frequently found associated with dry lakes and clay pans in the Murravian Gulf area. These are crescentic in shape, hugging the eastern side of the lake. Usually they are clays, and have come to their place as saltating clay aggregates from the adjacent lake floor when this was dry.

A local character in dunes results from their origin in the wind erosion of local materials. Any coarse component remains as lag gravel, the saltating sand accumulates as local dunes, and only the dust component travels long distances. It may move long distances down wind and become so mixed as to assume a regional character. It would be expected that the components, lag gravels, dune sands and dust or parna, would be different in the northern dune areas where Tertiary weathering zones are the source, compared with the parna and other components having their origin in the Murravian Gulf area. In addition to difference in composition there would be a difference depending on the hardness of the country i.e. its susceptibility to wind erosion. Much of the old Tertiary weathering material is hard and concretionary or otherwise indurated, whereas materials of the littoral environment, especially calcareous and saline clays in the Murravian Gulf area, are likely to be soft and granular when dry.

SOILS OF THE PARNA-MANTLED LANDSCAPE

The dust component of wind erosion-sedimentation process is regionally recognised as parna, an aeolian clay (Butler, 1956). It has been identified and studied at a number of places in and adjacent to the Riverine Plain of South Eastern Australia. Churchward (1963) studied parna at

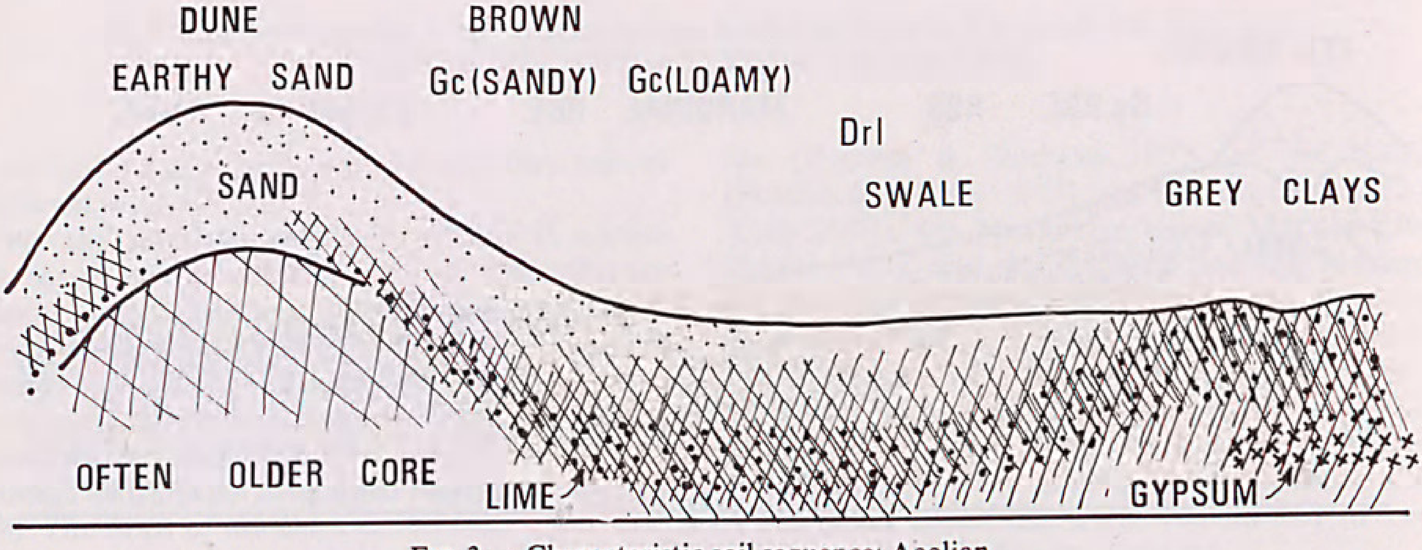

FIG. 3 — Characteristic soil sequence: Aeolian.

Swan Hill with regard to its source in the wind erosion of soils and its graded distribution in the structure of sand dunes. Van Dijk (1958) identified parna at Griffith, both as a mantle overlying riverine beds on the plain and as a mantle on the adjacent hillslopes. Sleeman (1975) studied the parna mantle on the granite hills of Pyramid Hill in relation to the mineralogical contrasts between it and the substrate. Beattie (1970, 1972) studied the parna on the hillsides at Wagga Wagga giving particular attention to its peculiar characteristics: sub-plasticity, basicity, dolomite and baryte concretions and palygorskite cutans. Beattie (priv.comm. 1977) has also examined the contrast in Ti/Zr ratio of the parna and of the underlying weathered granite at Wagga, and finds them significantly different at the 0.1% level.

The separate identity of the parna can be proved where it mantles the hills, but proof is not so convincing on the plain. However its occurrence at widespread points like Swan Hill, Pyramid Hill, Griffith and Wagga Wagga leads to the inference that it was also spread over the intervening plain. Experience in soil survey had already lead to this conclusion (Butler 1958). Soil surveys at Rutherglen suggest the occurrence of parna there, (Poutsma & Skene 1961) and the occurrence of the array of soils in Fig. 4 at Dookie near Shepparton (Downes 1949) leads us now to the proposition that parna mantles the slopes and plain there.

The occurrence of parna as a widespread mantle on the riverine structures and sediments of the Riverine Plain of South Eastern Australia could well impose the unified character of the soils of the several alluvial fans which are found there, and which is in contrast to the variation of soils in the alluvial fans of the Darling Riverine Plain.

The characteristic sequence of soils for the parna from the Murravian Gulf region is shown in Fig. 4. Parna, like loess, takes the form of the substrate, and the main theme of variation in soil profile depends on the drainage status of the site. In the well-drained, elevated position the profile is a red earth with gradual build-up of clay with depth, sub-plastic properties in the sub-soil clay and leaching of alkaline earths. The soil in the level to slightly sloping site is a red-brown earth with clay and lime B horizons and tending toward a solonized profile in the flatter position. In the flat or depressed positions the soils are brown and grey clays, self-mulching, gilgaied and calcareous. These soils often contain gypsum and appreciable soluble salts at depth as do also, to a lesser degree, the solonized red-brown earths.

The parna mantle is characteristically high in clay, in alkaline earths, and significantly salty: however it has been in place long enough for marked leaching and soil development to have occurred where the drainage of the site favours this.

SOILS OF THE NORMAL HILLSIDE SEQUENCE

In the greater part of the catchment of the Murray-Darling System, especially on the east and south, the soils fit a general sequence shown in Fig. 5. This sequence varies with drainage, and has red earths and red-podzolics in the well-drained sites, and yellow podzolic and gleyed-podzolic soils in the

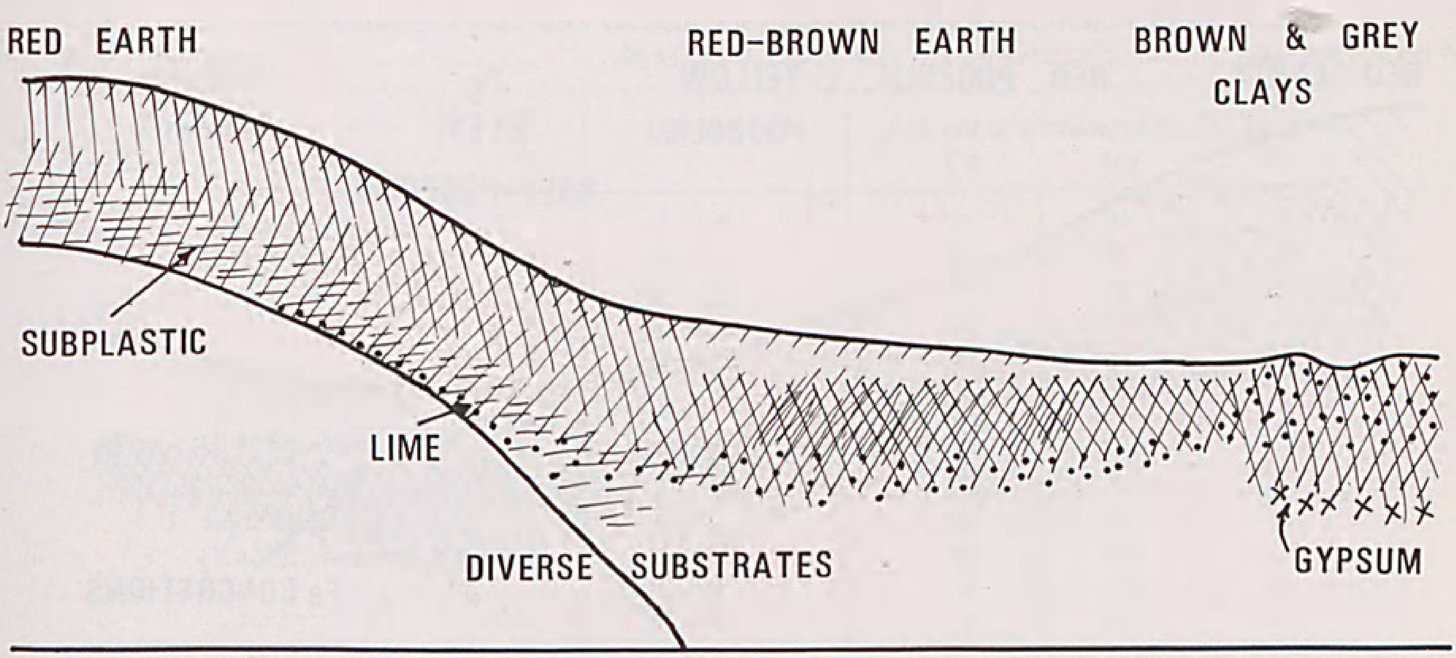

FIG. 4 — Characteristic soil sequence: Parna Mantle.

poorly drained areas. There may be a tendency toward solonized conditions and lime in some of the poorly drained sites.

There are many variants from this sequence due to parent material differences: hardness, thickness of the mantle, age, degree of horizon contrasts. The main contrasts from our point of view are differences associated with basalt as a parent material, and those due to Murravian Gulf parna as a parent material. The basalt sequence (except for old weathering) is characterised by black earth soils at the drier and poorly drained end, and krasnozems and chocolate soils at the well drained end. The parna sequence should be easily distinguished from the 'normal' hillside sequence, especially by its poorly drained member. Though there are some similarities between the parna sequence and the basaltic sequence, these are hardly likely to cause confusion in practice.

THE DISTRIBUTION OF PARNA IN THE MURRAY-DARLING SYSTEM

The distribution of parna from the Murravian Gulf region is roughly indicated, at least on the south and east. The dune orientation (shown in Fig. 1) indicates an easterly extent from the Murravian Gulf area, but there is little evidence of its extending far to the east of Wagga Wagga. There is evidence of parna in the Macquarie alluvial fan, to the west and northwest of Dubbo, in the extent of red-brown earths there as shown in the soil maps of Downes and Sleeman (1955). Their maps show also 'brown acid soils' on the Bourke Tableland north and south of Nyngan, and the characteristics of these conform to the red earth sub-plastic member of Fig. 4. Further suggestion that these soils are formed on parna is to be found in the observation of Downes and Sleeman (1955, p.23) that their brown acid soils occur on both alluvial and stony substrates. From the present senior author's observations, evidence for parna similar to that at Griffith occurs on the Bourke Tableland out as far as Bourke. But there is no evidence for parna elsewhere in the Darling Riverine Plain. The individual character of each alluvial fan precludes any general spread of parna there.

The question of parna occurrence in the northwest of the Murray-Darling System is an open one, though the dune landscapes suggest it. The orientation of the linear dunes indicates a northeasterly, not an easterly extension, and the absence of parna from the Darling Riverine Plain is perhaps not surprising, as that region is at the place where the change of directions of the wind system would tend to disperse or attenuate any dust deposit. However parna may be sought on the western portions of the Bourke Tableland. As mentioned above, it should there have a character determined by the soils of the Tertiary weathering zones which are its source there. These would be dominantly kaolinite clays, perhaps rather low in lime. Dominant soils in the Bourke Tableland area according to Northcote *et al.* (1975) are 'red earths', and show extensive uniformity of type, notwithstanding the variety of the substrates. These red earths are not necessarily different from the Downes and Sleeman 'brown acid soils' mentioned above. Further west many of them are described as residual 'hard' mulga soils and are clearly associated with the old Tertiary land surfaces. But

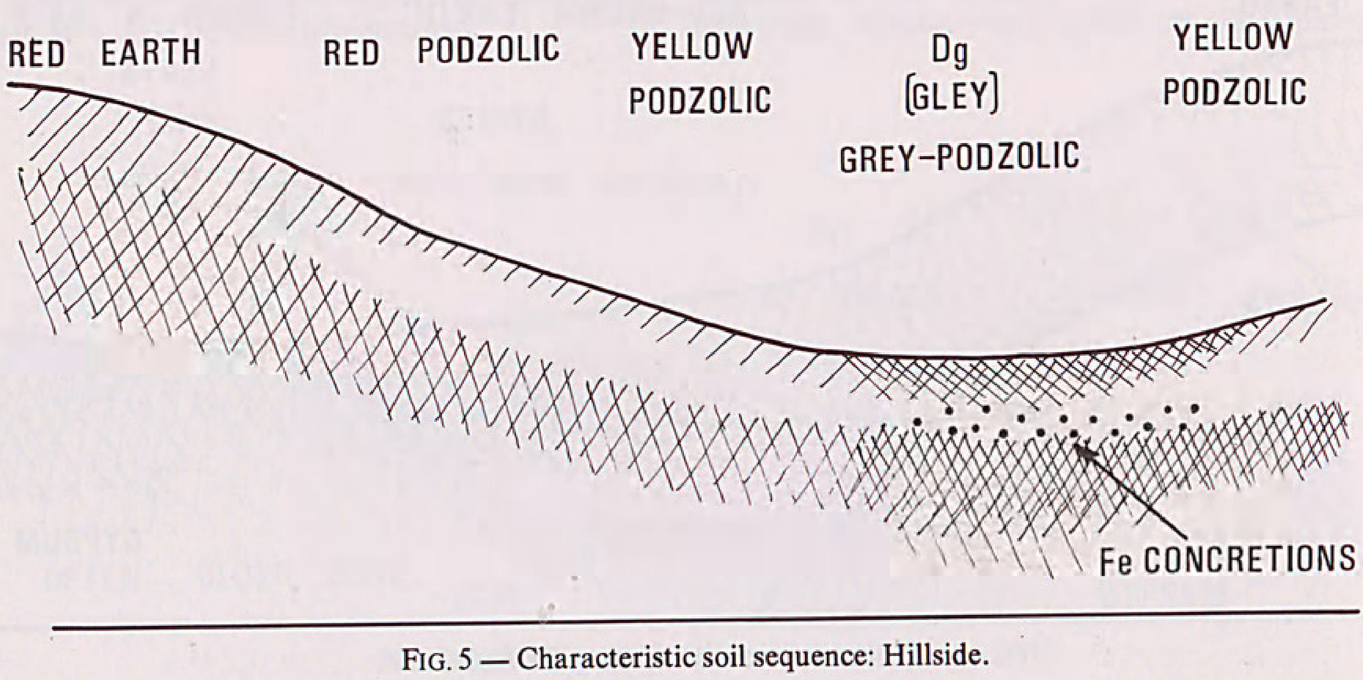

FIG. 5 — Characteristic soil sequence: Hillside.

other areas are described as 'soft' mulga country and could possibly be regional parna. This would be the well-drained member of the sequence; the poorly drained member would probably be a solonized red-brown earth. Lime and soluble salts, though present, are probably less than in the soils of the Murravian Gulf parna.

FURTHER CONDENSATION OF THE SOIL DATA

The foregoing condensation of soil data for the Murray-Darling River System has been based on the characteristic sequence of soils for the several landscape classes into which the area is subdivided. The characteristic sequence show the soils which are found adjacent to one another most often, and the topographic change associated with such soil transitions. The soil changes are of two kinds: those associated with texture change (sand to clay) and those associated with slope and topographic position of the site. In the riverine sequence and the dune sequence these two variables coincide, but in the hillside sequence and the parna mantle sequence there is only the slope variable. The operation of this variable gives the range of states understood by soil workers as variation in the 'leaching' factor: the sloping, elevated sites are highly leached, the flat or depressed sites poorly leached. The characteristic sequence of soils in all cases spans the range from highly leached to poorly leached. This is indeed the main local soil variable, and it is associated with topographic change.

If we disregard these variations at the next higher level of condensation we are left with a limited realm of variation such as can be seen in passing transversally from one characteristic sequence to the other at (say) the second position from the left of Figs. 2, 3, 4, and 5. At such a transect the soils are rather similar and the differences that persist can be related to parent material differences. In the range of parent materials occurring in the Murray-Darling System the following may be singled out:
(i) The parna of the southern portion, high in clay, alkaline earths, moderate in soluble salts.
(ii) The Tertiary weathered material of the north-western and northern portion of the area, high in kaolin clay.
(iii) The 'normal' parent materials of the catchment areas beyond the effects of (i) and (ii).

The parna of the southern portion has been typified, in its red earth profile, by Beattie (1970). It is a kaolinite-illite clay with evidence, though leached, of high basicity, including the segregation of palygorskite. The typical red-brown earth profile has been leached of much of its basicity, but remains alkaline. Exchangeable cations show Ca and Mg roughly equal but with reciprocal trends in depth (illustrated in Table 1 by entry 2 from Griffith).

The Tertiary weathering, whether in-situ as alluvial deposits, or (presumably) as wind-sorted deposits, is typified by kaolin and the solodized-solonetz soil profile. In this profile the contrast and transition from A to B horizon is still more marked

TABLE 1

EXCHANGEABLE CATIONS OF SOIL PROFILES REPRESENTING THREE PARENT MATERIAL CLASSES

Location	*Depth (cm)*	*Percent of exchangeable cations as:—* *Ca*	*Mg*	*Na*
1. Gwydir irrigation area.* (Montmorillonite)	0–10	79	14	2
	10–20	85	8	1
	20–30	77	12	10
	30–46	68	17	7
	46–60	75	9	13
2. Griffith.** (Kaolin, illite)	0–18	66	24	1
	18–48	54	37	2
	76–100	39	44	10
3. Inglewood.*** (Kaolin, montmorillonite)	0–15	32	51	10
	15–25	43	46	10
	25–38	6	67	26
	38–76	3	66	30

* from Stannard & Kelly (1968), ** from Taylor & Hooper (1938), *** from Isbell (1957).

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than in the red-brown earth, and the tendency for exchangeable Mg to increase at the expense of Ca is still greater, as shown in Table 1, entry 3 from Inglewood.

The 'normal' parent material can not be defined, but in this study it is interesting to refer the characteristics of the two above-mentioned parent materials to the soils formed on basaltic alluvium in the Namoi and Gwydir alluvial fans. The representative soil there is a grey self-mulching clay, a montmorillonite clay, with exchangeable cations, dominated by Ca as shown in Table 1, entry 1. Without claiming that this is typical of the whole catchment area it is evident that the cyclic accession of salt in the environment, and the geomorphic set-up, do not in themselves make the solodized characteristic of soils, as Downes and Sleeman (1955, p.43) propose. Parent material is also a factor.

The three parent material classes proposed for the region are typified in Table 1 by their exchangeable cation profiles. These are probably a reflection of the complex of clay minerals in each type of parent material. There is a broad uniformity of parent material over large areas of land when these parent material classes are adopted. They are natural sub-divisions for the region because they fit the history of the region in terms of the distribution of parna, the long-time stability of landscape surfaces, and the contrasting normal.

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REFERENCES

BEATTIE, J. A., 1970. Peculiar features of soil development in parna deposits in the eastern Riverina N.S.W. *Aust. J. Soil Res.* 8: 145-56.

———, *1972. Groundsurfaces of the Wagga Wagga region N.S.W. CSIRO Aust. Soil Pub. No.28.*

BUTLER, B. E. 1950. Theory of prior streams as a causal factor of the distribution of soils in the Riverine Plain of South Eastern Australia. *Aust. J. Agric. Res.* 1: 231-52.

———, *1956. Parna — an aeolian clay. Aust. J. Sci.* 18: 145-51.

———, *1958. Depositional systems of the Riverine Plain in relation to soils. CSIRO Aust. Soil Pub. No. 10.*

BUTLER, B. E., BLACKBURN, G., BOWLER, J. N., LAWRENCE, C. R., NEWELL, J. W. & PELS, S. 1975. *Geomorphic map of the riverine plain.* Aust. Natl. Univ. Press, Canberra.

CHURCHWARD, H. N., 1963. Soil studies at Swan Hill. II. Dune moulding and parna formation. *Aust. J. Soil Res.* 1: 103-06.

VAN DIJK, D. C., 1958. Principles of soil distribution in the Griffith-Yenda district N.S.W. *CSIRO Aust. Soil Pub. No. 11.*

DOWNES, R. G., 1949. Soil, land use and erosion survey around Dookie, Victoria. *CSIRO Aust. Bull. No. 243.*

DOWNES, R. G. & SLEEMAN, J. R., 1955. Soils of the Macquarie region N.S.W.*CSIRO Aust. Soil Pub. No. 4.*

GUNN, R. H., 1974. Soils of the Balonne-Maranoa area. *CSIRO Aust. Land Res. Ser. No. 34, Part 7, pp. 148-79.*

ISBELL, R. F., 1957. Soils of the Inglewood-Talwood-Tara-Glenmorgan region, Queensland. *Queensland Bureau of Investigations Tech. Bull. No. 5.*

LÖFFLER, E. & RUXTON, B. P., 1969. Relief and landform map of Australia 1:5 million. *Aust. Water Resources Council, Canberra.*

NORTHCOTE, K. H., 1971. *A factual key for the recognition of Australian soils.* 3rd Ed. Rellim Press, Glenside, South Aust.

NORTHCOTE, K. H., HUBBLE, G. D., ISBELL, R. F., THOMPSON, C. H. & BETTENAY, E., 1975. *A description of Australian soils.* CSIRO Aust., Melbourne.

POUTSMA, T. J. & SKENE, J. K. N., 1961. Soils of the Rutherglen Research Station, *Vic. Dept. Agric. Tech. Bull. No. 12.*

SLEEMAN, J. R., 1975. Micromorphology and mineralogy of a layered Red-brown earth profile. *Aust. J. Soil Res.* 13: 101-17.

STACE, H. C. T., HUBBLE, G. D., BREWER, R., NORTHCOTE, K. H., SLEEMAN, J. R., MULCAHY, M. J. & HALLSWORTH, E. G.,1968. *Handbook of Australian soils.* Rellim Tech. Pub., Glenside, South Aust.

STANNARD, M. E., 1977. Irrigation potential of the lower Namoi valley. *Water Resources Comm., Sydney*, 62 pp. plus Appendices.

STANNARD, M.E. & KELLY, I.D., 1968. Irrigation potential of the lower Gwydir valley. *Water Cons. & Irrign. Comm., Sydney.* 18 pp. plus Appendix.

TAYLOR, J. K. & HOOPER, P. D., 1938. Soil survey of the horticultural soils in the M.I.A., N.S.W. *CSIRO. Melb. Bull. 118.*