

**THE SYDNEY DURICRUSTS:
THEIR TERMINOLOGY AND NOMENCLATURE****ADETOYE FANIRAN**

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Abstract

Two main duricrust types — laterites and ferricretes — and their underlying materials are mapped and described for the northern parts of the Sydney district, New South Wales. Laterites are by far the more widespread, being found both in the Wainamatta-Shales and in the Hawkesbury-Sandstone areas, particularly on the broad hilltops and interfluves of the major divide between the three drainage systems — the north-flowing Hawkesbury-Broken Bay, the south-flowing Parramatta-Port Jackson and the east-flowing Pacific Ocean systems. The ferricretes occur mainly in the drier parts of the northwest, especially in the conglomeratic river gravels of the Maroota area. The two materials have similar profile characteristics but they are different in hand specimen, in textural and structural characteristics, and also in mineralogical composition. The duricrusts and their profiles have been widely destroyed and differentially truncated, so that their various zones and subzones are presently exposed at different places. These materials, especially in respect of laterites, are classified from field and laboratory evidence, according to their recognised, or assigned, position in the typical deep weathering profile. Names are assigned, depending on the area where the best examples were found.

INTRODUCTION

The materials which cap the tops of some of the hills, plateaus and interfluves of the Sydney area of New South Wales have so far been called laterites (cf. Burges and Beadle, 1952; Walker, 1960; Mumme, 1965; Frankel, 1966). This usage of the term *laterite* appears inappropriate and unsatisfactory, partly because of the current attitude to the use of this term, and partly because of the nature of the materials themselves. The term *laterite* after a long period of apparent misuse is now being applied, by a growing number of workers, to a particular duricrust type; it is being used for the *indurated zone* of a duricrust profile, especially when this zone is concretionary, and also when substantial quantities of the oxides of iron and aluminium are present in them (cf. Connah and Hubble, 1960; Langford-Smith and Dury, 1966). This is a slight modification of the original (Buchanan, 1807) connotation of this term, which apparently refers to the *mottled zone* of a deep-weathering profile, i.e. the zone directly beneath the duricrust or indurated zone, and which is in turn underlain by the *pallid zone*, in a complete section from surface to bedrock. The terms *indurated zone*, *mottled zone* and *pallid zone* are by now generally understood (Dury, 1969, p. 79), but a number of other terms being used in connection with deep weathering and duricrusts are not. *Duricrust* has been justifiably suggested as a replacement for *laterite*, for all forms of surface crusts, whether or not they are associated with deep weathering (Woolnough, 1927; Dury, 1969, pp. 77-78); however, in this paper, this term refers specifically to the indurated zone of a deep-weathering profile. Similarly, *laterite* refers to a type of duricrust which is typically concretionary and is rich in both iron and alumina. By contrast, *ferricrete* is mostly iron-cemented crust and non-concretionary. It is generally poor in alumina. In the same sense the term *bauxites* may be used for alumina-rich duricrusts, *silcrettes* or silica-rich duricrusts, and so on.

The study area proper is the northern Sydney district (Fig. 1a), but observations have also been made in the surrounding areas of the South Sydney district, e.g. in the Royal National Park area, the Blue Mountains region and the areas north of the Hawkesbury River. Most of the observations in these other areas generally conform to and confirm those from the study area. The methods used include (a) the mapping from published and, more importantly, field evidence of outcrops of the various products of deep weathering; (b) field observation and description of deep weathering profiles; and (c) laboratory (petrographical) study of samples of duricrust, including chemical, X-ray mineralogical, thin-section, polished-section and heavy-mineral (bromoform) analyses. Finally, suitable data were subjected to rigorous statistical tests, including analysis of variance and the *F* and *t* tests.

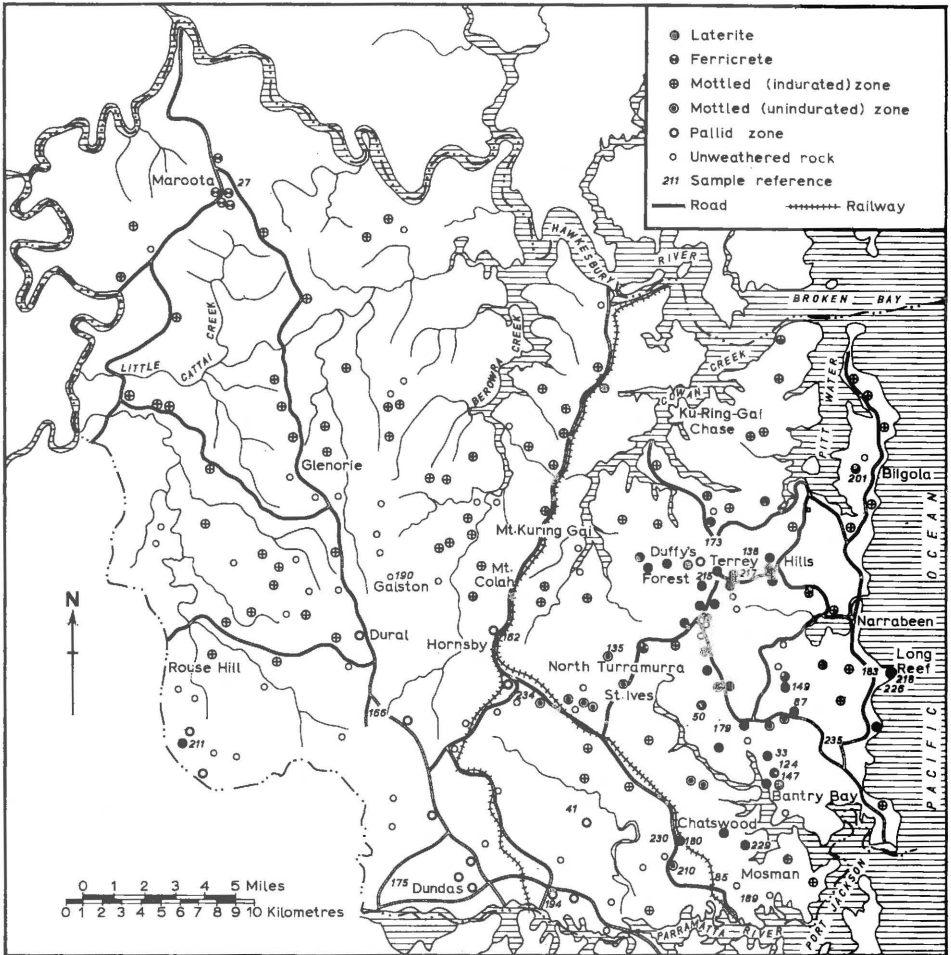


Figure 1a. The distribution of duricrusts and related materials in the northern Sydney district. The author also observed similar materials in the Royal National Park area of South Sydney, around the Blue Mountains, and also in areas just north of the Hawkesbury River.

THE STUDY AREA

The Sydney district is one of the best studied parts of New South Wales. Physiographically, the area coincides roughly with the *Coastal Plateau* of Walker (1960, p. 9), or with the *Wianamatta Ridges* and the *Dissected Sandstone Plateau* (Hornsby Plateau), and also part of the *Undulating Clay Plain*, of the County of Cumberland report (Anon., 1948, p. 25). Geological mapping is quite detailed (cf. McElroy, 1966); the latest maps are the 1 : 50,000 sheets being prepared by the New South Wales Geological Survey Department.

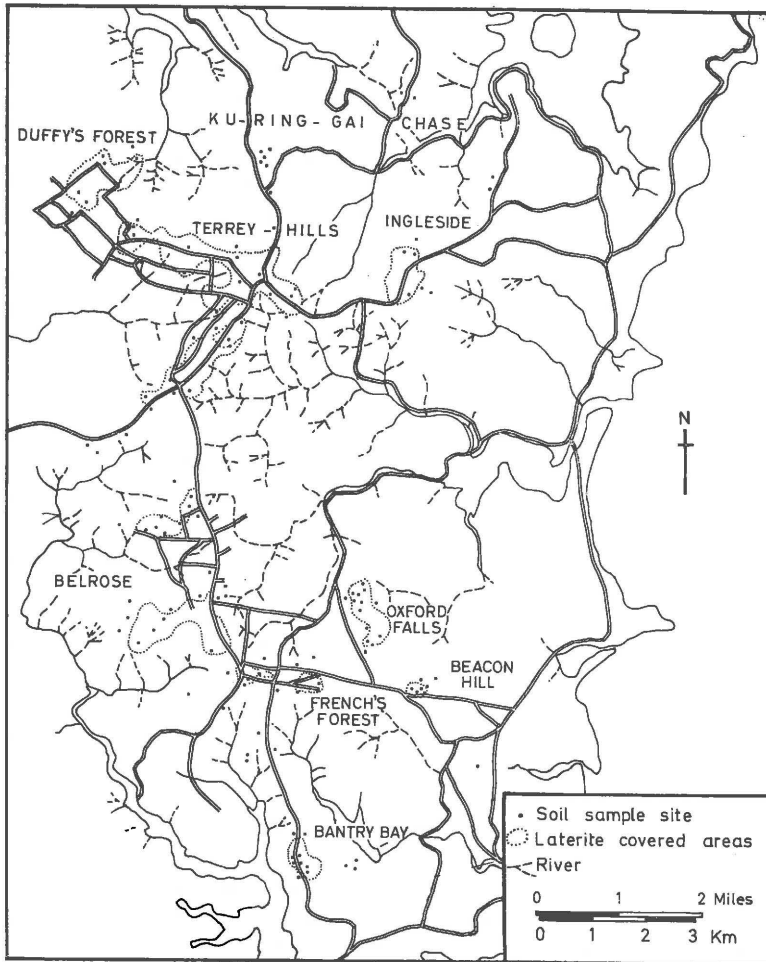


Figure 1b. Laterite-covered areas in the major interfluve region of the northern Sydney District.

Of particular interest here are the analyses of rainfall, drainage, dissection and slopes, all of which affect the present-day distribution and attitude of the duricrusts. The duricrusts, for example, are mostly preserved on the interfluves, especially those with relatively broad tops, low relief and gentle slopes (cf. Faniran, 1969a). Furthermore, the laterites occur almost invariably in areas where the annual rainfall is 50 inches or more, i.e. in the southern and southeastern parts, and also where

the depth of dissection, volume of removal and drainage intensity are the lowest (Faniran, 1969b). These various points are further discussed at the relevant places in what follows.

THE DURICRUSTS AND THEIR STUDY

Choosing the Samples

Although the duricrusts (laterites) and the other forms of weathered rock of the Sydney area have previously been studied from many standpoints, little or no attempts have yet been made either to map their occurrence or to differentiate between them. This is perhaps due to the fact that these other studies are concerned with specific aspects, e.g. soils (Walker, 1960) or mineralogy (Frankel, 1966). Moreover, the samples so far studied are either not large enough or have not been taken according to any pre-defined, standard procedures, or both. These samples are therefore apparently biased and unrepresentative of the materials in question. For instance, the three samples of 'laterite' studied by Burges and Beadle (1952) were all taken from shale areas; hence the conclusion reached that the laterites were formed in shale is to be expected. This conclusion has not been confirmed by subsequent studies which, on the contrary, have shown that laterites occur also in the sandstones, albeit close to the shales and the basic igneous rocks (*cf.* Frankel, 1966; Faniran, 1970).

The procedure followed in the present study is different in certain respects from the previous ones. It consists of (a) reconnaissance surveys of the entire study area, during which all available samples of weathered rock were collected: these were later mapped, as shown in Fig. 1a; (b) random selection of representative samples of the various types of duricrust recognised in hand specimen; (c) analyses of these samples by all available petrographical techniques; (d) statistical tests of the significance of the difference by the most appropriate statistical techniques and (e) the semi-detailed study of the soils formed on the various materials presently exposed to currently-operating pedogenic processes (Fig. 1b). Samples for chemical and X-ray mineralogical analyses were chosen to reflect both the available income and the nature of the various materials. Twenty random samples were analysed chemically and fewer still by X-ray methods, being the maximum that could be afforded. These sets of data were not treated statistically, but were found very useful all the same. Rather, statistical analyses were based on the thin-section and the polished-section data, since it was possible, from the point of view of time and money alike, to analyse a representative sample in each case. Thus, while the samples for chemical analysis, and also for X-ray mineralogical analysis, were chosen from the entire area without any stratification, samples for petrographical (thin-section and polished-section) analyses were obtained according to the stratified random technique, the strata being based on the recognised types of duricrusts, from the observation of hand specimens.

The recognised types include :

- (i) Laterites in sandstone, e.g. from the French's Forest - Belrose - Terrey Hills areas;
- (ii) Laterites and indurated mottled-zones in shale from the North-Sydney - Chatswood - Hornsby areas;
- (iii) Ferruginised sandstones from the intensely dissected northern parts, e.g. the Mt. Colah - Canoelands areas;

- (iv) Iron-cemented conglomerates from the Maroota area;
- (v) Pallid zone and apparently little weathered shales, e.g. from the Rogan's Hill area;
- (vi) Pallid zone and other iron-poor sandstones;
- (vii) Weathered volcanic rocks.

Fifty out of a total of 235 collected samples were studied, shared proportionately among the various categories to reflect both the number of available samples and the observed internal variability of each category. Consequently, the sample sizes vary from 2 to 12. The pallid zones and unweathered rocks were far more homogeneous than the others and so had the fewest samples allotted to them, while laterites were the most heterogeneous and had the greatest number of samples. All told, about 20 samples of laterite of various categories were studied.

The procedure followed in choosing the required samples was roughly as follows:

- (1) The map showing the duricrust samples was covered (overlain) by a transparent gridded (graph) paper. The basic grid unit was taken as the one-inch square and a unit qualified for inclusion in the population if it had at least one recorded sample.
- (2) The map was divided into the seven strata listed above and the required number of samples assigned to each stratum
- (3) The required number of samples for each stratum was chosen with the aid of a table of random numbers. Where more than one specimen occurred in a grid unit, resort was made to the ballot system.

Between two and four or even six thin sections and polished sections were cut and studied from each of the chosen samples, to afford replication and facilitate modal analysis (Chayes, 1956).

The Analysis

Chemical and X-ray (quantitative) mineralogical analyses were undertaken, respectively, by Mr John Corbett of the Department of Agriculture, The University of Sydney and Dr Peter Bayliss, formerly of the Department of Applied Geology, University of New South Wales, Kensington. Thin-section, polished-section and X-ray (powder-diffraction) photographic studies were made by the author at the Department of Geology and Geophysics, The University of Sydney. Heavy mineral (bromofom) studies were done at the Department of Geography of the last named University, but the results proved rather dubious, mainly because of the nature of the materials, particularly the laterites, in which the sesquioxide minerals occurred mostly as intimate mixtures of at least two and in some cases more compounds. Some of the analysed 'grains' or aggregates, however, proved quite useful in the X-ray (powder-diffraction) studies. The results of these analyses as well as of their statistical analyses are discussed in a previous study (Faniran, 1970) and so will not all be repeated here, except for the chemical data given in Table 1. In general, the petrographical studies show, among other things, that the materials especially the laterites, can be subdivided into a number of sub-types, as shown in what follows.

Laterites and the Laterite Profile

Laterites occur mostly in the areas of shales and sandstones. They are typified by the occurrence of (a) mottled and/or pallid zone understrata, overlying the country rock, (b) concretionary (colloform) textures and (c) relatively high proportion of Al_2O_3 , mainly as gibbsite (Table 1). In almost all cases, especially where it is preserved intact, the laterite or indurated zone is further divisible into at least three sub-zones: namely upper, middle and lower. The upper-indurated zone, especially in sandstone where pisolitic textures are best developed, is generally characterised by rather small, but hard and highly spherical pisolites or concretions; these textures become bigger, softer, and less spherical with depth, until they finally disappear somewhere in the lower-indurated zone, or the zone below it (Fig. 2, a and b). The average sizes of the pisolites, measured from thin and also polished sections, were about 1 cm, 2 cm and 3 cm, respectively, for the materials of the upper-, middle-, and lower-indurated zones, while visually estimated indices of sphericity were, respectively, > 0.7 , $0.7 - 0.4$ and < 0.4 . In addition, the materials of the upper indurated zone were readily cut into relatively good thin and polished sections, but varying degrees of impregnation were necessary in the case of the other materials, many of which made poor sections, even after impregnation in canada balsam. Variations pertaining to rock type were also studied and established from statistical tests of significance, based on the available data on quartz size and content, as well as on the data of the sesquioxides. Finally, hematite appears confined mostly to the upper zones and goethite to the lower ones, maghemite ($\gamma\text{-Fe}_2\text{O}_3$) being restricted to the black-cored pisolites of the upper-indurated zone (Faniran, 1970).

The mottled zone of the laterite profile may also be divisible into upper and lower portions. The upper zone, where present, appears to be partly a continuation of the zone transitional between the indurated and the mottled zone; it usually shows (particularly in shales) red and yellow mottling. This merges into a ferruginous (uniformly red) zone, here called the lower-mottled zone. The mottled zone in most sandstone profiles is ferruginised sandstone, which gives an impression of mere iron enrichment or replacement. Where exposed, these materials have hardened considerably; at present they cap most of the hills and ridges in the intensely dissected parts to the north, e.g. around Mt. Colah.

The last zone is the pallid zone, which is of mostly white or greyish-white material. It varies in thickness from indistinct, in some coarse-grained sandstones, to more than 100 ft in shales. Particularly thick pallid zones are exposed in quarries, especially in the suburbs of St. Ives South, North Sydney and Ryde. Pallid zones, unlike the overlying materials, do not harden on exposure, except in the case of those on shales. Laterite profiles, similar to the above, have been described elsewhere in Australia, especially in the Northern Territory (Wright, 1963, Hays, 1967).

Ferricretes

The material here described as ferricrete is similar in certain respects to laterite and in other respects to ferruginised sandstones. Underlain by typically mottled and pallid zones, it is like laterite, connected with deep weathering and duricrusting. Also like laterites, it contains hematite and especially maghemite. Ferricretes are, however, poor in alumina, which characteristic it has in common with most ferruginised sandstones and *re-worked* (or *ground-water*) laterites. The silica (quartz) content is also much higher than in laterites (silica is likewise

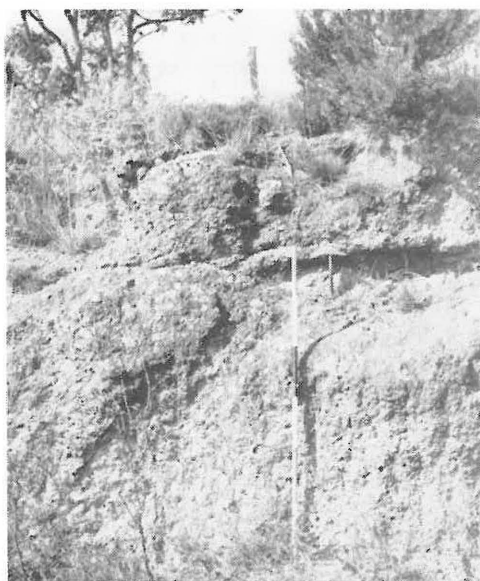


Figure 2a. Laterite profile from Terrey Hills (quarry at the junction of McCarr's Creek Road and Yulong Avenue), showing: about 2 ft of upper-, 5 ft of middle- and 6 ft of lower-indurated zones. Top of hammer (c. 14 in. long) marks approximate lower boundary of upper-indurated zone; the lower-indurated zone starts about halfway down the profile. Quarry floor is mainly transitional zone material and a pit dug into this exposed the mottled and pallid zones overlying weathering (massive) sandstone (*cf.* Fig. 2b).

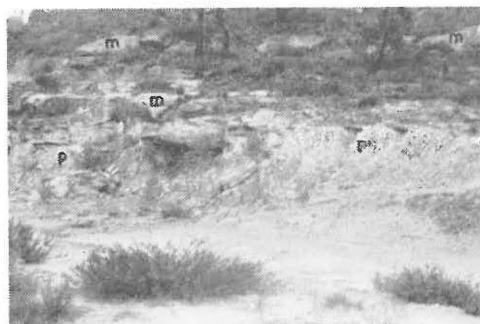


Figure 2d. Ferruginised sandstone from Terrey Hills (the Warringah Shire-tip). Note the massive nature of the top (mottled, *M*) zone directly underlain by the pallid zone (*P*). Location is on the hillside; the hilltop is capped by concretionary laterite.

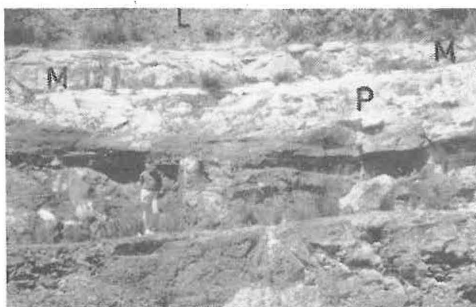


Figure 2b. Deep weathering (laterite) profile at the Beacon-Hill quarry, taken from behind the newly-built Methodist Church. Profile shows, from top to bottom, 2 ft-4 ft of indurated (laterite, *L*) zone, 3 ft-4 ft of mottled (ferruginised sandstone, *M*) zone, and 1 ft-4 ft of pallid (*P*) zone, overlying about 2 ft of weathering sandstone. Bands of black shale penetrate the sandstones; the shale was being mined for the tile and brick works nearby. The boy is about 4 ft tall.

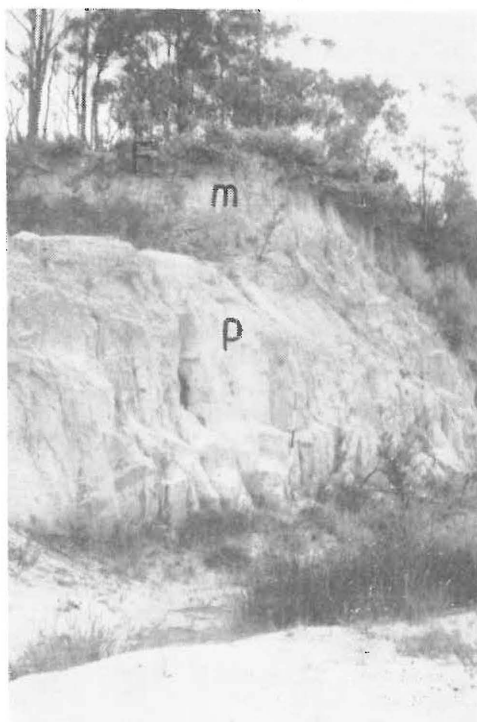


Figure 2c. Ferricrete profile near Maroota, exposed by a quarry near the Northern Road/Windsor Road Junction. Profile shows, massive ferricrete (*F*) underlain successively by soft mottled (*M*) and about 20 feet of pallid zone (*P*).

very high in ferruginised sandstones), obviously, in both cases, on account of the parent material. Indeed, ferricretes may be indistinguishable from ferruginised sandstones in hand specimen. They have here been distinguished (a) on mineralogical grounds and (b) in profile. The iron cement of most ferruginised sandstones is mostly goethite, not found at all in ferricretes, while the ferruginised sandstones in the study area are mostly underlain by typically pallid zones (*cf.* Fig. 2, c and d). These two features group the latter materials with the mottled zones of typical deep-weathering profiles. Finally, although the ferricretes of this area are restricted to the driest parts, the fact that a type of laterite (re-worked) is found in the equally dry southwestern parts (specimen 211, Fig. 1a) suggests that climate is perhaps not a decisive factor. Rather, it seems that the nature of the country rock (*i.e.*, the index of porosity and permeability) and also the quantity of available sesquioxides are the deciding factors. Coarse-grained rocks such as the conglomerates have little scope for the sesquioxides needed for lateritisation.

The present use of the term *ferricrete* agrees with Lamplugh's (1907) original use. Nevertheless, the term can safely be extended to *ferruginous* or *iron-oxide duricrusts* in which the crust material is essentially iron-oxide ore. Other terms used in a similar sense include *silcrete* and *calcrete*; the list of such terms is, of course, quite long as contained in Dury (1969, p. 78), but none of these other materials, including *bauxites*, or essentially *aluminous duricrusts*, were found in this area. The highest recorded $\text{Al}_2\text{O}_3/\text{Fe}_2\text{O}_3$ ratio was 2.2, and in this particular case (specimen 212, Table 1), Fe_2O_3 formed 24.9 per cent of the sample. SiO_2 is high in most samples, the lowest recorded proportion being 19.3 per cent. Iron pans occur on the floors of some ditches, gutters and the like but these have been deposited by surface and seepage waters; they have not been studied here because they are not associated with *in situ* weathering and typical deep-weathering profiles. They are therefore not, strictly speaking, duricrusts, at least not in the same sense as *laterites* and *ferricretes* are here designated.

Table 1. Chemical Analyses of the Sydney Duricrusts and Related Materials

Sample Type	Reference Location	Specimen Number	Chemical Content (Wt. %)						
			SiO_2	Fe_2O_3	Al_2O_3	TiO_2	MnO_2	Others	Total
Laterite	Terrey Hills	173	39.80	23.80	35.30	0.10	0.11	0.89	100.00
Laterite	Bilgola	201	48.90	17.90	32.80	0.90	0.20	0.00	100.30
Laterite	Belrose	212	19.30	24.90	55.30	0.20	0.06	0.24	100.00
Laterite	Bantry Bay	147	44.40	27.10	27.20	0.40	0.25	0.65	100.00
Laterite	Chatswood	180	35.06	40.05	40.90	0.80	0.20	0.00	100.00
Indurated lateritic clay	N. Sydney	30	42.00	42.08	14.40	0.80	0.00	0.00	100.00
Indurated lateritic clay	Wahroonga	234	55.60	19.00	24.20	0.50	0.10	0.60	100.00
Ferruginised sandstone	Mt. Colah	116	78.50	13.30	6.50	0.50	0.60	0.60	100.00
Ferruginised sandstone	Canoelands	169	62.60	24.90	11.40	0.10	0.20	0.80	100.00
Ferricrete	Maroota	27	72.10	17.90	9.30	0.50	0.05	0.15	100.00

Notes: (1) Analyst is Mr John Corbett, Department of Agriculture, The University of Sydney.

(2) X-ray mineralogical analyses show that SiO_2 was mainly quartz; Fe_2O_3 combine maghemite, hematite, goethite, and in the case of Maroota sample, ilmenite; Al_2O_3 was mainly gibbsite; while TiO_2 and MnO_2 were not identified in any form in any sample, perhaps because they were minor elements. Kaolin was present in doubtful forms.

Finally, it is of particular interest to attempt a comparison of the materials here with those discussed among others by Dury (1969, pp. 77-84). In doing this, it is necessary to note that the materials being discussed belong to different portions of the duricrust profile, while such differentiation has not been made for Dury's samples. Furthermore, only the random (bulk) samples need be considered in Fig. 3, since the others are analyses of particular textures. For instance, samples 21 and 22 are, respectively, the pisolite and the matrix textures of sample 8 (specimen 212). Similarly, sample 25 is that of a pisolite belonging to sample 9 (specimen 173).

When Fig. 3 is compared with Dury's (1969, p. 82) Fig. 1, the following rather rough correlations emerge: (a) The *ferruginised sandstone* (sample 16, specimen 116) roughly corresponds to the *silitic* type; (b) The pallid-zone shale (sample 19, specimen 166) is *sialitic*; (c) The ferricrete (sample 3, specimen 27) is close to being *ferrisilitic*; while (d) The bulk of the remaining samples are mostly *ferralsilitic*. Similar comparison with a modified form of Konta's (1958) classification shows that the materials are difficult to distinguish by their chemical analyses. Sample 16 roughly falls in the category of *silcrettes*, samples 3 and 7 (specimens 27 and 169 respectively) are *ferruginous clays*, possibly ferricretes, while sample 19 is a *bauxite clay* or *silica-rich bauxite*. The rest of the samples do not strictly fall into any of the other categories specified by or even modified from Konta's graph.

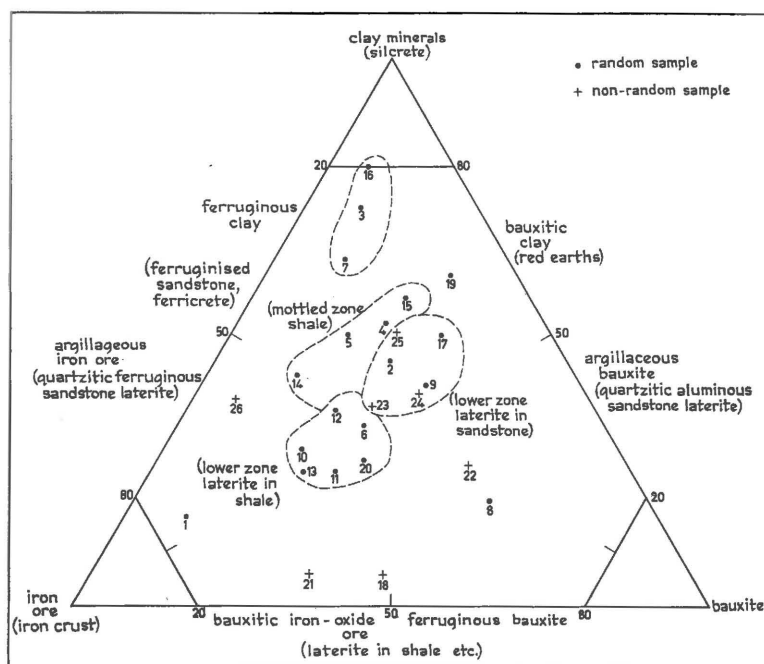


Figure 3. Graphical representation and classification of the Sydney duricrusts from their chemical analyses (Table 1), modified from Konta (1958). Note the position of the samples relative to the terminology both of Konta (1958) and of Dury (1969). Note also the position of the non-random samples relative to the random ones, particularly those from a single specimen. Samples 8, 21 and 22 are from specimen 212 (fine-grained sandstone laterite), while samples 9 and 25 are from specimen 173.

The difficulty encountered in these comparisons may be attributed to two main causes. In the first place, the materials are perhaps not similar in all cases. As pointed out earlier, the Sydney district samples vary from indurated-zone to pallid-zone materials, and the country rock ranges from shales to conglomerates. Chemical data have also been found most unreliable in the classification of weathered rocks and soils (Pendleton, 1936); chemical data do not here reflect the observed variations of the materials, which have been confirmed by microscopical study and modal analyses. Thus it is difficult to distinguish between indurated zones (laterites) in sandstones and mottled and lower zones in shales from Fig. 3, the grouping shown being based on previous knowledge about the samples, confirmed by modal analyses. Even then the groupings are not clear-cut. Sample 6 is mottled-zone shale, sample 20 is lower-zone laterite in sandstone, sample 8 is upper-zone laterite in sandstone while sample 10 is re-worked laterite. Sample 1 is supposed to be upper-zone laterite in sandstone, similar to sample 9, but its position is too far out to be accurate; it has therefore been left out of the consideration here.

POST-DURICRUST DISSECTION AND THE DURICRUSTS

The materials just described have been studied in single duricrust profiles (Fig. 2a) and also along valley-side slopes of dissected regions. This suggests that the original deeply-weathered profiles have been extensively dissected and truncated. Other evidence for large-scale truncation is the present-day location of the duricrust on the major interfluves; they have, apparently, been destroyed in the other areas, especially in the heavily dissected parts. The arguments for post deep-weathering diastrophic activities and the resulting dissection and differential truncation of the duricrust profiles have already been discussed in previously referenced paper (Faniran, 1969a). The result of these events in the exposure at the present time, of the various portions of the typical duricrust profile, depending on the degree and extent of truncation. These exposures are roughly shown in Fig. 1a. They are classified, from the various petrographical studies in Table 2.

It is significant to note in Fig. 1a that the laterites and ferricretes occur in the least dissected regions. For instance, laterites occur mostly around the main interfluve region separating the three major drainage basins, i.e. the Hawkesbury-Broken Bay, the Parramatta-Port Jackson and the east-flowing Pacific-Ocean systems. They also occur within the last two systems which are also the smallest basins — draining, respectively, 20 per cent and 10 per cent of the study area compared to 70 per cent by the Hawkesbury-Broken Bay system. The northern parts are also among the most intensely dissected region with deep valleys, narrow ridges and steep slopes. It seems, therefore, that these materials, if originally formed here, have been largely destroyed, leaving mostly truncated profiles. The exception is around Maroota where the interfluves are broad enough for the preservation of complete profiles especially around the junction of the Northern and Windsor Roads.

Table 2, on its own part, shows a possible classification of the duricrusts of this area based on correlations of the materials found in the various parts with those found in complete and intact profiles. It is significant to note here that only the laterites have been grouped into sub-types, according to the portion of the deep-weathering profile to which the materials belong or have been assigned. By contrast, the ferricretes are quite homogenous.

Material	Sub-Types	Representative Areas
Laterite	1. Upper Indurated Zone	
	(a) Coarse-grained sandstone or The Terrey-Hills Type	Terrey Hills, Ingleside, Ku-ring-gai Chase
	(b) Fine-grained sandstone or The Belrose Type	Belrose, French's Forest
	2. Middle-Indurated Zone	
	(a) The Oxford Falls-Beacon Hill Type	Oxford Falls, Beacon Hill, Terrey Hills, Ingleside, Ku-ring-gai Chase
	(b) The Duffy's Forest Type	Duffy's Forest, Belrose, French's Forest, Bantry Bay
	3. Lower-Indurated Zone	
	(a) The Bilgola-Plateau Type	Bilgola Plateau, Northbridge, Castle Crag
	(b) The French's Forest Type	French's Forest, Bantry Bay, Duffy's Forest, Rydalmere
	(c) The Chatswood (Shale) Type	Chatswood, Long Reef
Red Earth/ Brown Earth	4. (a) Ferruginised sandstones or The Mt. Colah Type Coarse-grained sandstone	Caprock of most ridges in the north e.g., Mt. Colah, Fiddletown, Canoe-lands
	(b) The Cammeray Type or Fine-grained sandstone	Caprock of most hills and ridges in the south, e.g., St. Leonard's Park, Cammeray.
	(c) The North-Sydney Type or Indurated lateritic clays	North Sydney, Wahroonga, Hornsby.
	5. The Maroota Type	Maroota-Weavers Cooper.
Ferricrete		

CONCLUSIONS

Three factors have been discussed in relation to the present-day distribution and attitude of the Sydney duricrusts. First, the duricrusts vary according to rock type and also according to their location in profile. Generally, laterites are associated with relatively fine-grained rocks such as the shale, the sandstones, and, perhaps more importantly, the basic igneous rocks. The laterites almost invariably occur in areas where sesquioxide-rich shales and especially basic igneous rocks have been mapped. By contrast, the ferricretes occur in rocks with mean grain size more than 0.5 mm, particularly in the conglomerates of the Maroota area. Second, the laterites seem to be restricted to areas of higher rainfall while ferricretes occur in the drier areas. But while this last factor may contribute in some degree to the explanation of the observed variations, the fact that coarse-grained rocks generally have a limited content of the sesquioxides needed for lateritisation and the development of thick zones of concretion and pisolitic textures suggests that climate may not be very important. Finally, the crusts and duricrust profiles in this area have been widely destroyed, mainly by post-duricrust processes of removal.

All evidence in this area suggests that the deeply-weathered and duricrusted surface was that of low relief, close to sea-level and has been subsequently uplifted and dissected. There is also a close correlation between the size of drainage basin

and the extent of destruction and truncation of the duricrusts. Whereas there are hardly any laterites left within the largest drainage basin — i.e. the Hawkesbury-Broken Bay system — except in the Maroota area where preservation (of ferriteres) is due to the existence of a broad undissected interfluvial region — laterites occur within the Pacific Ocean system and also in the region separating the major drainage systems. Destruction everywhere has been by fluvial action of down-cutting and slope processes, with the result that different portions of the crust and duricrust profiles are now exposed on the interfluvial and slopes of the dissected country.

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REFERENCES

- Anon, 1948: *The County of Cumberland Report*, Sydney, 226 p.
- Buchanan, F., 1807: *A Journey from Malabar Through the Countries of Mysore, Canara, and Malabar*, East India Co., London, vol. 2, pp. 436-460.
- Burges, A. N., and Beadle, N. C. W., 1952: The Laterites of the Sydney District, *Aust. J. Sci.*, 14, pp. 161-162.
- Chayes, F., 1956: *Petrographical Modal Analysis*, John Wiley, New York, 113 p.
- Connah, T. H., and Hubble, G. D., 1960: Laterites; In: *The Geology of Queensland*, ed. D. Hill and A. K. Denmead, *J. Geol. Soc. Aust.*, 7, pp. 373-386.
- Dury, G. H., 1969: Rational Descriptive Classification of Duricrust, *Earth Sci. J.*, 3, (2), pp. 77-86.
- Faniran, A., 1969a: Duricrusts, Relief and Slope Populations in the Sydney District, New South Wales, *Nigerian Geog. J.*, 12 (1 and 2), pp. 53-62.
- , 1969b: The Index of Drainage Intensity: a Provisional New Drainage Factor, *Aust. J. Sci.*, 31 (9), pp. 328-330.
- , 1970, Maghemite in the Sydney Duricrusts, *Amer. Mineral.*, 55 (5 and 6), pp. 725-733.
- Frankel, J. J., 1966: Some Mineralogical Observations on Australian Lateritic Rocks, *Aust. J. Sci.*, 29, pp. 115-117.
- Hays, J., 1967: Land Surfaces and Laterites in the North of the Northern Territory, In: *Landform Studies from Australia and New Zealand*, ed. J. N. Jennings and J. A. Mabbutt, A.N.U. Press, Canberra, 434 p.
- Konta, J., 1958: Proposed Classification and Terminology of Rocks in the Series Bauxite clay-iron-oxide ore, *J. Sed. Petr.*, 28, pp. 83-86.
- Lamplugh, G. W., 1907: The Geology of the Zambezi Basin, *Qt. J. Geol. Soc. Lond.*, 63, pp. 162-227.
- Langford-Smith, T., and Dury, G. H., 1966: Australian Landform Examples No. 6, Duricrust. The Deep Weathering Profile, *Aust. Geog.*, 10 (1), pp. 47-48.
- McElroy, C. T., 1966: Sydney 4-mile Geological, *Bur. Min. Resour. Aust.*, *Explan. Notes* 6, 48 p. and map (in fold).
- Mumme, J. A., 1965: Radioactive Laterites in the National Park Area. *J. Proc. Roy. Soc. N.S.W.*, 98, pp. 101-104.
- Walker, P. H., 1960: A Soil Survey of the County of Cumberland, Sydney Region, New South Wales, *Bull. N.S.W. Dept. Agric. Soil Surv. Unit.*, 2, 109 p.
- Woolnough, W. G., 1927: The Duricrusts of Australia, *J. Proc. Roy. Soc. N.S.W.*, 61, pp. 24-53.
- Wright, R. L., 1963: Deep Weathering and Erosion Surfaces in the Daly River Basin, Northern Territory, *J. Geol. Surv. Aust.*, 10, pp. 151-167.