OBSERVATIONS ON LATERITE AND OTHER IRONSTONE SOILS IN NORTH QUEENSLAND.

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Abstract.

Four major types of laterite soils and two types of ironstone soil profiles are discussed. The relationship of the laterite soils to water table fluctuations of considerable amplitude between the wet and dry seasons, and the relation between the ironstone soils and temporary perched water tables is discussed. Some conditions under which laterite development does not occur (in conjunction with severe sheet flooding) in low-lying sites are described. The laterites appear to be of Tertiary, Pleistocene and Recent age; the ironstone soils are post-Tertiary.

Soils containing ironstone concretions and pans are widespread in the Lower Cape York Peninsula of North Queensland. Among the most important of such soils are relict Tertiary soils mapped as Residual Lateritic Podzols and Sandplains in the Soils map of the Atlas of Australian Resources (1952). There also occur relict Lateritic Red Earths of comparable age. Soils of post-Tertiary development with profiles broadly similar to the relict laterite groups are also to be found. In addition there are other soils of post-Tertiary development which contain ironstone, but they differ in profile from the "laterite" soils, chiefly in the dissimilar character of the horizons beneath the zone of maximum iron accumulation. The origin of the ironstone in those soils of the above groups selected for treatment in this paper appears to be bound up with either seasonal water-table fluctuations of considerable amplitude (the laterite soils), or with temporary wet-season waterlogging above an horizon of clay accumulation (the ironstone soils).

The very general observations which form the basis of this paper were made during the course of a land use survey of the lower Peninsula, carried out by the writer in the dry seasons of 1949 and 1950. The arguments advanced are tentative. The nomenclature followed is that adopted by Stephens (1953) in the Manual of Australian Soils, except for four groups of soils, namely "Grey Laterite Soils", Calcareous Grey Laterite Soils, Grey Ironstone Soils and Calcareous Grey Ironstone Soils. It is emphasized that these terms are used only in a general, descriptive, collective sense and are not proposed as new soil names.

Rainfalls in this area range from 26 inches, at Spring Creek, to the south of Mount Garnet, to over 180 inches per annum, at Tully, on the east coast. Much the greater part of the area, however—especially that portion west of the Great Dividing Range, where there are extensive lateritic remnants of the late Tertiary peneplain—has rainfalls from 26 to 40 inches a year. Only in the eastern mountains (80 to 200 inches), on the Atherton Tableland (40 to 150 inches) and along the east coast lowlands (70 to 180 inches) are much higher rainfalls noted.
Lateritic soils in the lower Peninsula are associated with three major types of land surface:

(1) Relics of the late Tertiary peneplain, which was uplifted during late Pliocene-early Pleistocene time, and variably dissected. The laterite soils occur on granites, sandstones and shales, predominantly, but not always, on the lower slopes. With the lowering of the water-table accompanying dissection they are now being truncated or dismembered to some degree. As noted above, these relict soils lie west of the Great Dividing Range and are bordered in turn to the west by the Pliocene and Pleistocene deposits of the broad plains fringing the Gulf of Carpentaria.

(2) Some lower slopes of the Pleistocene valleys incised in the Tertiary surfaces just mentioned. A Pleistocene, rather than a Recent origin, is suggested by the fact that in the Spring Creek area near Einasleigh, Recent or very late Pleistocene basalts (bombs, cones, unmodified flow walls, cavernous drainage and black soils are all typical) have in several areas lapped over the lateritic soils developed on granites in the lower slopes of the Pleistocene valleys. Included in this group are some Pleistocene river terraces and lower valley slopes of the east coast between Cairns and Tully. The parent rocks are largely granitic or schistose.

(3) The lower slopes of valleys etched in very late Pleistocene or early Recent basalts (comparable in age to those mentioned above), developed most strikingly in the high rainfall zone around Innisfail on the east coast. The ironstone soils are associated in large part with the following erosion surfaces and deposits:

(1) The loosely consolidated sediments between Croydon and Normanton, flanking the eastern side of the Gulf of Carpentaria. These sediments are probably to be correlated with Whitehouse's (1940) Pliocene Glendo Series. The lower sites are preferred sites for ironstone-soil development.

(2) Low-lying sites on Pleistocene alluvials of rivers emptying into both the Coral Sea and the Gulf of Carpentaria. Good examples are to be found along the Mulgrave River to the south of Cairns and on the Gilbert River near Strathmore Station (see Text-fig. 1).

The Laterite Soils.

Four major groups of laterite soils are to be found in the lower Peninsula. They are, in decreasing order of areal extent, (i) the Grey Laterite Soils developed on both Tertiary and Pleistocene surfaces; (ii) the Lateritic Red Earths of the relict Tertiary surfaces; (iii) the Calcareous Grey Laterite Soils of the low rainfall districts around Croydon and Einasleigh, developed on granite in the lower sites of Pleistocene valleys; and (iv) the Lateritic Krasnozems on Recent basalts and on very ferruginous schists near Innisfail in the eastern lowlands. Details of each of these soils are given below, along with a typical profile for each.

(i) Grey Laterite Soils.

Grey Laterite Soils have developed most widely on acid rocks such as granite, sandstone, slate and schist. They have acid, grey, brownish-grey or yellowish-grey upper horizons which are light textured and usually have sesquioxidic concretions at their base. The concretions may merge into a hardpan extending into an underlying, mottled clay horizon. Extending through the mottled clay horizon may be individual pisoliths, vermicular masses or vertical "pipes" of hard ironstone material. Mottling is predominantly of pale tones, yellow, orange and grey being most frequent. With increasing depth grey and even white tones become dominant, this horizon (for which Whitehouse (1940) introduced the term "pallid zone") being overwhelmingly one of kaolinitic clays. In other parts of Australia silicification of sections of this last layer into "billy" has been recorded. Little evidence of "billy" formation was seen in north Queensland.
Text-fig. 1.—Lower Cape York Peninsula, North Queensland, giving the location of places mentioned in the text.

Location of observed and recorded laterite profiles of Tertiary age shown thus: ●
Location of observed and recorded laterite profiles of post-Tertiary age shown thus: ★
Location of ironstone soil profiles shown thus: ▲.
A typical Grey Laterite profile of Tertiary age is as follows:

The Strathmore Tertiary Profile. Developed on Mesozoic shaly sandstone near Dismal Creek on Strathmore Station. The profile is exposed at the edge of a low mesa. Present rainfall, 31 inches. Vegetation a monospecific scrub of Melaleuca leucadendron.

<table>
<thead>
<tr>
<th>Depth (in)</th>
<th>Description</th>
<th>pH</th>
<th>Clay (%)</th>
<th>Chlorides (%)</th>
<th>Ferruginous Pisolites</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–5</td>
<td>Pinkish grey fine sand; pH 5.1; clay 7%; organic carbon 0.6%; chlorides 0.003%; merging to</td>
<td>5.1</td>
<td>7%</td>
<td>0.003%</td>
<td></td>
</tr>
<tr>
<td>5–18</td>
<td>Yellowish grey sand; occasional iron pisolites; pH 4.9; clay 7%; chlorides 0.007%; merging to</td>
<td>4.9</td>
<td>7%</td>
<td>0.007%</td>
<td></td>
</tr>
<tr>
<td>18–24</td>
<td>Light yellow sand to loamy sand; pH 5.2; clay 10%; chlorides 0.007%; numerous ferruginous pisolites, increase to base, where they are cemented into</td>
<td>5.2</td>
<td>10%</td>
<td>0.007%</td>
<td></td>
</tr>
<tr>
<td>24–48</td>
<td>Hardpan of pisolitic laterite; yellow-brown to red-brown on fracture. Changes sharply to</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>48–120</td>
<td>Cellular mottled horizon with yellow-brown to red-brown cell-walls and pipes of ironstone; grey and yellow mottled sandy clay infilling. Ironstone cells diminish with depth giving way to</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>120–150</td>
<td>Greyish white pallid zone, flecked with red and yellow.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>150+</td>
<td>Base of exposure.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Generally speaking, the old Tertiary soils have deeper, more strongly differentiated horizons than those initiated during the Pleistocene. They also tend to be more acid throughout the profile, showing in particular more intense levels of acidity in the deep subsoils below the iron pans than is typical for the Pleistocene Grey Laterite Soils. The extent of each of these groups is shown on the accompanying map (Figure 2).

Comparable profiles found elsewhere in Australia include many of those described as Residual Podzols by Prescott (1944), as Lateritic Podzolic Soils by Stephens (1953) and Stewart (1954), and as Ferruginous Laterites by Hallsworth and Costin (1953).

(ii) Lateritic Red Earths.

The Lateritic Red Earths of the lower Peninsula are overwhelmingly relict, being associated with remnants of the Tertiary land surfaces. They have developed on acid-intermediate and some acid rocks, notably shales, granodiorite, granite, ferruginous quartzites, phyllites and schists. Stephens (1953) has characterized these soils as "red to light red soils containing a horizon of laterite with mottled and pallid kaolinitic horizons beneath. The A horizon is commonly sandy to loamy in texture and darkened with a little organic matter. It passes gradually into a slightly finer textured B horizon which is usually a bright red in colour and of compact but somewhat vesicular structure. The horizon of laterite is found at various depths and it is of variable character, nodular, pisolitic, vermicular or massive. The mottled and pallid horizons beneath the laterite are variable in depth and may occasionally be missing. Frequently they contain a siliceous horizon of 'billy'." In this area they have developed on sandstones, granites and other acid to intermediate rocks.

A typical profile is recorded below.

The Mount Garnet Profile. Is developed on the upper slopes of a long 1°–2° slope on granite some 20 miles south of Mount Garnet, on the highway linking Mount Garnet to Charters Towers. Grades down slope into a Grey Laterite Soil. Tall woodland of Eucalyptus crebra-E. dichromophloia.

<table>
<thead>
<tr>
<th>Depth (in)</th>
<th>Description</th>
<th>pH</th>
<th>Clay (%)</th>
<th>Chlorides (%)</th>
<th>Ferruginous Pisolites</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–12</td>
<td>Light reddish grey-brown sandy loam, with very occasional firm pisolites. Merges to</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12–24</td>
<td>Red compact loam to clay loam with numerous firm pisolites which become very hard on exposure.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24–40</td>
<td>Latentic mottled horizon with much irregular vermicular ironstone.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40+</td>
<td>Decomposing granite, much weathered and with irregular ironstone masses.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
(iii) Calcareous Grey Laterite Soils.

In the low rainfall districts of Croydon (28 inches p.a.) and on Spring Creek, Lyndhurst, and Carpentaria Downs Stations near Einasleigh (25 inches p.a.), Calcareous Grey Laterite Soils have developed at the ends of long gentle slopes on granite and granodiorite. They are all of post-Tertiary age. A typical profile is given below.

The Lyndhurst Profile. Occurs towards the end of a long 1\(\frac{1}{2}\) slope (of two miles) on granodiorite near Bundock Creek on Lyndhurst Station. Grades upslope into a Yellow Podzolic soil. Open savannah woodland of Eucalyptus leptophleba-E. brownii vell. aff. Rainfall about 26 inches.

0–18 in. Grey to light yellowish grey loamy sand to sandy loam.
18–36 in. Yellow and grey reticulately mottled sandy clay with yellow-brown ironstone pisolites scattered throughout and in parts cemented into a firm hardpan.
36–70 in. Yellow sandy clay reticulately mottled with grey with weakly developed vertical cells and pipes of ironstone.
70–96 in. As above, with large calcium carbonate concretions up to one inch across or more.
96 in. Decomposing granodiorite.

(iv) Lateritic Krasnozems.

Lateritic Krasnozems (the term follows Stephens' (1953) usage) are restricted to the lower slopes of Recent basalts, mixed basalt and schist colluvial-alluvial materials, and occasional very ferruginous schists in the high rainfall areas of the east coast, notably in the Innisfail district (140 inches).

The Mena Creek Recent Profile. Typical of end-of-slope laterite development on basalt in the Mena Creek area near Innisfail. Profile through end of 2°–3° slope, cut by cane tramway. This profile has been sampled and described by Teakle (1950), and analyses carried out by the Division of Soils, C.S.I.R.O. Rainfall about 150 inches. Original cover rainforest, now cleared for sugar cane.

0–6 in. Disturbed by cutting.
6 in. to Partly disturbed in the upper section by tram cutting. Light, brownish red light clay with occasional hard, irregular purplish-red ironstone masses up to four inches across.
4–6 ft. Very light brownish red light clay. Contains numerous pieces of irregular ironstone, purplish-red in colour. Tendency to cellular structure in parts, in others a weakly developed cellular structure is apparent. Merges into
6–10 ft. Brownish red clay with large irregular, cellular ironstone masses. Merges into
10–18 ft. Yellow grey and olive grey clay with slight segregation of iron into small irregular masses. Appears to be a weakly developed "pallid zone".

Teakle (1950) considers that this profile is that of a "very immature laterite".

Catenary Relationships of the Laterite Soils.

The Tertiary Laterites.

In areas of dissected Tertiary laterites a varied assemblage of soils develops on the different horizons exposed by erosion, as well as on transported material derived from the laterite. No study of these derived soils was made, but in all probability they follow a pattern similar to that outlined by Stephens (1946) for southern Australia. Where the site is undisturbed the catena members depend upon the acidity of the parent materials and the degree of slope. A form of listing is adopted below (Table 1) to make the various sequences clear.

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1 Professor W. H. Bryan, University of Queensland, considers these basalts to be very late Pleistocene or early Recent in age (personal communication).
LATERITE AND OTHER IRONSTONE SOILS IN NORTH QUEENSLAND.

The last sequence listed above is of considerable interest for the light it throws on the nature of the water-table fluctuations on long very gentle slopes and may be examined further. The evidence for this sequence (namely Red Podzolic—Yellow Podzolic-transitional—Grey Laterite Soil—Meadow Podzolic) is based upon an interesting topographic succession described from the Northern Territory by Stewart (1954) and a parallel sequence in north Queensland developed on the broad, low, weakly-dissected shaly-sandstone mesas (mesa walls 15–20 feet high) between the Gilbert and Mitchell rivers to the north of Croydon. These examples are illustrated in Text-figure 3.

### Table 1.

<table>
<thead>
<tr>
<th>Acidity of Parent Material</th>
<th>Degree of Slope</th>
<th>Catenary Sequence Moving Downslope to the Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid—Intermediate shales, granodiorite, etc.</td>
<td>More than 1–2°</td>
<td>Krasnozem-transitional—Lateritic Red Earth.</td>
</tr>
<tr>
<td></td>
<td>Less than 1–2°</td>
<td>Transitional Lateritic Red Earth—Lateritic Red Earth.</td>
</tr>
<tr>
<td></td>
<td>Very long and gentle, less than 1°</td>
<td>Transitional Lateritic Red Earth—Lateritic Red Earth—Grey Laterite Soil.</td>
</tr>
<tr>
<td>Acid sandstone, granite, etc.</td>
<td>More than 1–2°</td>
<td>Red Podzolic—Yellow Podzolic-transitional—Grey Laterite Soil.</td>
</tr>
</tbody>
</table>

Referring to the example from the Territory, Stewart notes that "in many places massive laterite outcrops around the higher margins of the Marrakai soils (described as Meadow Podzolics) of the creek flats or depressions. Apparently the ferruginous zone represents the range of fluctuation of the water-table in the wet season. In the Marrakai soil the water-table is above the surface of the soil and the soil undergoes similar pedological processes to those of the subsoils of lateritic soils. In the anaerobic conditions of the waterlogged soil iron is reduced.

to the ferrous form and is removed upwards from the solum. Even though flooded, the soils are very strongly leached, i.e. they must be reasonably permeable, and the water-table above soil level is apparently due to their low topographic position and the high regional wet season water-table.” In general, the same topographic relations hold in the zone to the north of Croydon and Stewart’s argument is applicable there also. Although these seasonally inundated soils may have been subjected to some slight post-Tertiary erosion, they probably approximate closely to the original Tertiary lowest members.

From these examples we might conclude that on very gentle long slopes on acid rocks the lowest areas subject to seasonal ponding would not tend to develop Grey Laterite Soils because the water-table fluctuations would not be of the type needed for their formation, whereas at the base of slightly steeper slopes where long-continued surface ponding is restricted they would constitute the lowest member. The areas of excessively high rainfall on the east coast provide a partial exception to this generalization for even on slopes which elsewhere would carry Grey Laterite Soils some surface ponding is common and Meadow Podzolics are often noted in such inundated zones.

The Post-Tertiary Laterites.

In the post-Tertiary laterites, as is the case with the Tertiary group, parent materials, slope and also rainfall greatly influence the course of development of the laterites and their associated soils. In Table 2 given below some general relationships are shown.

<table>
<thead>
<tr>
<th>Parent Material</th>
<th>Present Annual Rainfall in Inches</th>
<th>Degree of Slope</th>
<th>Catenary Sequence Moving Down-slope to the Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basalt.</td>
<td>40 to 140</td>
<td>5°+ for upper to 1-2° on lower slopes.</td>
<td>Krasnozem on all slopes. East coast and Atherton Tableland.</td>
</tr>
<tr>
<td>Recent Basalt and very Ferruginous Schist.</td>
<td>140+</td>
<td>As above.</td>
<td>Krasnozem — Yellow Brown Latosols (occasional and on basalt only)—Lateritic Krasnozems. Well developed in the Innisfail district.</td>
</tr>
<tr>
<td>Granite.</td>
<td>25 to 30</td>
<td>As above.</td>
<td>Krasnozem (on ferruginous schists and basic granites and in the higher rainfall areas) or Red Podzolics—Red Podzoles—Yellow Podzolics — transitional — Grey Laterite Soils. East Coast and Inland districts.</td>
</tr>
<tr>
<td>Granite and Schist.</td>
<td>120+ and in some favourable sites, 90+.</td>
<td>As above plus gentle end of slope less than 1°.</td>
<td>Krasnozem — Red Podzolies — Yellow Podzolics—Meadow Podzolies. East coast, especially the Tully and Innisfail areas.</td>
</tr>
<tr>
<td>Alluvial Terraces.</td>
<td>75+</td>
<td>Level to very gentle.</td>
<td>Krasnozem — Red Podzolics — Yellow Podzolics—Grey Laterite Soils (or in some instances Grey Ironstone Soils).</td>
</tr>
</tbody>
</table>
The following comments are relevant to a study of the preceding table:

(i) Generally speaking, the Pleistocene and Recent laterites have formed on steeper slopes than the Tertiary examples. They occupy a smaller proportion of the catena, and are more markedly restricted to the lower slopes.

(ii) If the present rainfall pattern is a reasonable guide to that of the Pleistocene, then it seems that laterite will form on acid rocks under considerably lower rainfalls than on basic rocks.

(iii) On basaltic parent materials Lateritic Krasnozems are found only on the lower slopes of Recent basalts in the high rainfall area around Innisfail (140+ inches p.a.), while the higher sites are characterized by Krasnozems. In several instances soils with distinct affinities with Yellow Brown Latosols were observed on sites intermediate between the Krasnozems and the Lateritic Krasnozems in the Innisfail district, but it is not known whether they are an invariable intermediate member of the catena. Elsewhere in the coastal belt where rainfalls are lower than at Innisfail, Krasnozems generally occupy all sites, including the lowest on the Recent basalts. Even on the Atherton Tableland, where rainfalls range up to 150 inches, no Lateritic Krasnozems have been observed by Teakle (1950) or the writer either on the Recent basalts in the north or on the Tertiary flows in the south. The hilly nature of the southern high rainfall zone of the Tableland and the sharp decline in rainfall (40 to 80 inches) over the more undulating and rolling lands to the north evidently has not favoured laterite development. It would appear, therefore, in north Queensland that only in undulating to rolling country where rainfalls exceed 140 inches can the persistent high water-tables needed for the formation of laterite at moderate depth be maintained on the normally free-draining Krasnozems which tend to develop over basalts at rainfall levels above about 40 inches.

(iv) Along the east coast where rainfalls are above 120 inches—and in some areas where they are as low as 90 inches per annum—laterite development is uncommon on granite and schist. This contrasts to the situation on basalt, where lateritic soils do not develop until some 140 inches are received. This contrasting situation is probably in part related to the more frequent occurrence of long very gentle slopes and flats at the base of granitic and schistose hills than is the case with the shorter and more undulating to rolling slopes on basalt. On these very gentle slopes, backed by a considerable sheet-flood catchment upslope, many low-level sites on granite and schist are waterlogged for almost the entire year and apparently do not experience water-table fluctuations of the type needed for laterite profile development. In this high rainfall area where even the dry season from July to October averages more than 16 inches sheet and imbricate rill flow of excess water is common across the gentle aprons skirting the steep hills. In such areas Meadow Podzolics, rather than Grey Laterite Soils, are the norm.

(v) The Krasnozems and Red Podzolics which are typical of all slopes over 2° on schistose alluvial-colluvial slopes to the south of Cairns (in the rainfall range 90+ inches) in some instances have lateritic ironstone and mottled and pallid horizons occurring in the very deep subsoils 15 to 25 feet or more below the surface. Fine examples of these deep horizons are exposed by deep stream gashes in the Mulgrave Valley colluvials between Meringa and Cairns; on road cuttings between Tully and Innisfail; and at Bingil Beach to the east of Tully. Whether these deep horizons are related to present-day deep water-table fluctuations or are related to earlier water-table positions—and hence are relict—the writer cannot say. However, the marked dissection of the exposure at Bingil Beach is at least suggestive of the latter possibility.
On the genesis of laterite soils in Australia there is a general consensus of opinion on the role of water-table fluctuations by which the pallid, mottled and portion at least of the ironstone horizons are developed. Stephens (1946), Whitehouse (1940), Teakle (1950) and Hallsworth and Costin (1953) have discussed the mechanism thoroughly, and the latter in particular have pointed out several possible ways in which the appropriate water-table fluctuations could arise in both tropical and sub-tropical areas, noting that water-table movements on the lower, gentle slopes of hills as well as regional water-tables on long gentle slopes could be involved in the production of laterite soils. These writers agree that—irrespective of the nature of the surface horizons—a well-developed lateritic soil contains an ironstone horizon in the subsoil, underlain in turn by a mottled and then a pallid zone, and then, in occasional instances, by a silicified horizon of "billy". There is also agreement that during the formation of these soils the pallid zone, and to a lesser degree the mottled zone, are the site of a permanent or semi-permanent water-table, and that seasonal fluctuations in the water-table take place up to and occasionally above the level of the ironstone horizon. The development of the ironstone horizon is attributed by Teakle (1950) to deposition from iron-charged ground waters, the iron being derived "(a) from the surface as the leaching waters descend, (b) from remote places, as ground waters slowly move laterally under gravity, and (c) from the water saturating the pallid and mottled zone, where reducing conditions will prevail... (and deposition) would naturally occur at or near the fluctuating capillary fringe (of the water-table) where intermittent aeration would promote oxidation of the ferrous carbonate to ferric oxide ".

As noted in the profiles described earlier, the soil overlying, and in part included within the ironstone horizon, varies from a Krasnozem to a Red Earth, to a podzolic type soil (the Grey Laterite Soil) depending on the parent material, topographic site, rainfall and age. For the Grey Laterite Soils the development of the podzolic type surface soils may be pursued further around the question "did the podzolic type surface horizons develop contemporaneously with the deep-seated portions of the profile?"

Prescott (1931) and Stephens (1946) consider that both surface and deep profile features developed at the same time, but Hallsworth and Costin (1953) have stated that "this does not appear to be necessary" in New South Wales. They argue that, "in so far as the Monaro and Sydney Laterites are concerned, the upper podzolized layer is more logically interpreted as having been superimposed after lateritization as an effect of a strongly podzolizing climate (during the Pleistocene)". By implication this same argument may be applied to other areas of Australia. In the lower Peninsula the following observations suggest that contemporaneous development of the whole profile is normally the case:

(1) In the middle courses of the Einasleigh, Lynd and Etheridge Rivers are Mesozoic shaly sandstones which were strongly lateritized during the Tertiary, and were then gently warped and dissected into low mesas during and after the Kosciusko uplift of late Pliocene-early Pleistocene time. Grey Laterite Soils are now found, along with other soils, on both the mesa edges and in the interior portions of the mesas. Now, if the development of the upper grey podzolized horizon of the Grey Laterite Soils was confined to the Pleistocene, then we could reasonably expect to find considerable differences in profile between the free-draining areas at the mesa edges and the much less free-draining areas in the centres of the mesas. No such differences were observed in uneroded sites. Further, if podzolization were a Pleistocene phenomenon, then we could expect to find little difference in profile and intensity of podzolization between the various soils of the free-draining sites at the mesa edges. This is not the case,
and in fact there is a variety of soils matching those of the crests and troughs of the extremely gentle undulations of the mid-most parts of the mesas. In essence, then, the soils found on the mesas appear to reflect the pre-dissection topography and show little relation to the existing topography, which presumably was also typical of much of the Pleistocene. The writer concludes from this that, in the main, development of the surface as well as the deep profile features of the Grey Laterite Soils, antedated the Kosciusko uplift, and probably occurred at the same time.

(2) Grey Laterite Soils on granite and schist were observed in the Pleistocene valleys of the east coast, and on the lower slopes of the broad Pleistocene surfaces etched in the Tertiary upland surface at the headwaters of the Burdekin, Gilbert and Etheridge Rivers. These soils have also developed on the abandoned Pleistocene alluvials of the Mulgrave River near Cairns and on other Pleistocene terraces between Cairns and Tully. All these profiles are broadly similar to those on the mesas described above. Bearing in mind the site and time of formation differences between these groups, it is difficult to account for the development of these similar profile features through the action of two separate processes widely separated in time.

For these reasons, then, it is considered that polygenesis as a means of developing the Grey Laterite Soils is doubtful; contemporaneous development seems much the more likely. It is suggested that the same arguments hold for the development of the Lateritic Red Earths during the Tertiary and for the Lateritic Krasnozems on Recent basalts.

This argument seems much less certain for the Calcareous Grey Laterite Soils found on granite in the Croydon and Einasleigh districts. In these low rainfall areas (28 inches or less) secondary carbonate retention may be a relatively recent imposition on laterites formed during the Pleistocene, such retention presumably following from a shift to drier conditions after the Pleistocene. In other parts of Australia there is much evidence that late Pleistocene rainfalls were higher than the present (Crocker and Wood, 1947). No clear-cut evidence to this effect is available in the lower Peninsula. However, the presence of relic areas of Indo-Malaysian flora in the headwaters of the Einasleigh River under rainfalls of about 30 inches, and the development of Tropical Black Earths on Recent basalts alongside leached red soils on earlier flows (in the same headwater zone), is at least suggestive of such a change.

With the possible exception of the low rainfall areas above there would seem to be no reason why the lateritization process is not still operative throughout the lower Peninsula, although it may perhaps be geared to a different mean water-table position compared to earlier periods. Marked water-table fluctuations occur each year with the onset and passage of the monsoon and during the wet season reducing conditions exist as close to the surface as 6 to 12 inches in many low-lying sites.

Other Ironstone Soils.

In addition to the post-Tertiary Grey Laterite Soils and Calcareous Grey Laterite Soils and Calcareous Grey Laterite Soils occurring respectively in the high and low rainfall areas of the Peninsula, there are other ironstone soils with closely similar upper-profile features, but they lack the companion horizons of mottled and pallid kaolinitic clay and ironstone "pipes", which are replaced by non-mottled or weakly mottled clays. The development of these non-mottled or weakly mottled clays in the place of the companion horizons implies that such water-tables as do develop in these soils are perched above an impervious clay horizon, and that there is little deeper water-table development except perhaps at levels well below the surface. Although some workers in
Australia group such profiles with the fully developed laterite containing companion horizons, the writer feels that they should be separated. Until detailed work on these soils enables more suitable terms to be devised, Grey Ironstone Soils and Calcareous Grey Ironstone Soils may be used for convenience. Typical profile data are as follows:

Grey Ironstone Soils.

Grey Ironstone Soils were observed mainly in low-lying sites on Pleistocene terraces, notably along the east coast streams under rainfalls of 75 inches or more, and also on the alluvials of the Gilbert and Mitchell Rivers where present rainfalls range from 30 to 40 inches. The writer is unsure to what extent the sites along the distributory zones of the Gilbert and Mitchell Rivers should be regarded as Pleistocene or as Recent.

The Mulgrave Profile. On the abandoned Pleistocene terrace of the Mulgrave River near Gordonvale, to the south of Cairns. Lowest portion of terrace. Originally dry sclerophyll forest of *Eucalyptus alba*, *Tristania suaveolens*, *Melaleuca leucadendron* and numerous acacias. Rainfall about 75 inches.

- **0-6 in.** Brownish grey sandy loam; numerous soft, earth pisolites; pH 5.6, clay 17%; silt 14%, organic carbon 3.36%, chlorides 0.01%.
- **6-18 in.** Light grey and light yellow sandy clay loam; numerous firm pisolites becoming larger with depth; pH 5.5, clay 23%, silt 14%, chlorides 0.01%.
- **18-30 in.** Black and yellow pisolitic rubble; discrete; firm; but not exceptionally hard where not exposed to the air. On exposure the outer surfaces become very hard and are cemented together. pH 5.1.
- **30-54 in.** Red scattered pisolites in a yellow clay loam; pH 5.1.
- **54-80 in.** Red and yellowish red sandy loam becoming sandier with depth.

The catena on these Pleistocene alluvials in the high rainfall areas consists of Krasnozems or Red Podzolic Soils in the higher areas, the former generally being found on the heavier textured alluvials; these grade downslope through Yellow Podzolics into the Grey Ironstone Soils. It is important to note that in other sites on these alluvials where the water-table fluctuations are of the appropriate type, Grey Laterite Soils occur. Clearly, then, there is considerable affinity between these two groups of lower member soils with ironstone horizons—but there is still the necessity to separate those with companion horizons from those without. Insufficient sampling was carried out to determine the associated soils in the low rainfall areas.

Calcareous Grey Ironstone Soils.

Examples of Calcareous Grey Ironstone Soils are to be found in the low rainfall area (28 to 35 inches) to the west of Croydon on unconsolidated materials probably to be correlated with Whitehouse's (1940) Pliocene Glendower Series.

The Strathmore Profile. Site seven miles west of Strathmore homestead. End of long $\frac{1}{4}^\circ$ slope. Savannah woodland of *Eucalyptus microtheca*, *E. polycarpa* and *Petalostigma pubescens*. Rainfall about 30 inches.

- **0-12 in.** Ash grey very fine sandy loam; micaeous.
- **12-24 in.** Ash grey very fine sandy loam with occasional ferruginous pisolites.
- **24-48 in.** Yellow-brown clay with numerous ferruginous pisolites merging into a hardpan about 34 inches.
- **48-60 in.** Yellow brown clay.
- **60-70 in.** Yellow brown clay with calcium carbonate concretions.

These soils occupy only a small part of the catena, the Brown Soils of Light Texture (?) which occur upslope covering a much greater area. It is possible that they may have some affinities with the solodic soils described by Hallsworth, Costin and Gibbons (1953).
SUMMARY.

Soils containing ironstone concretions and pans are widespread in the lower Cape York Peninsula of north Queensland. The most common of these soils fall into two main groups:

1) The laterite soils, characterized by subsoil iron concretions and vermicular and cellular ironstone overlying mottled and "pallid" horizons, and apparently formed by fluctuations of considerable amplitude between the wet and dry season levels of the water-table. Four major types occur: (i) Grey Laterite Soils, (ii) Lateritic Red Earths, (iii) Calcareous Grey Laterite Soils, and (iv) Lateritic Krasnozems. Formation of laterite has occurred in the Tertiary, Pleistocene and Recent. Some conditions under which laterite development does not occur (in conjunction with severe sheet flooding) in low-lying sites are described. Common catenary relationships are also given.

2) The ironstone soils also possess horizons of ironstone concretions, but lack the deep mottled and pallid horizons which are replaced by non-mottled or slightly mottled clays. In these soils, temporary wet-season waterlogging above a clay horizon—rather than wholesale water-table fluctuations—appear to be important in developing the iron pans. Two main types occur: (i) Grey Ironstone Soils and (ii) Calcareous Grey Ironstone Soils. Both appear to be of post-Tertiary age.

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REFERENCES.


NOTE ON TEXT-Figure 2.

The soil boundaries given in Text-figure 2 are based upon limited reconnaissance, extended by discussions with graziers, and the use of Tri-metrogon aerial photographs (for the southern half of the area) both before and after going into the field. Useful four miles to one inch military maps were available for the Atherton, Einasleigh, Normanton and Galbraith areas. One inch to one mile military maps were used for the east coast and Atherton Tableland areas.

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